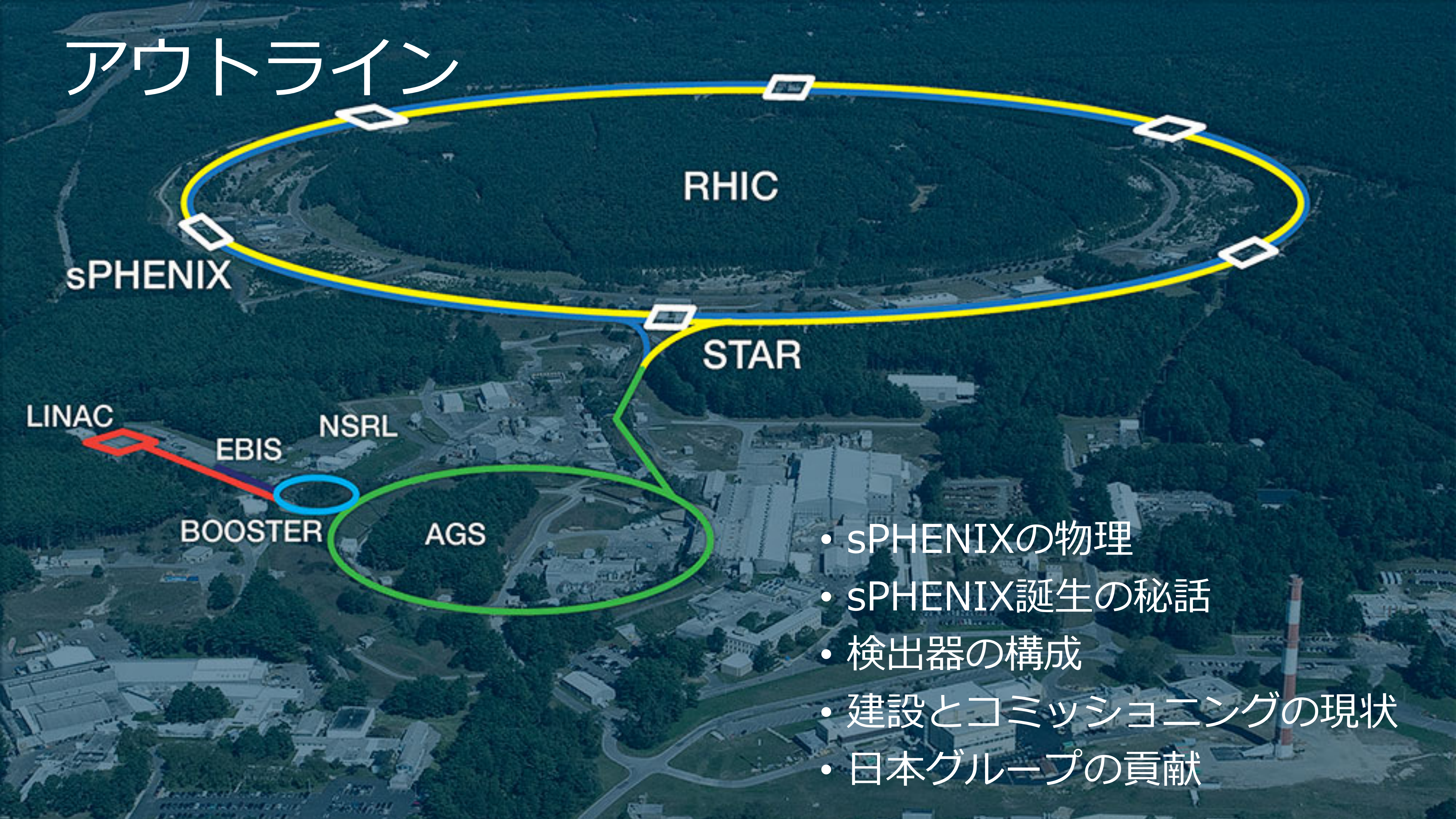
RHICにおける次世代ジェット検出器sPHENIXが展く物理と現状

理研仁科センター
中川格

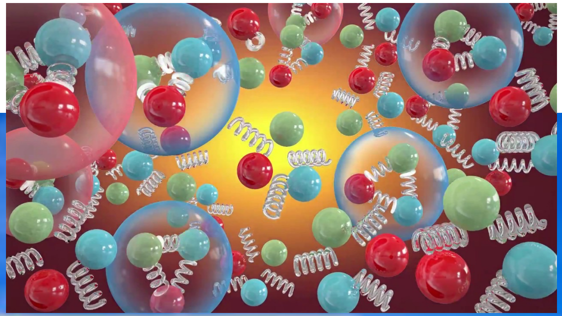
アウトライン



- sPHENIXの物理
- sPHENIX誕生の秘話
- 検出器の構成
- 建設とコミッショニングの現状
- 日本グループの貢献

sPHENIXの物理

RHIC(2000~)の物理

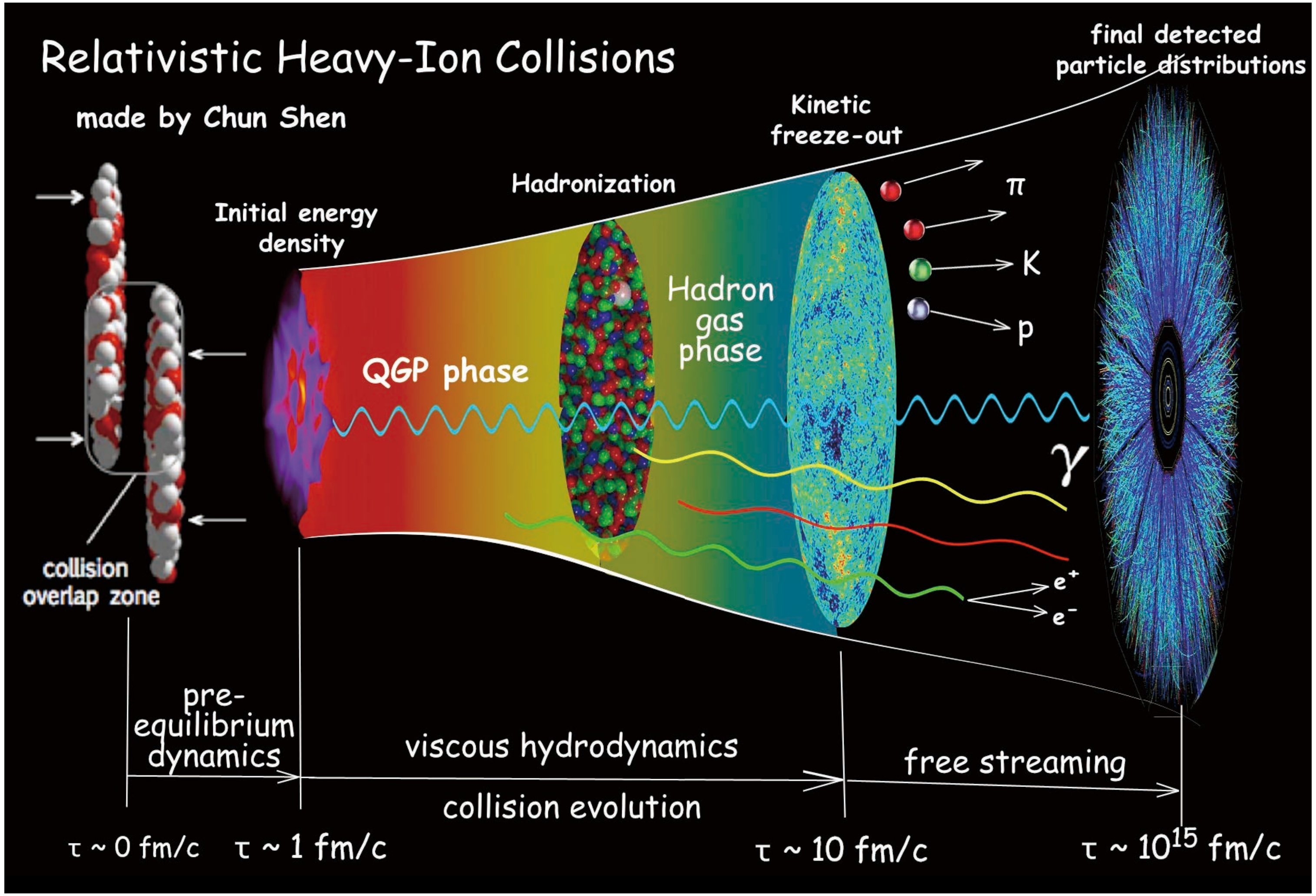


QGP・グルーオン抑制

陽子スピン・ハドロン構造

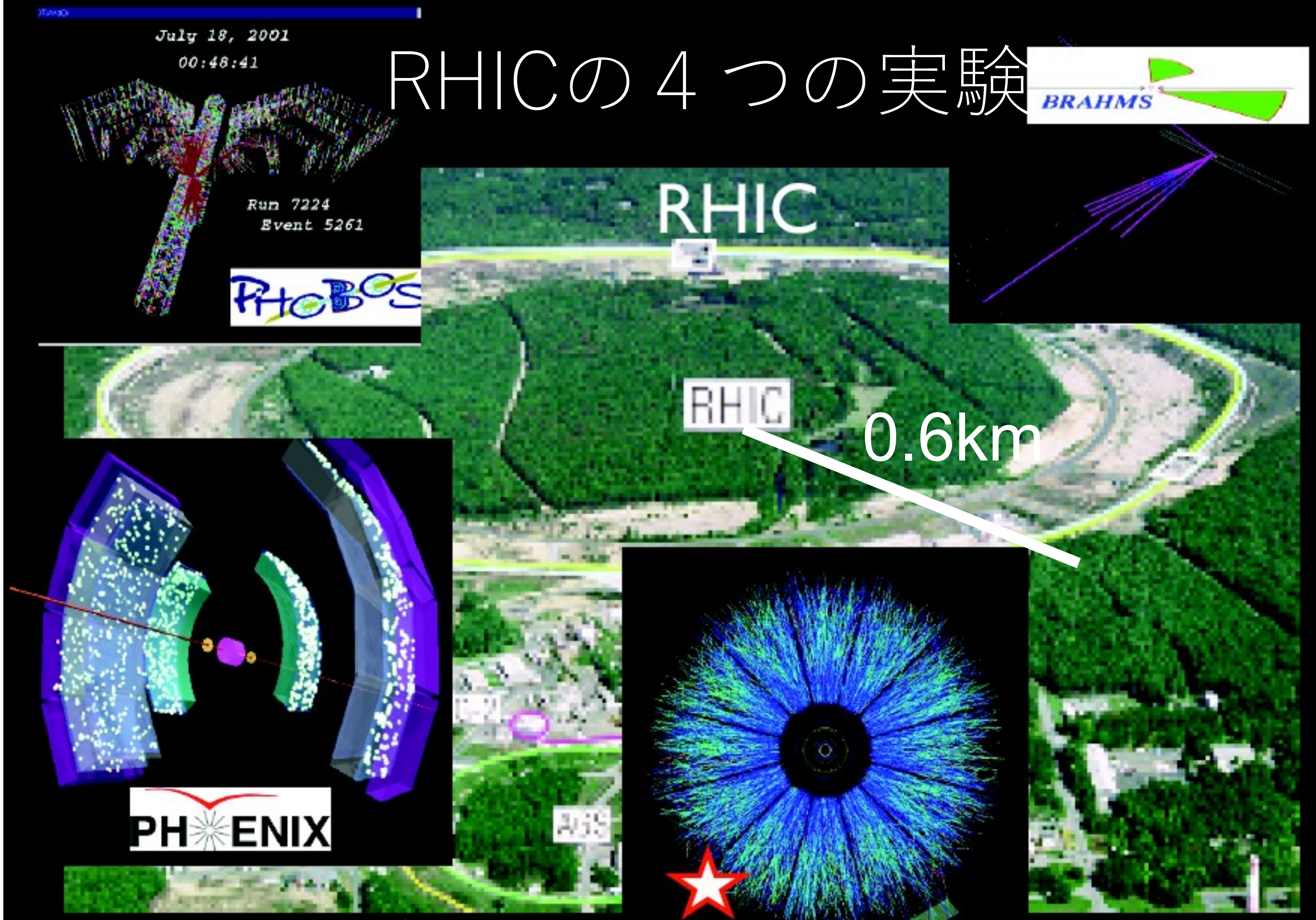
QGPとプローブ

Courtesy of Paul Sorensen and Chun Shen



従来RHICではハドロン化を経たハドロンを主なプローブとしてQGPを観測してきた

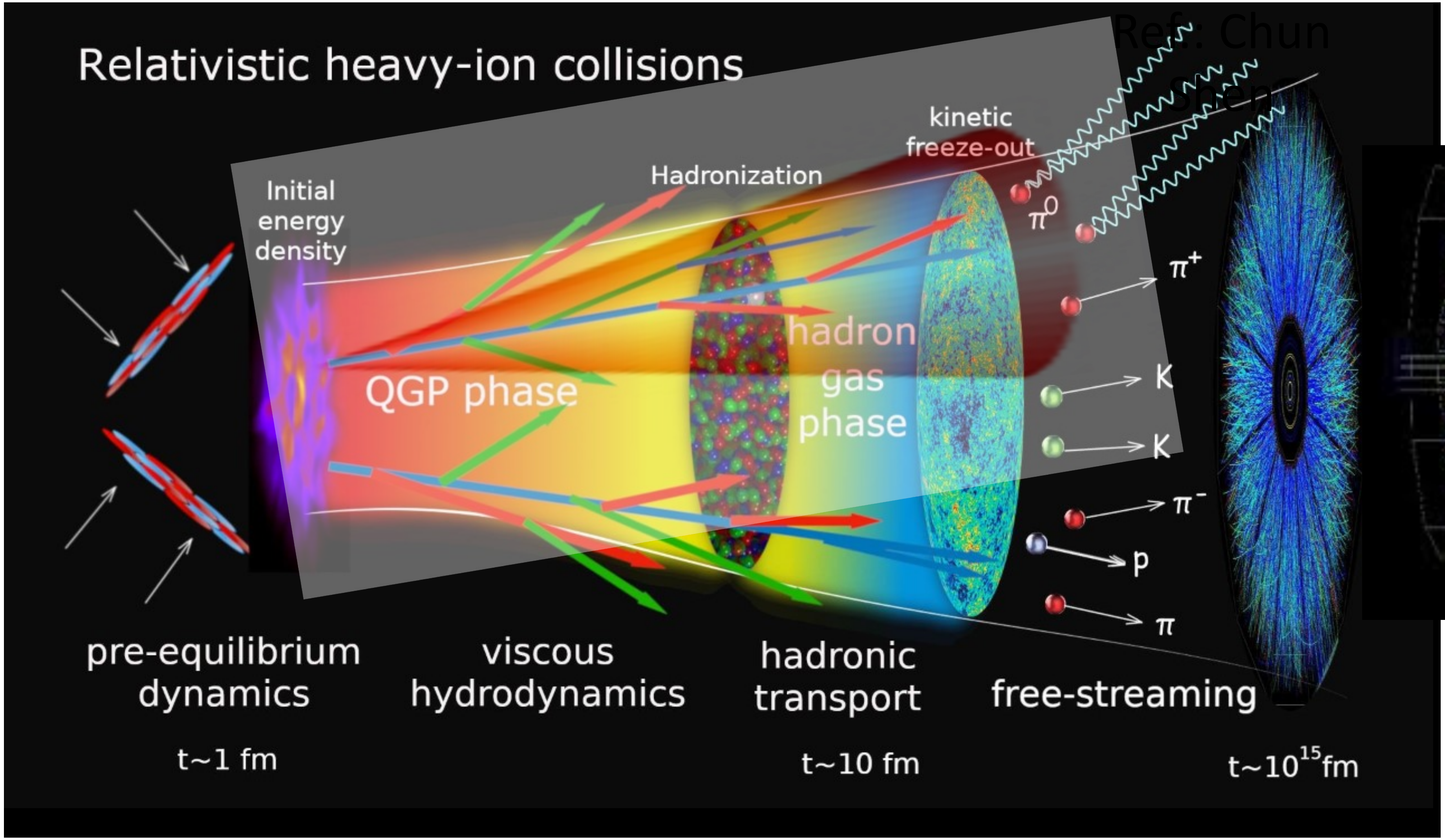
RHICの４つの実験



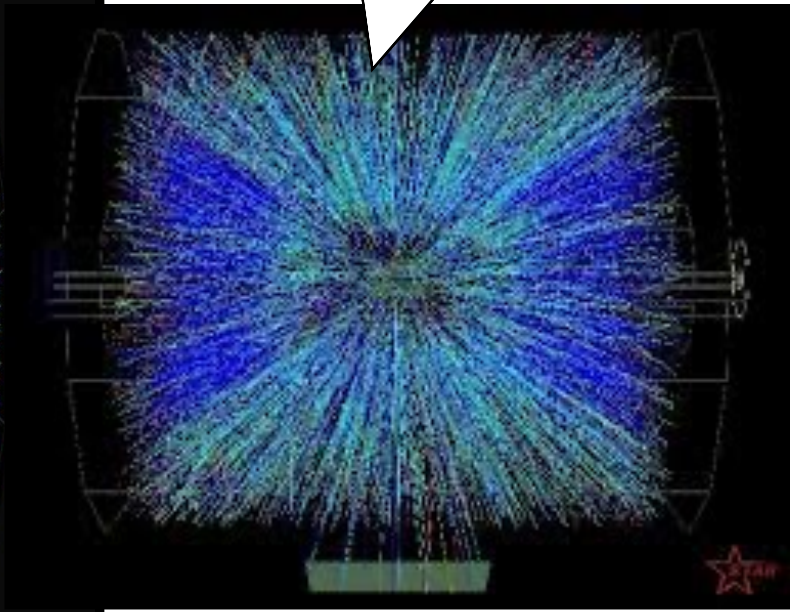
いずれもハドロンに特化された検出器群

QGPとプローブ

QM2019, Gojko Vujanovic



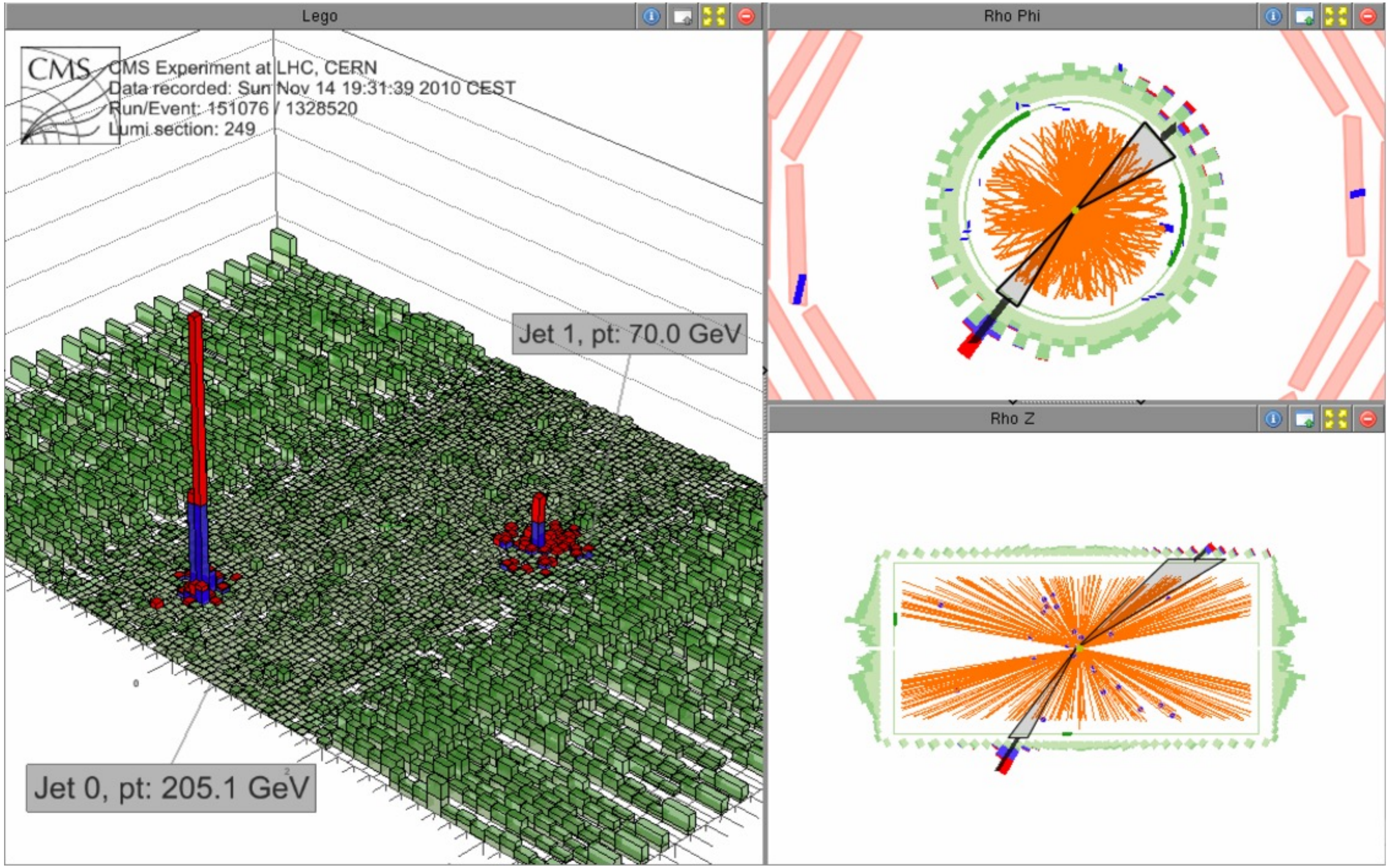
重イオン衝突で
ジェットなんて
ムリムリ！



STARイベントディスプレー

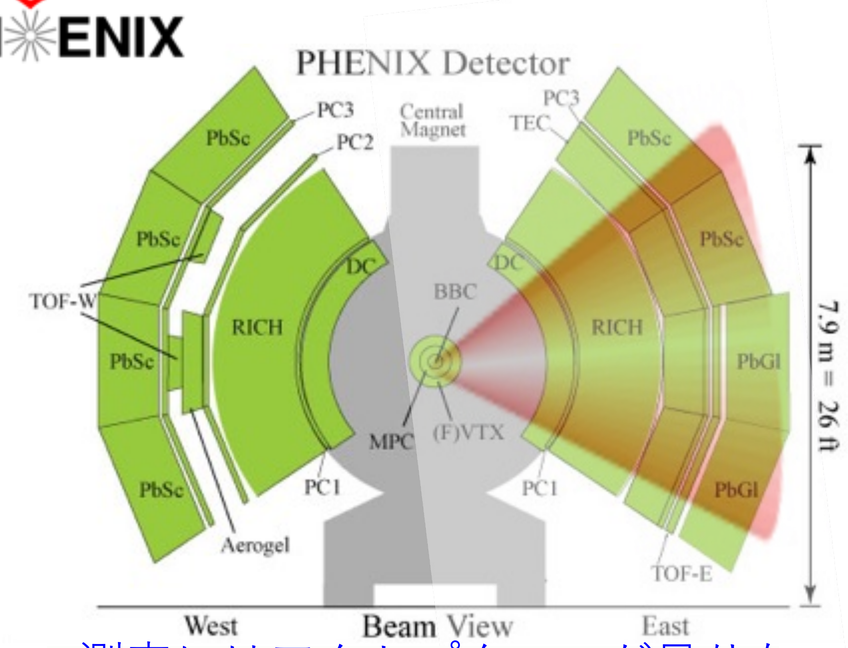
QGP物性をより精密に測定するには、ジェットはゴールデンプローブ

高エネルギー重イオン衝突とジェット測定

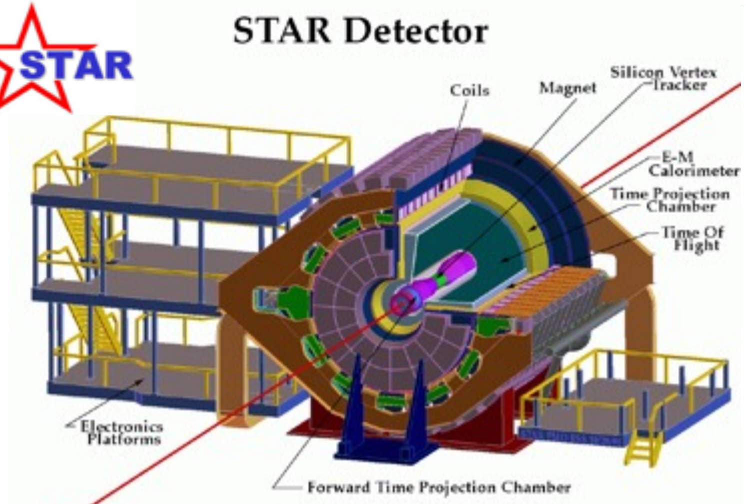


LHCで可能なことが証明された

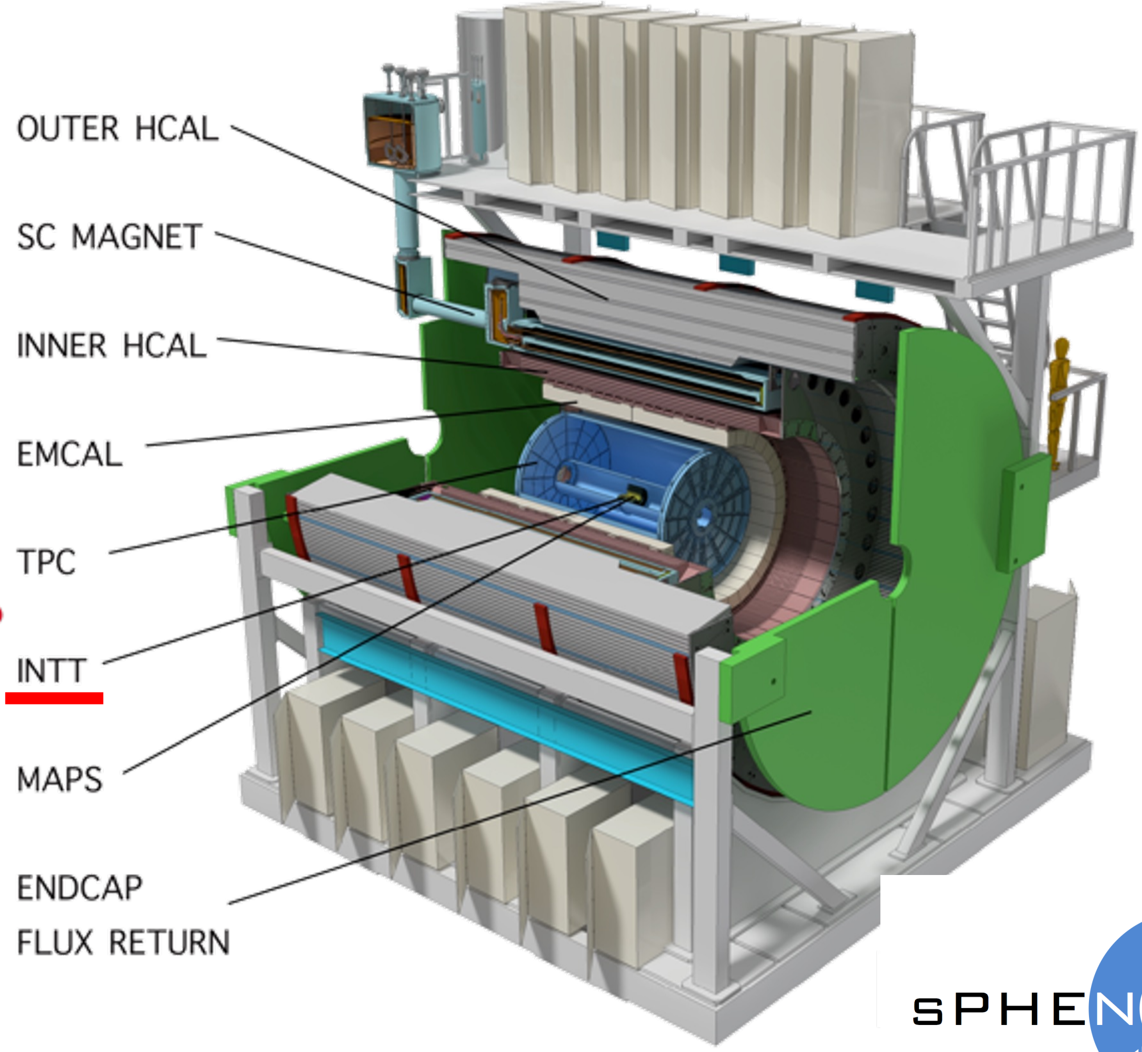
sPHENIX検出器のコンセプト



Jetの測定にはアクセプタンスが足りない

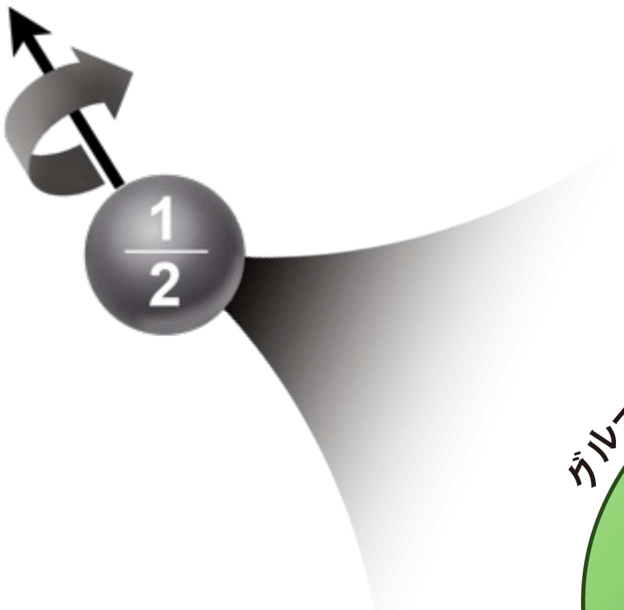


4π & -1<η<1だがHCAL無しのJet測定



4π & -1<η<1 をHCALで覆う
Jetに特化した検出器

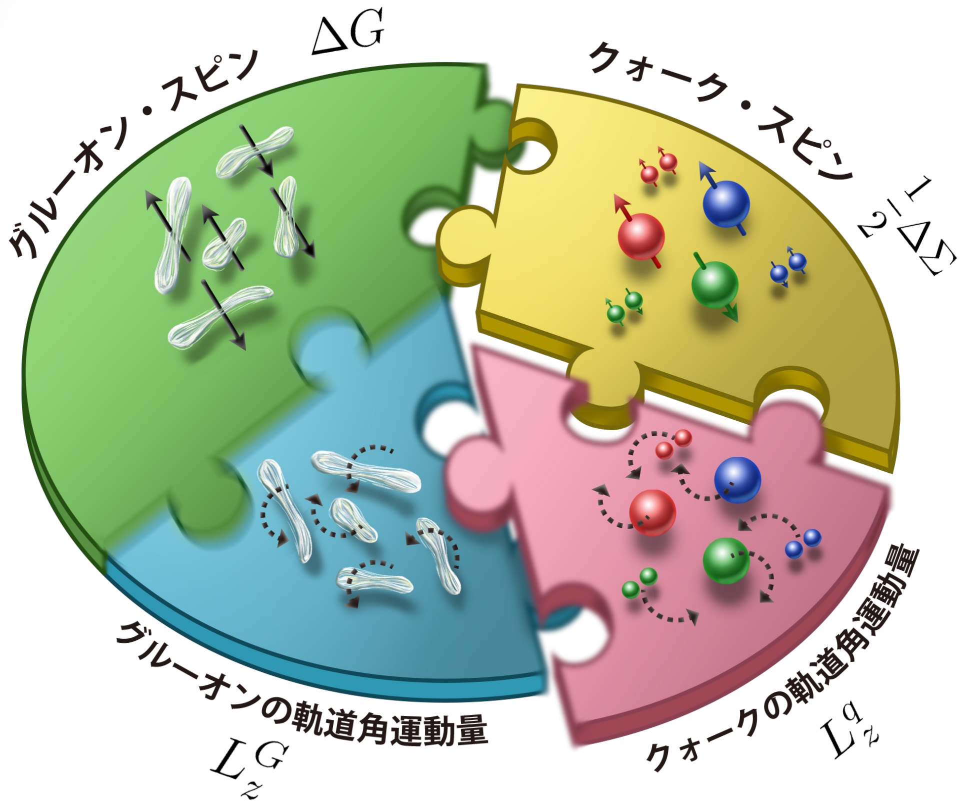
Cold-QCD: 陽子スピンのパズル（謎）



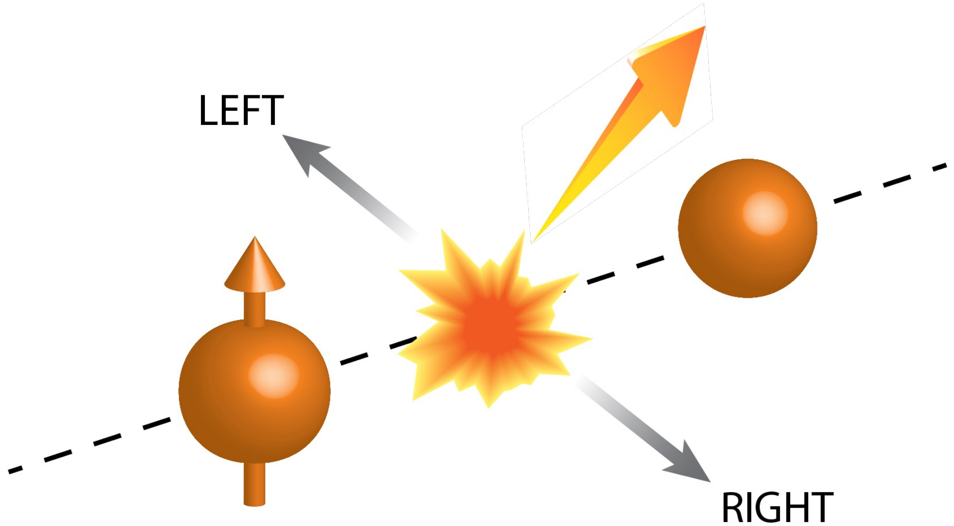
陽子スピン和則

$$S_z = \frac{1}{2}\Delta\Sigma + \Delta G + L_z$$

$\frac{1}{2}\Delta\Sigma$	ΔG	L_z
↓	↓	↓
~25%	~40%	??
1980's	2000~2018	

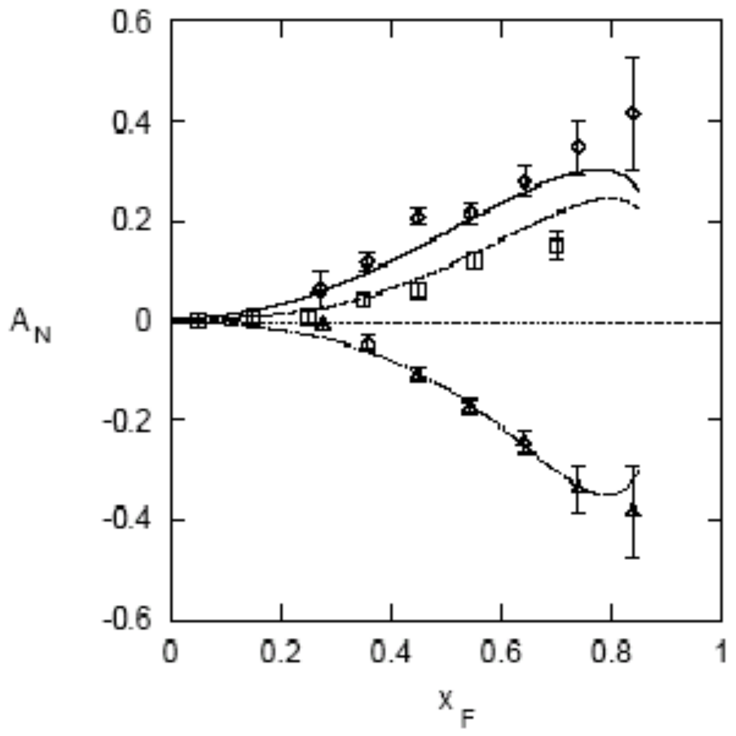


単偏極陽子衝突の生成ハドロン左右非対称性

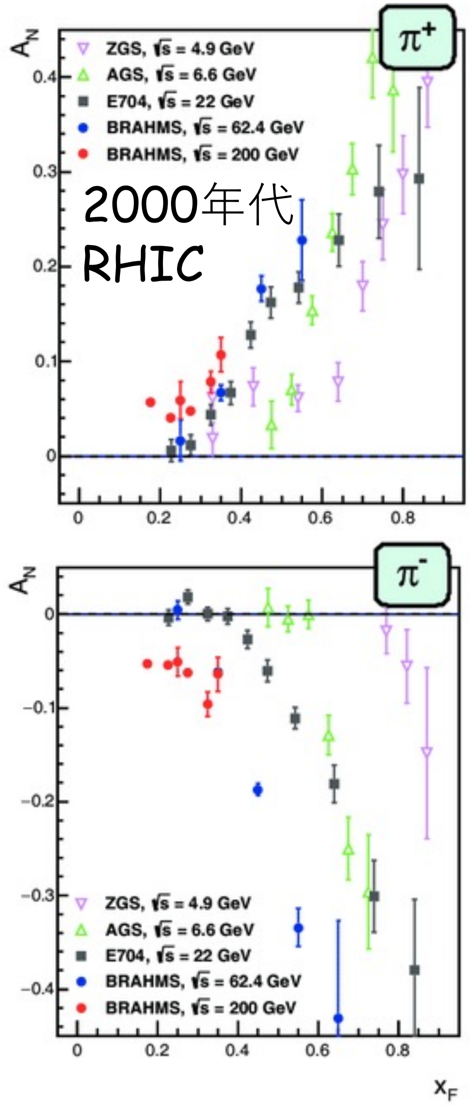


$$A_N = \frac{1}{P}\frac{\sigma_L^{\pi} - \sigma_R^{\pi}}{\sigma_L^{\pi} + \sigma_R^{\pi}}$$

E704: pion single spin asymmetry A_N

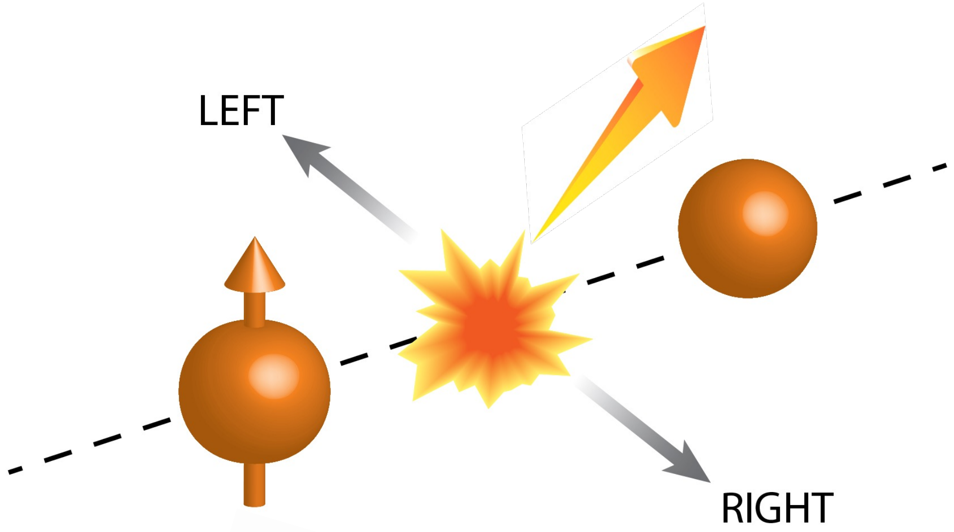


1980年代@フェルミ研究所

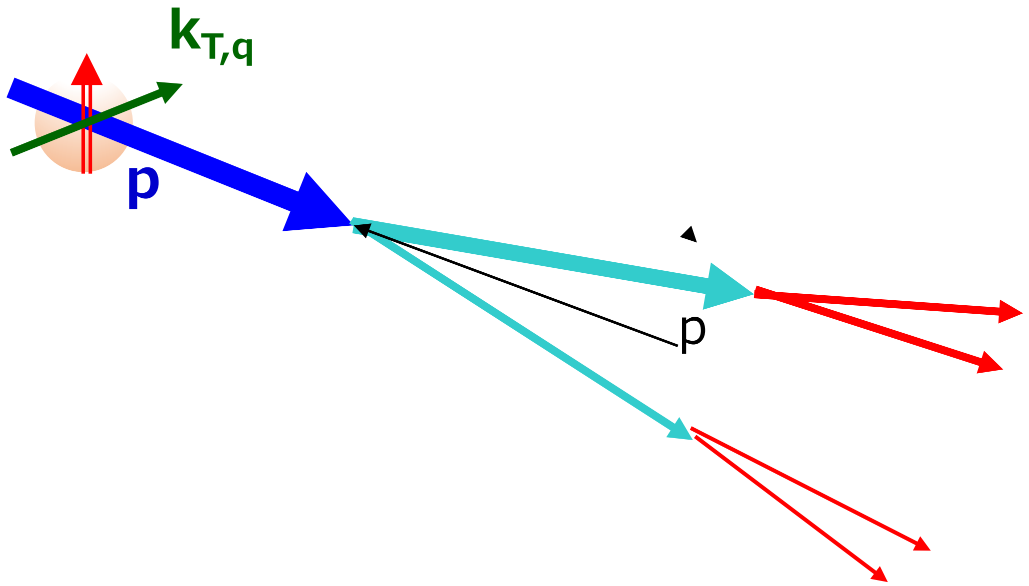


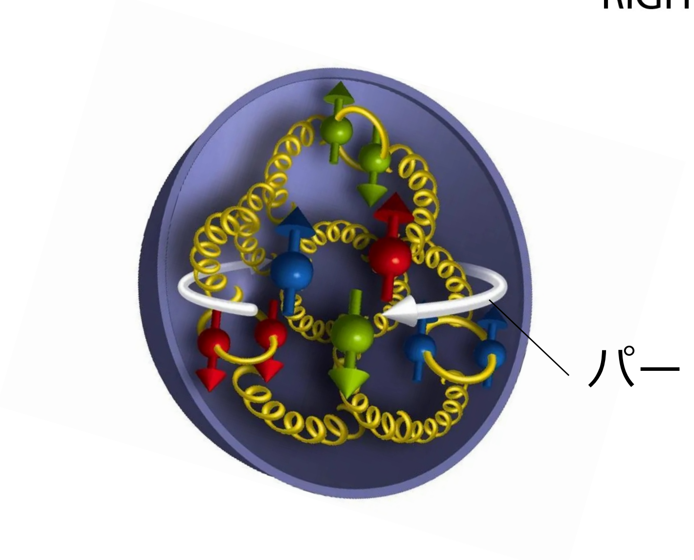
前方に40%もの巨大な左右非対称性

単偏極陽子衝突の生成ハドロン左右非対称性



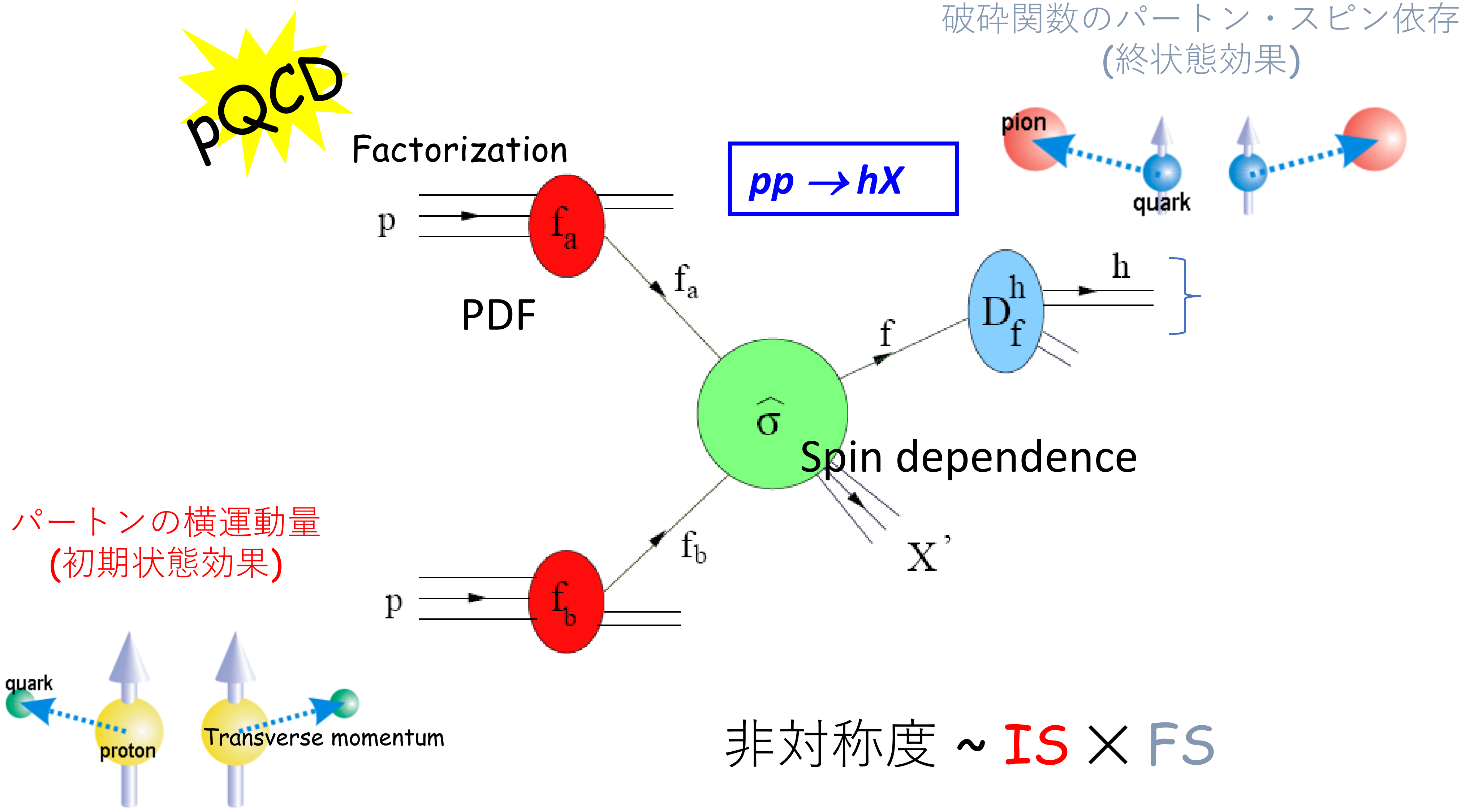
パートンの横運動量





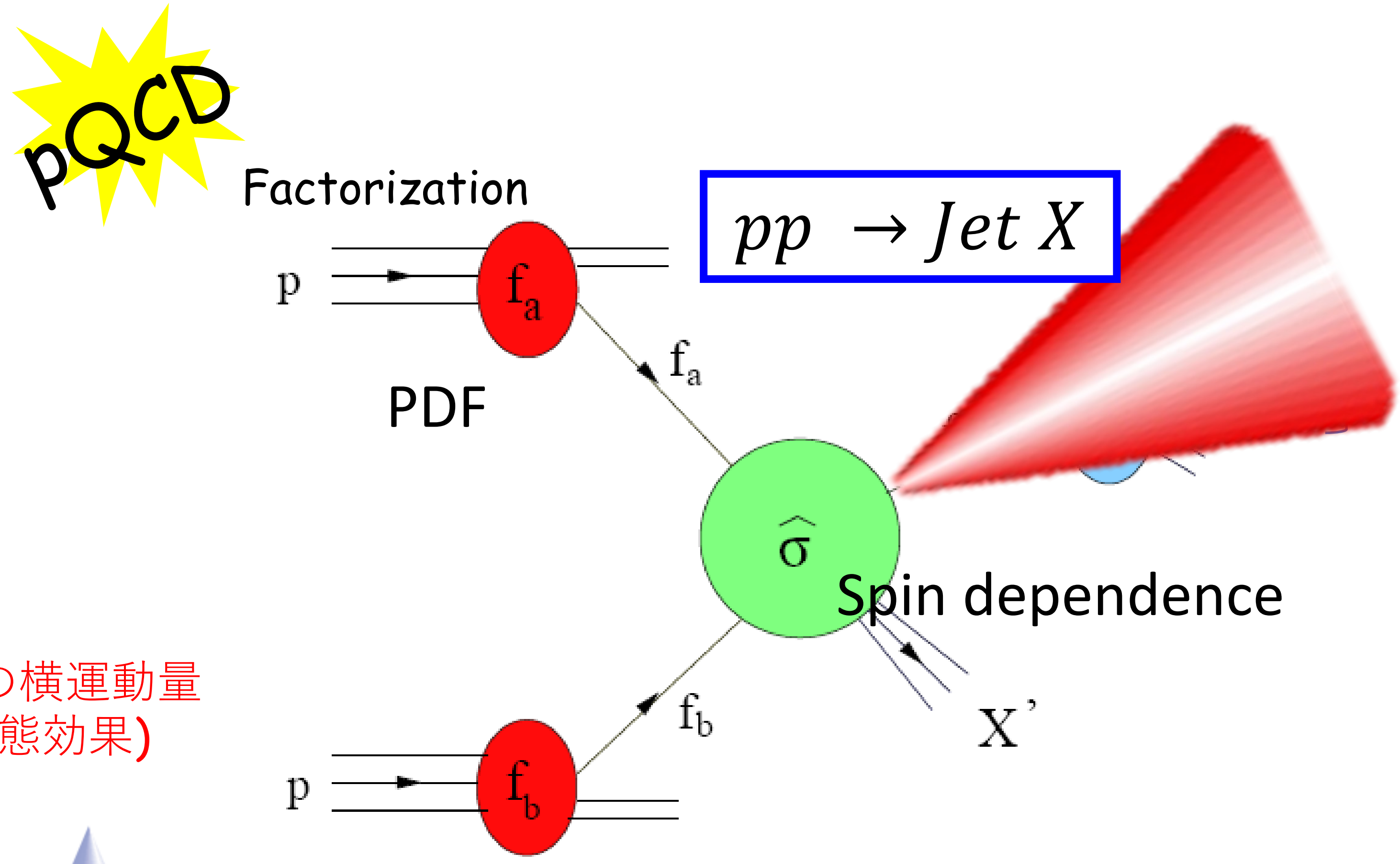
パートンの軌道角運動量～パートンの横運動量

左右非対称性の起源

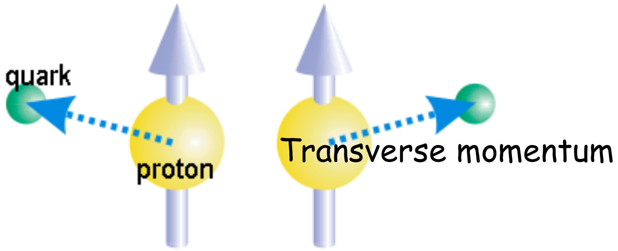


非対称度 ~ IS × FS

左右非対称性の起源



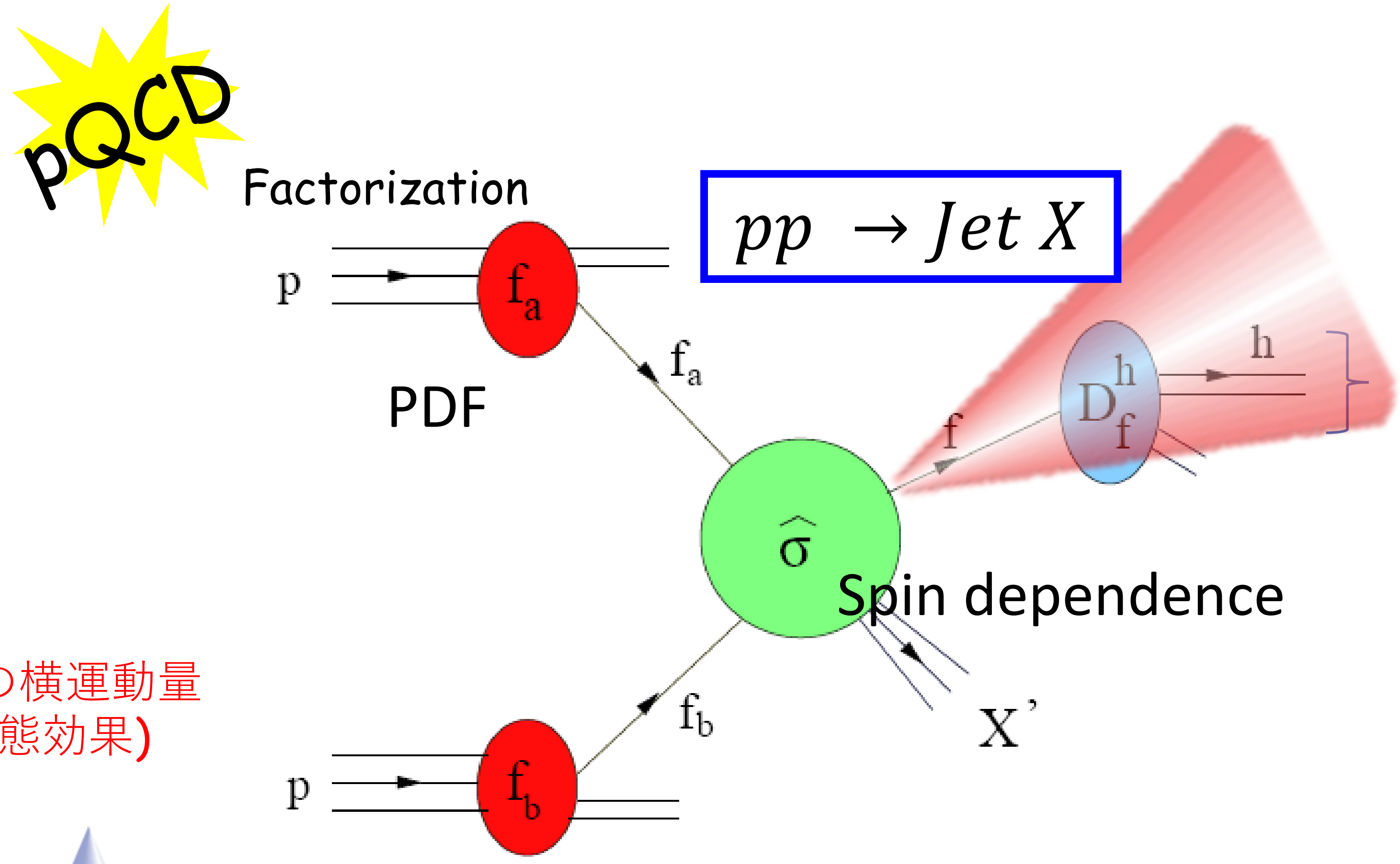
パートンの横運動量
(初期状態効果)



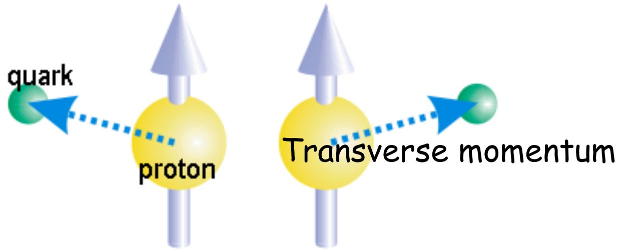
非対称度 ~ IS

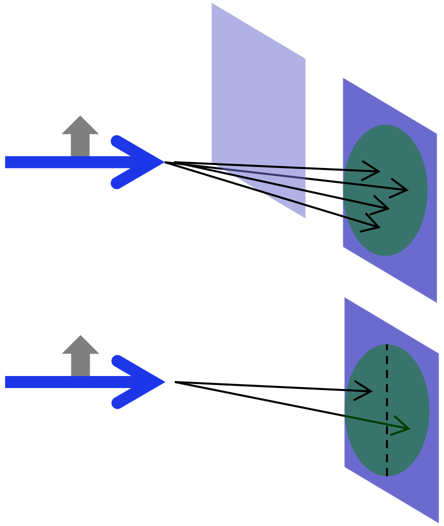
ジェットはやはり
ゴールデンプローブ！

左右非対称性の起源



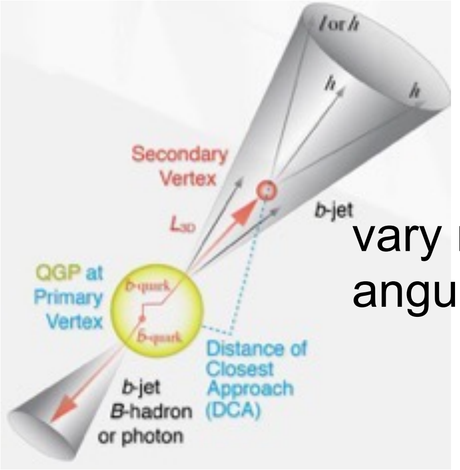
パートンの横運動量
(初期状態効果)

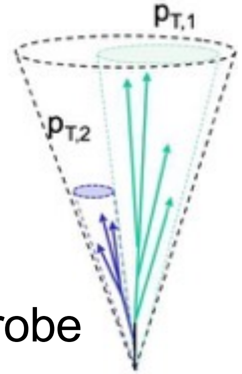




ジェット軸に対する
ハドロン生成左右非対称性~ FS

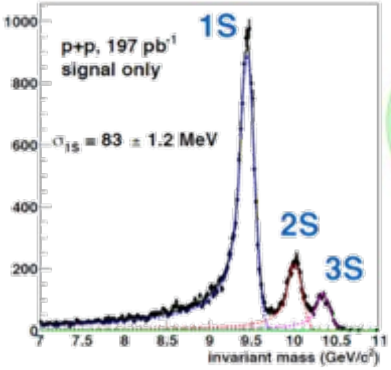
sPHENIXの目指す物理

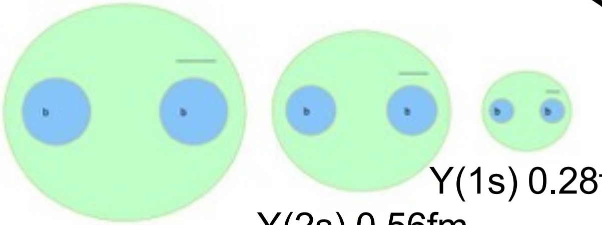




vary momentum & angular scale of probe

Jet physics

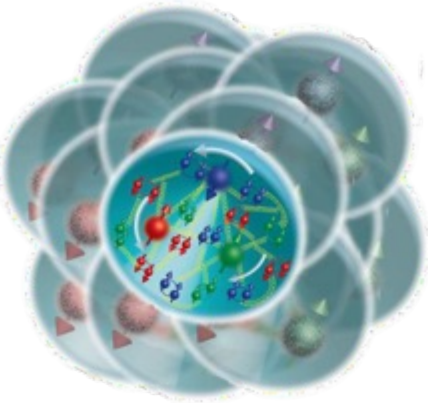




Υ(3s) 0.78fm Υ(2s) 0.56fm Υ(1s) 0.28fm

vary size of probe

Quarkonium spectroscopy



Cold QCD

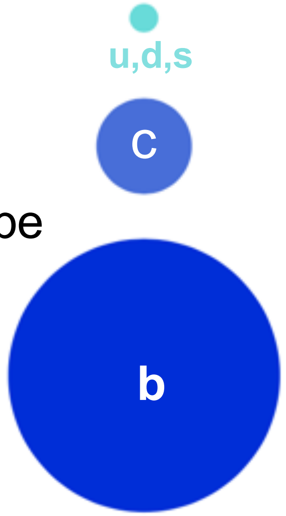
vary temperature of QCD matter

study proton spin, transverse-momentum, and cold nuclear effects

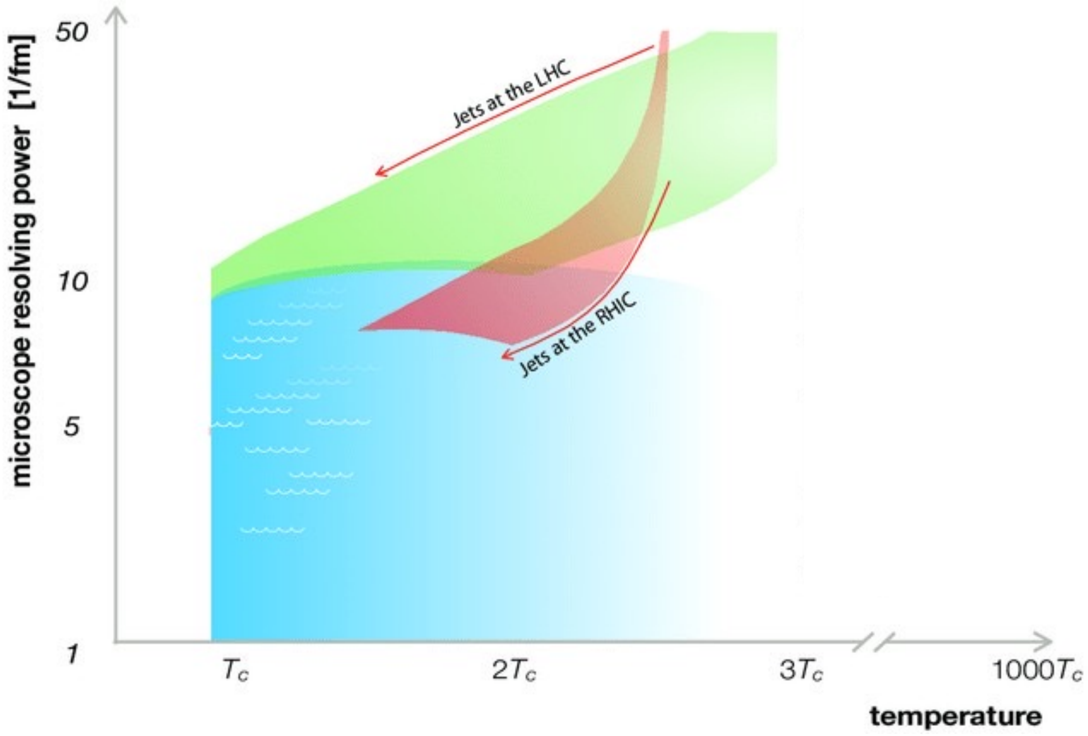
Parton energy loss

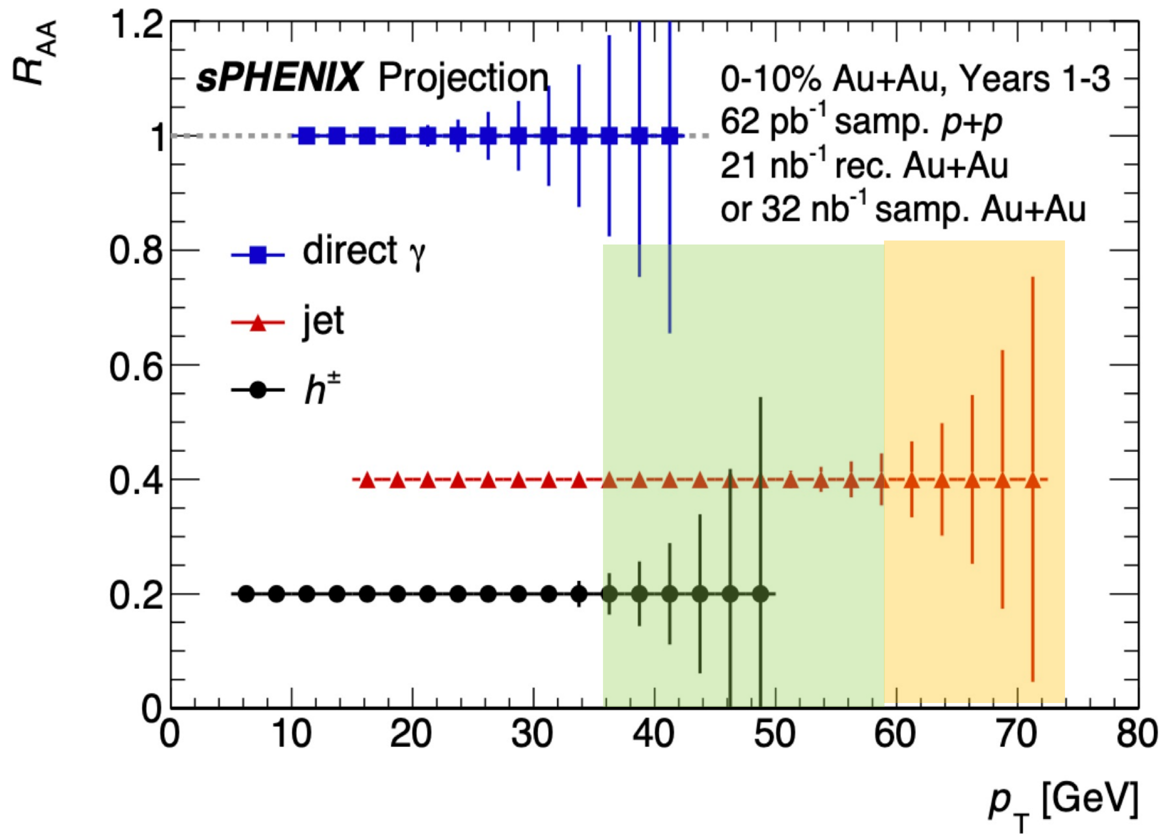
vary mass & momentum of probe

photon
gluon



RHICでJet観測する意義



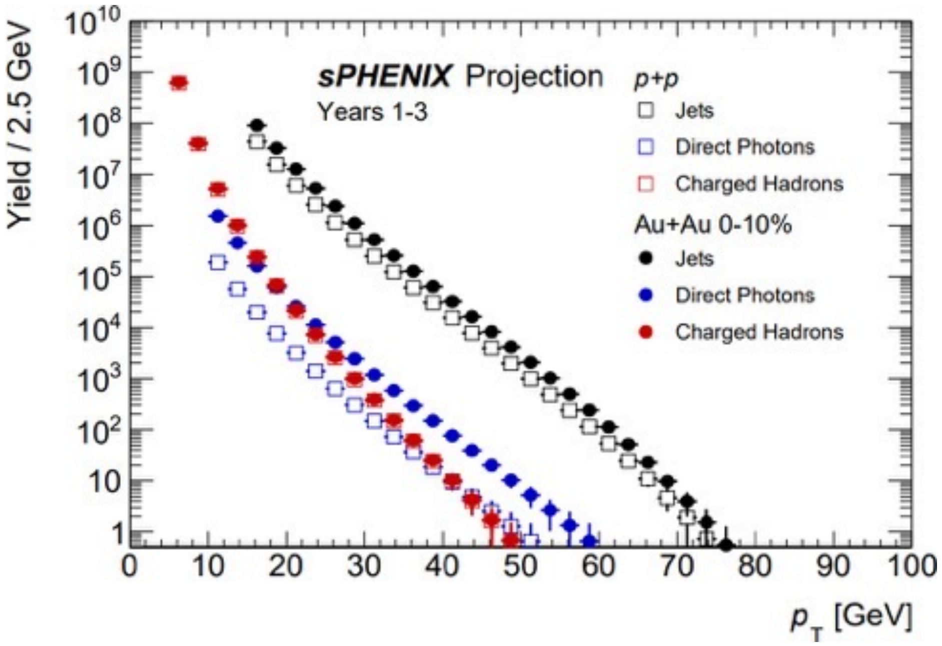


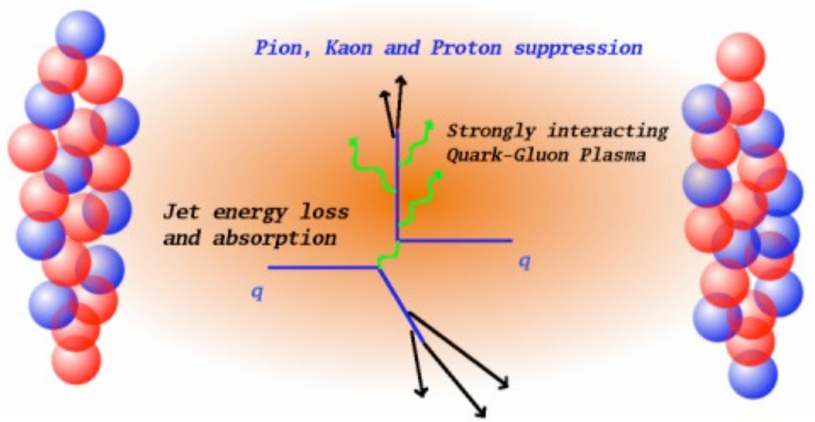
LHCと相補的な理解
- QGPの温度の違い
- プローブの分解能

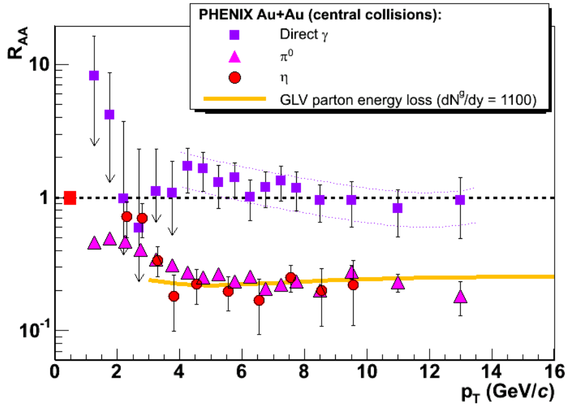
Overlapping region with LHC

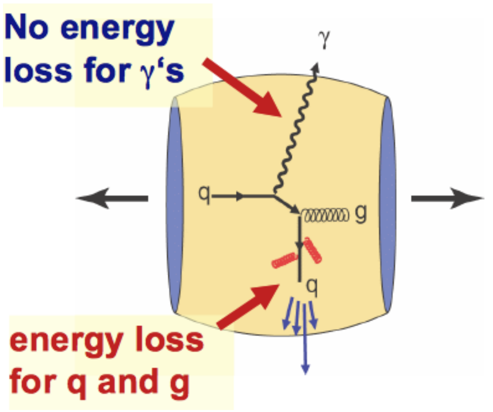
Unexplored region at RHIC and LHC

Jetで観るエネルギー損失

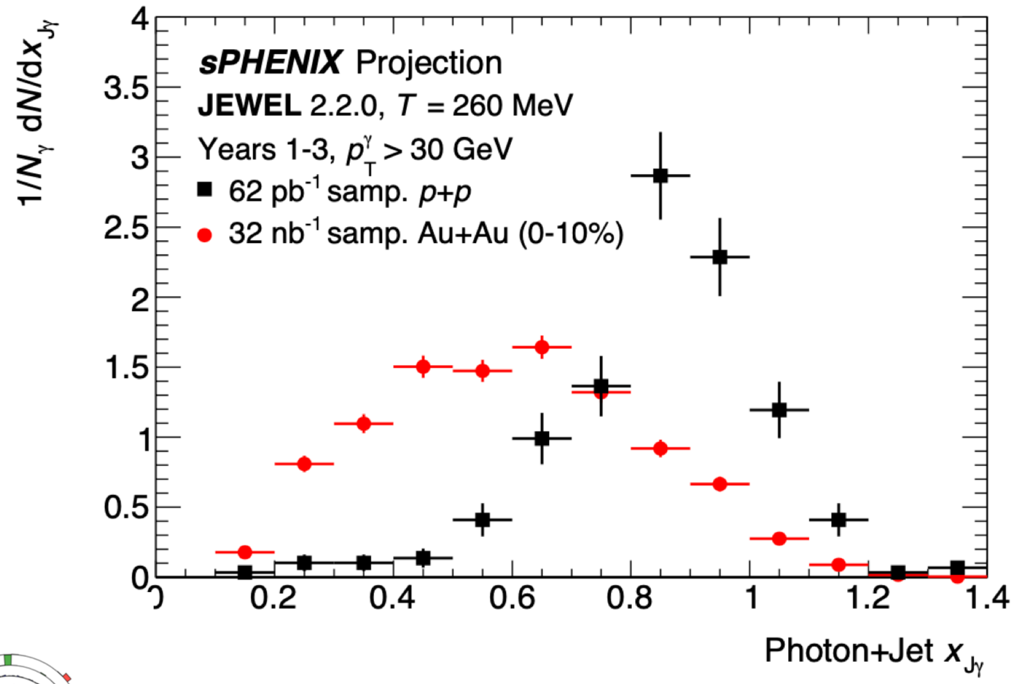


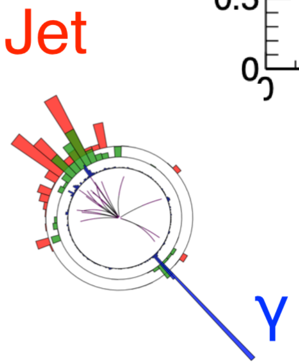






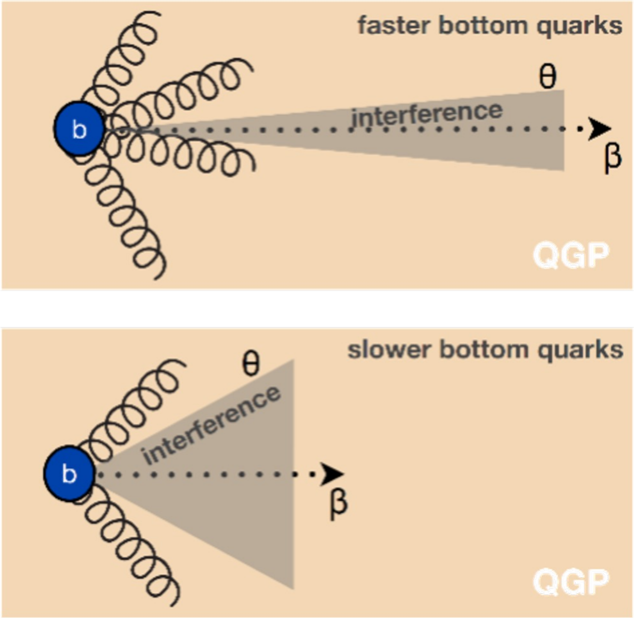
Jet-to-photon momentum balance

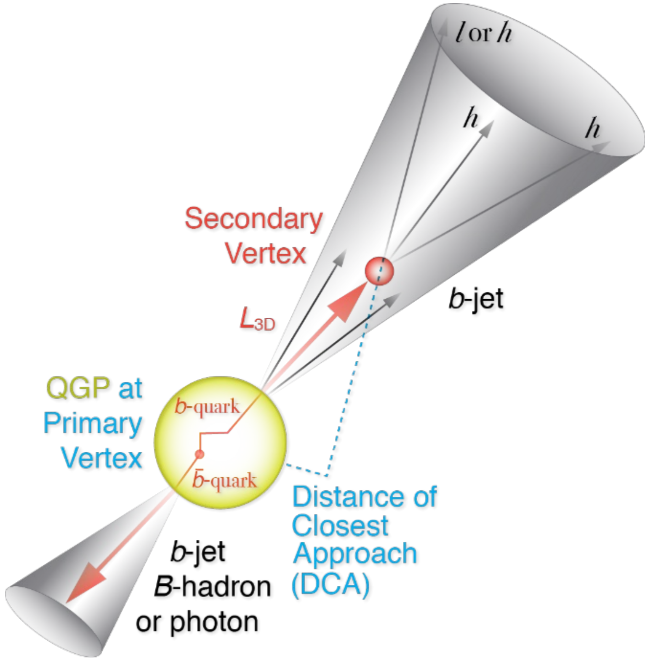


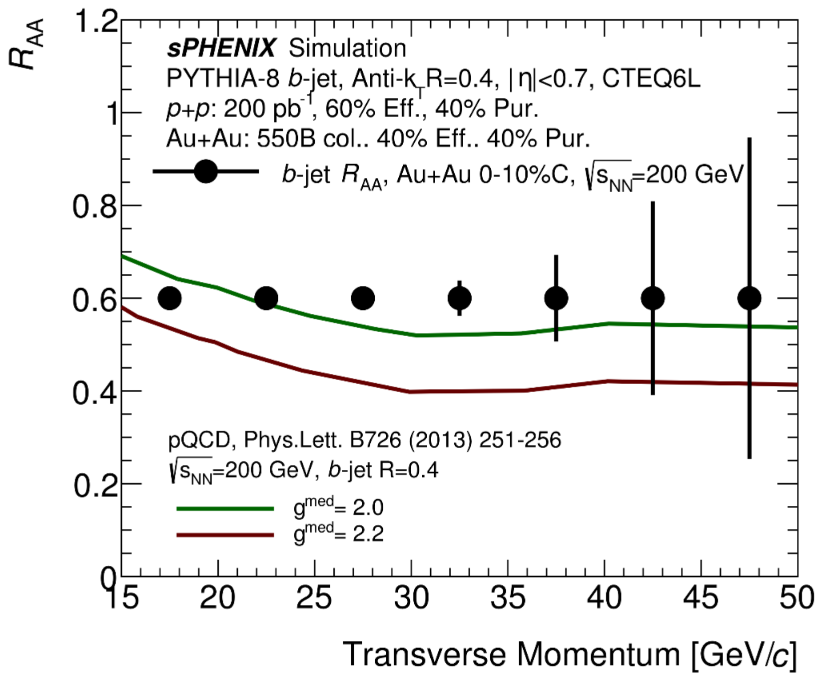


$$x_{J\gamma} = p_T^{jet} / p_T^{\gamma}$$

b-Jetの物理



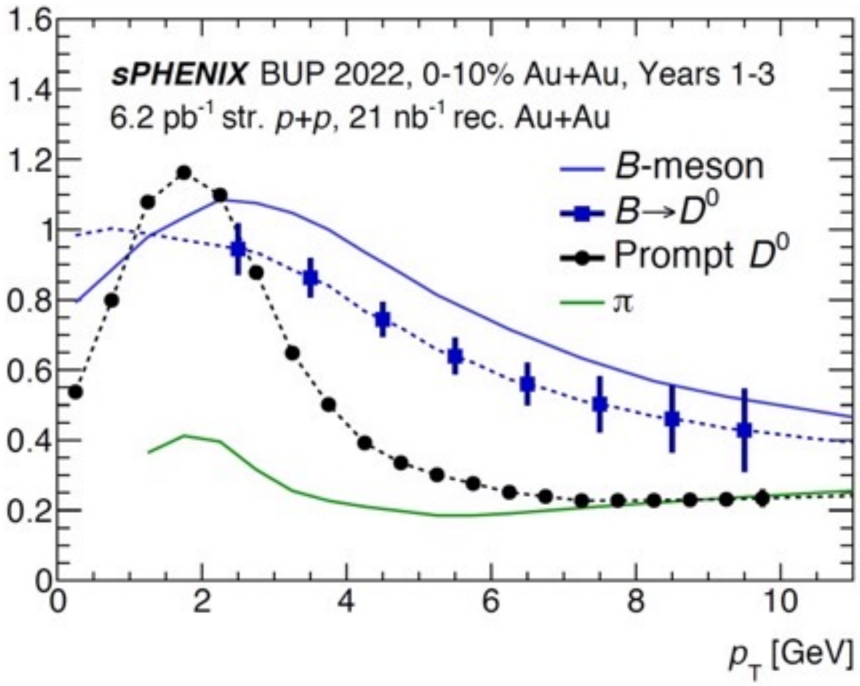




b-jet + light jet:

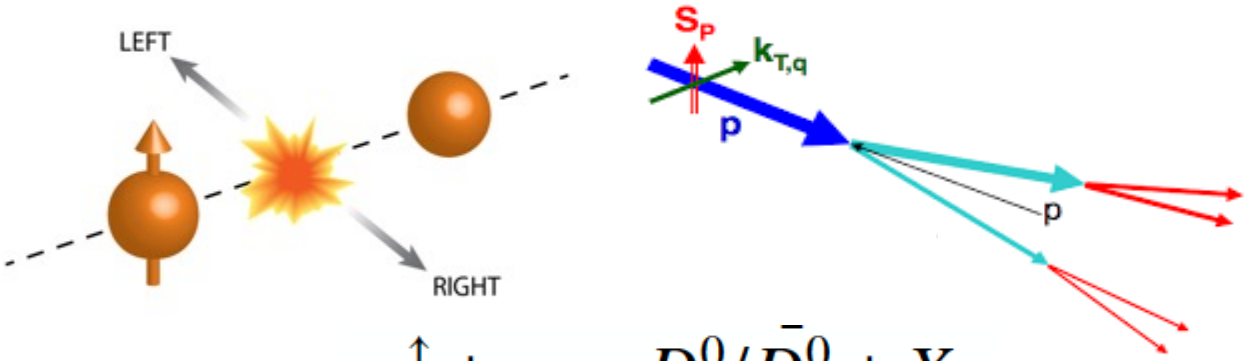
differential sensitivity to radiative energy loss VS collisional energy loss.

Open Heavy Flavor

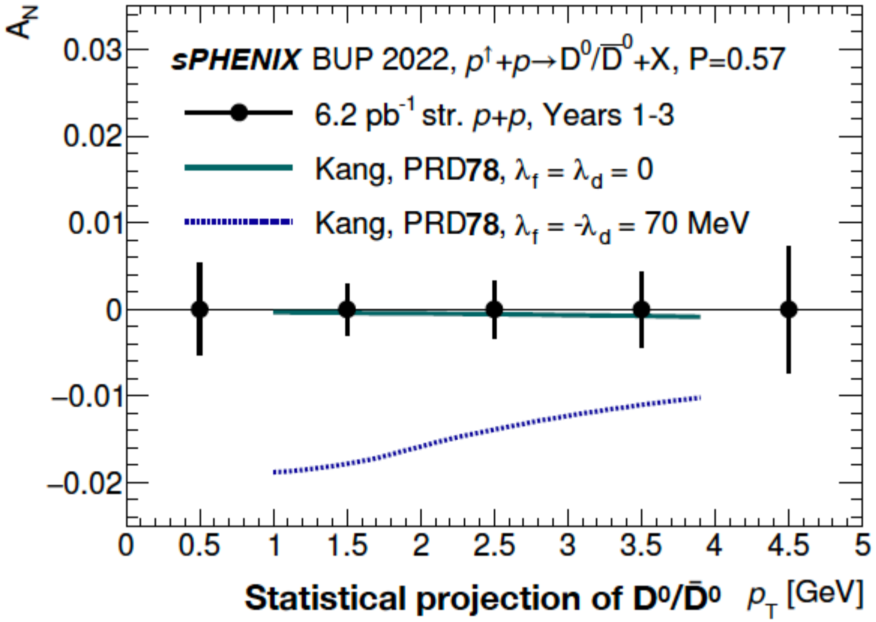


- ✓ Cleanly separate open bottom via DCA.
- ✓ Study mass dependence of energy loss and collectivity.
- ✓ Bottom quarks and light quarks are expected to be different for R_{AA} and v_2 for $p_T \lesssim 15$ GeV.

陽子のスピンプログラム



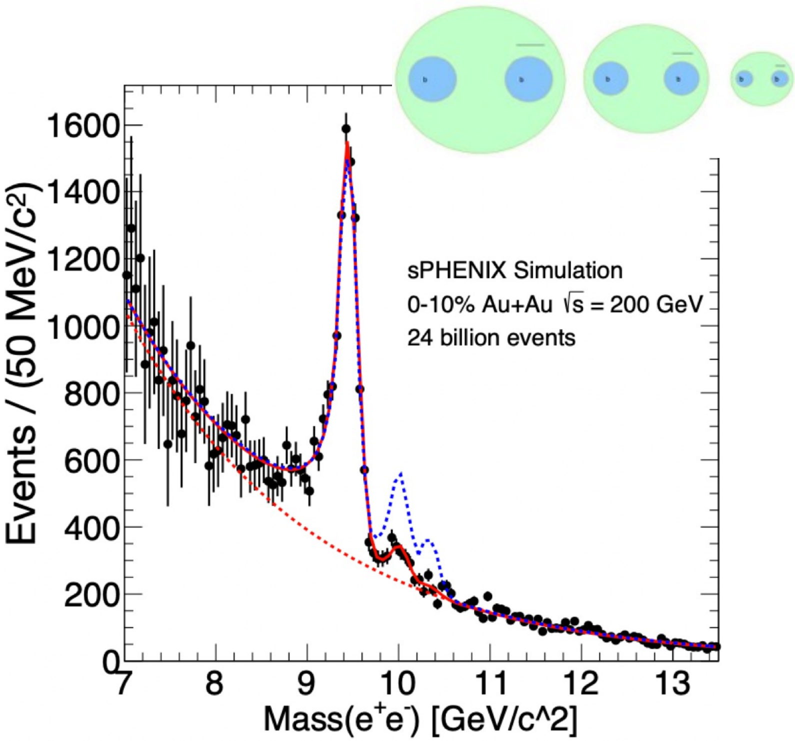
$$p^{\uparrow} + p \rightarrow D^0/\bar{D}^0 + X$$

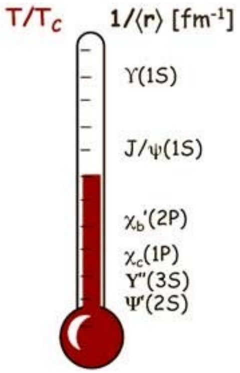


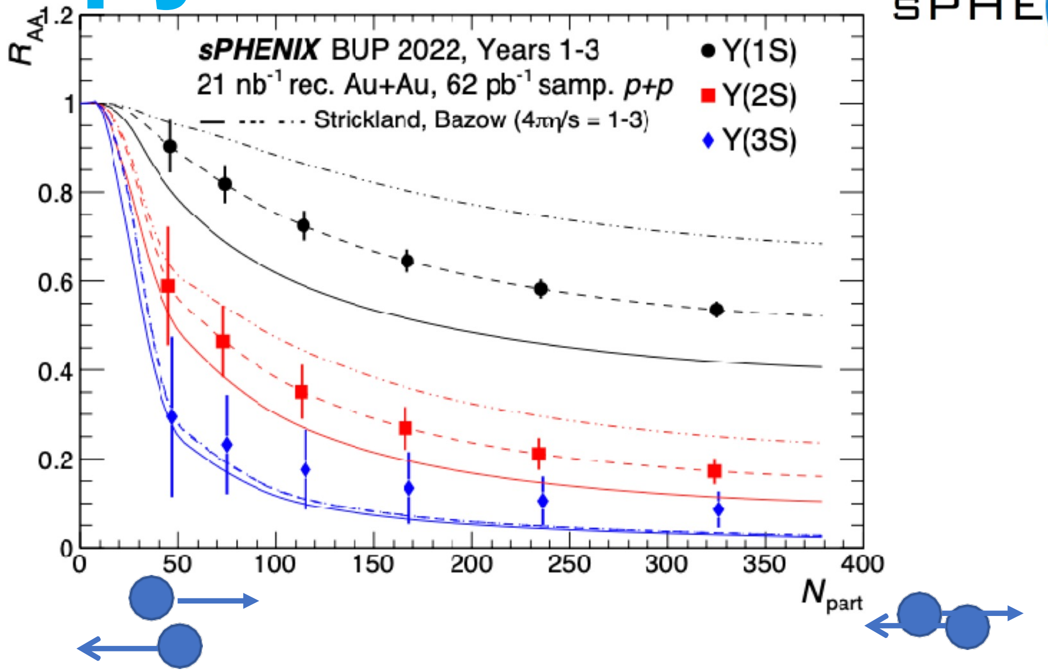
Statistical projection of $D^0/\bar{D}^0$ measurement at sPHENIX.

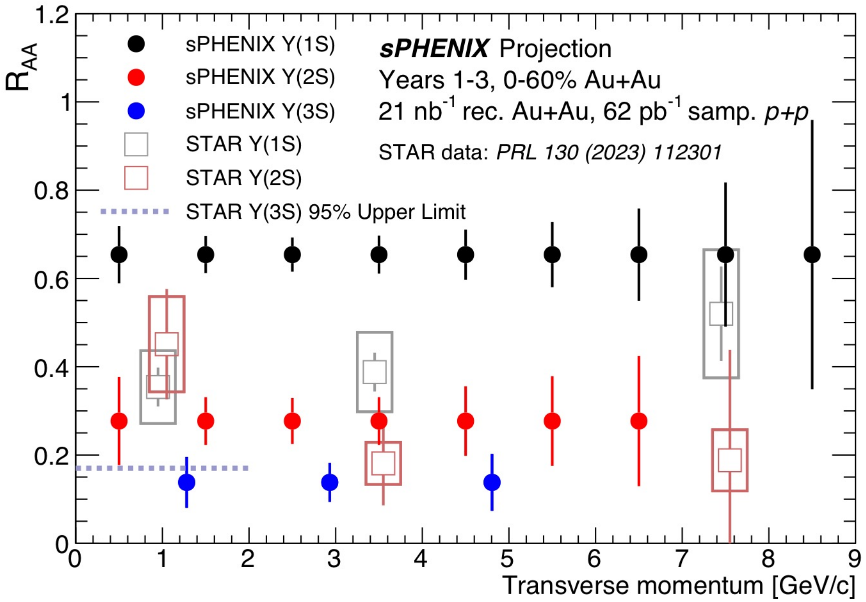
グルーオンの軌道運動に感度

Quarkonium spectroscopy









- Well separated three Upsilon states thanks to excellent mass resolution
- Potential first clean measurements of ϒ(3s) at RHIC

sPHENIX誕生の秘話

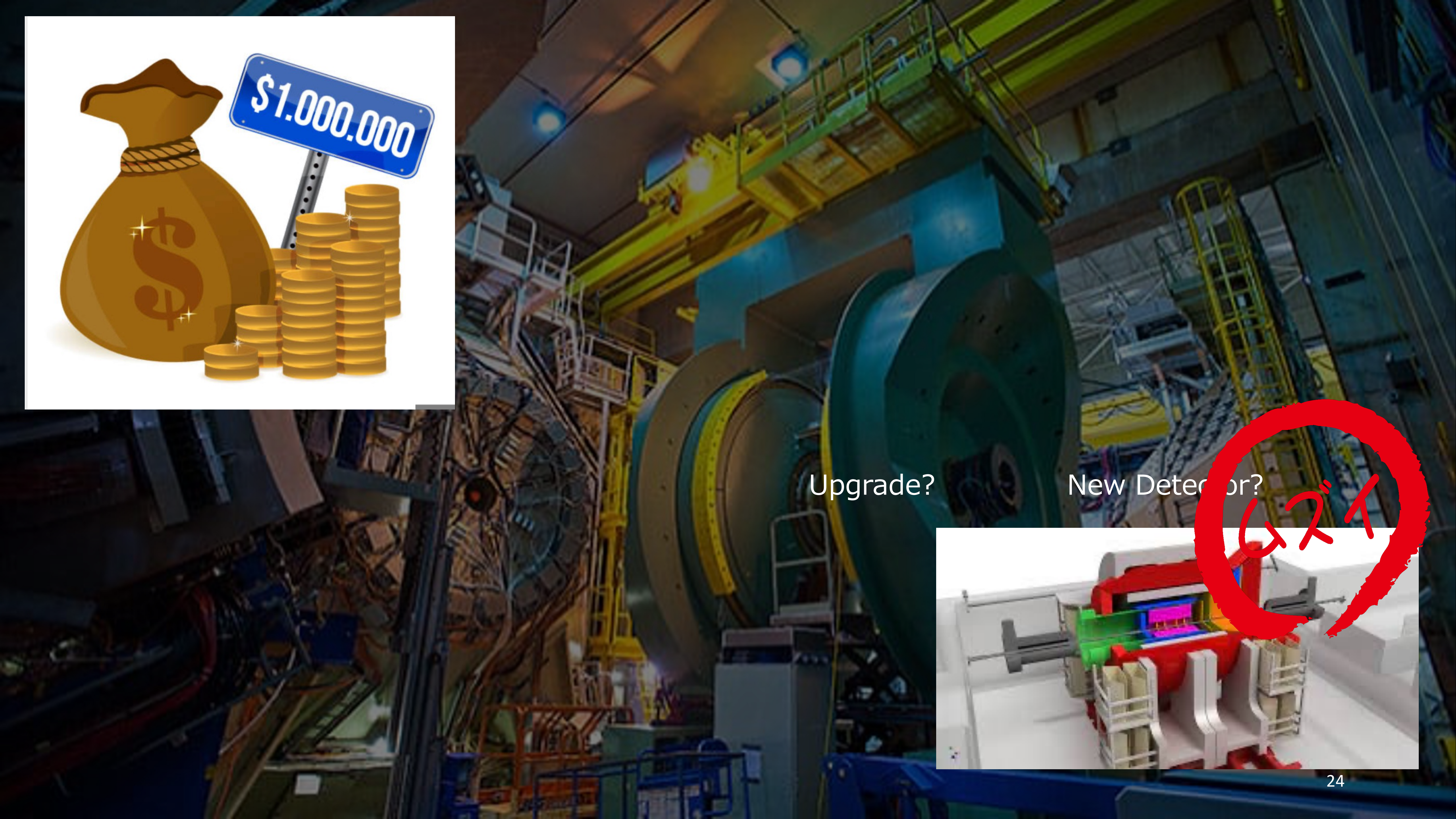
2009～2015年

PHENIX実験の延命か終焉か

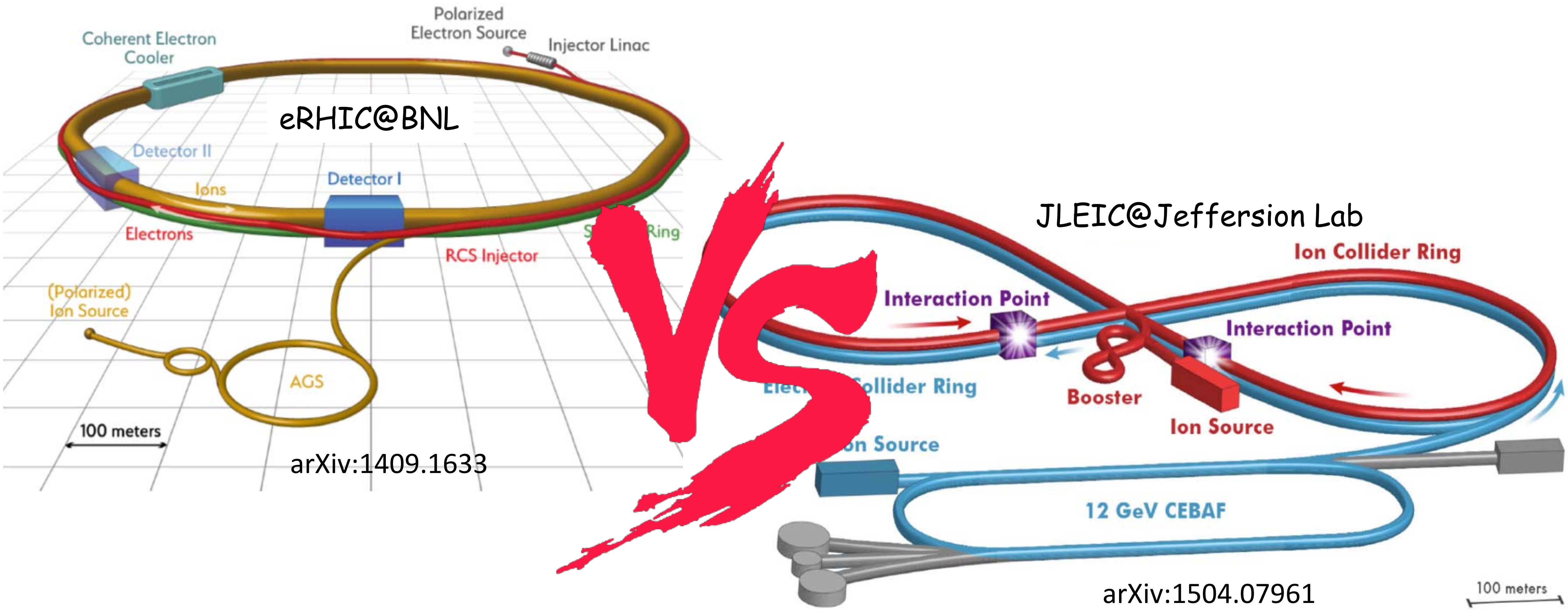
2000年～

Upgrade?

New Detector?

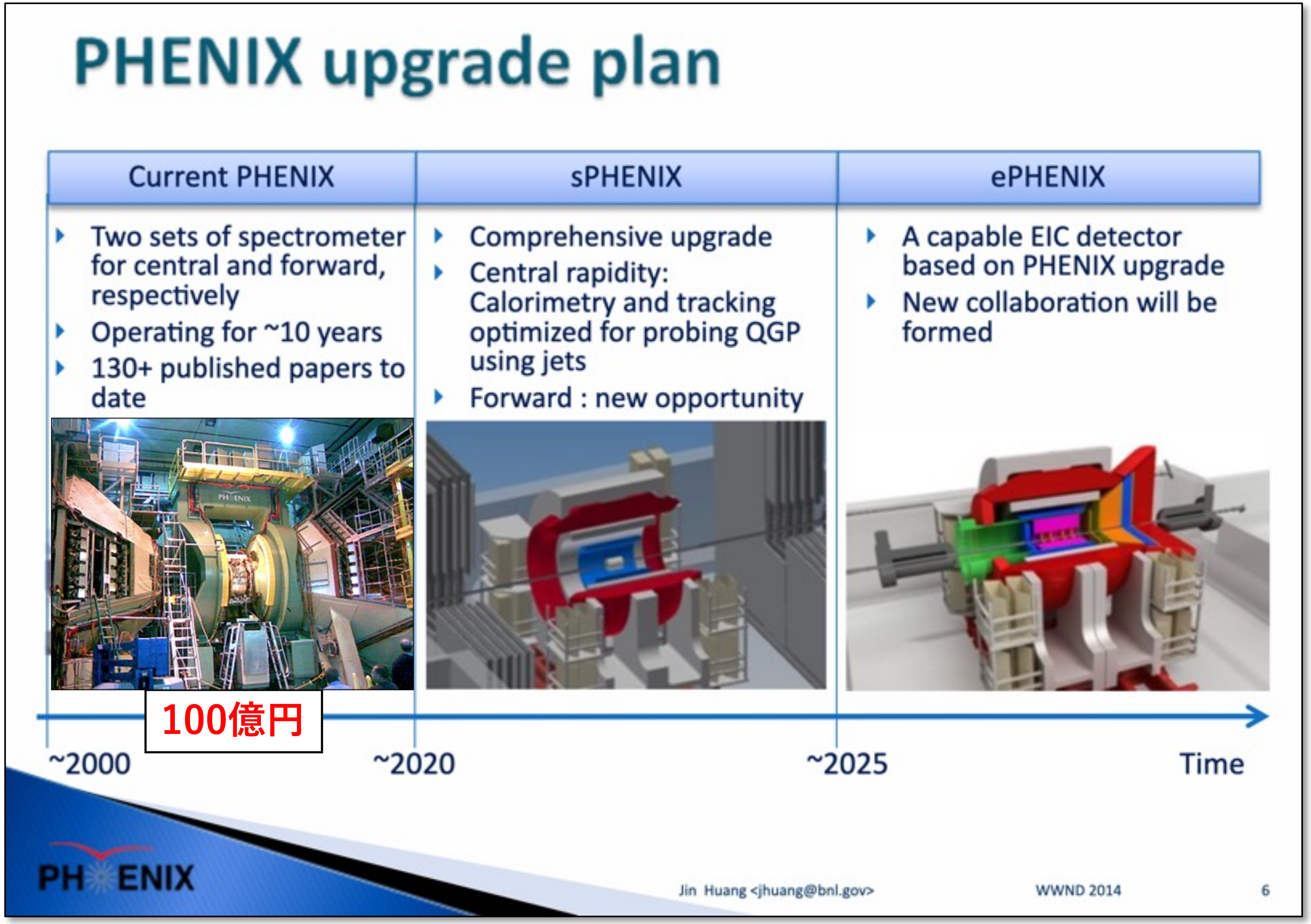

$1.000.000
Upgrade?
New Dete or?
ムズイ

BNLの思惑 ~EICサイトセレクション~



是非EICをBNLに誘致したい

Berndt Mullerの描いたシナリオ
（BNL副所長）

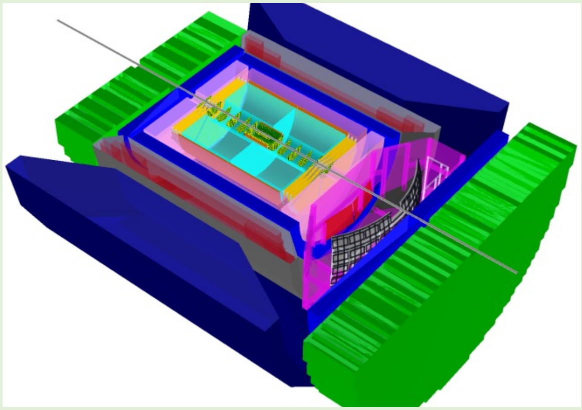


"sPHENIXはEICのDay-1検出器"

EICの４つの検出器案

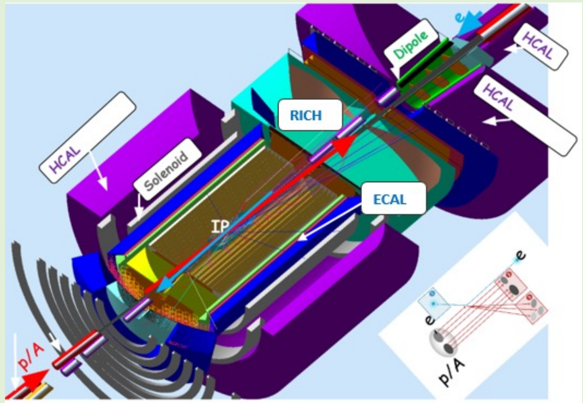
Brookhaven concept: BEAST

$$$



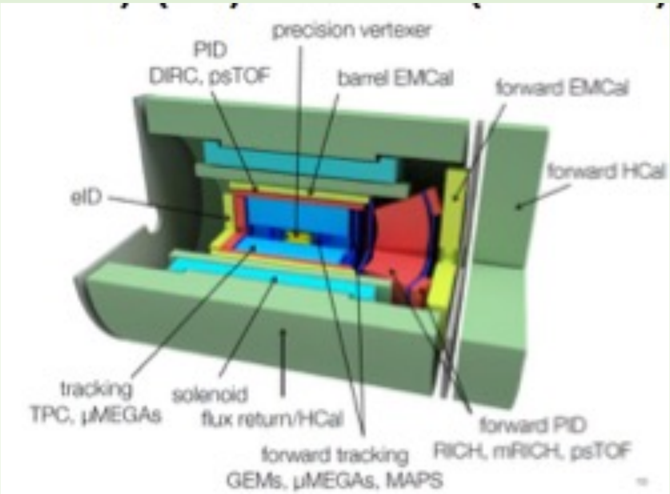
Jefferson lab concept: JLEIC

$$$



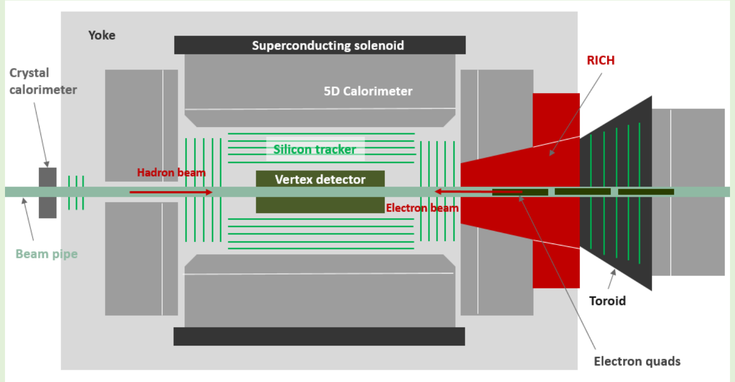
ePhenix/eSTAR

$!



Argonne concept: TOPSiDE

$$$



sPHENIXの再利用により、EICのDay-1検出器が格安で作れる

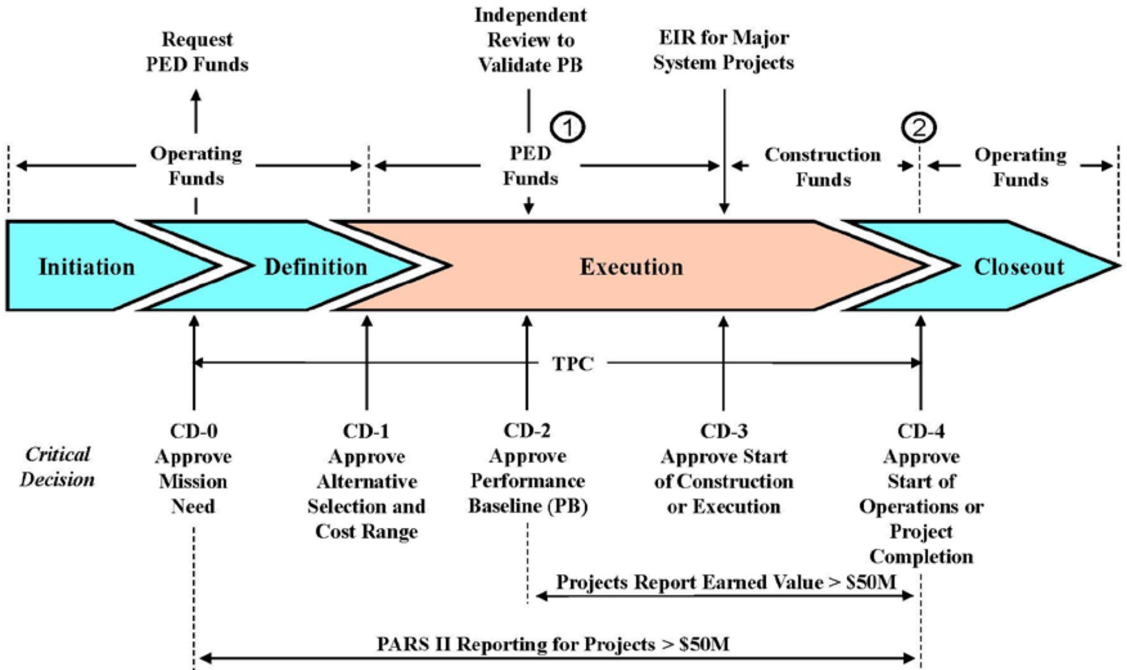
sPHENIX実現へ

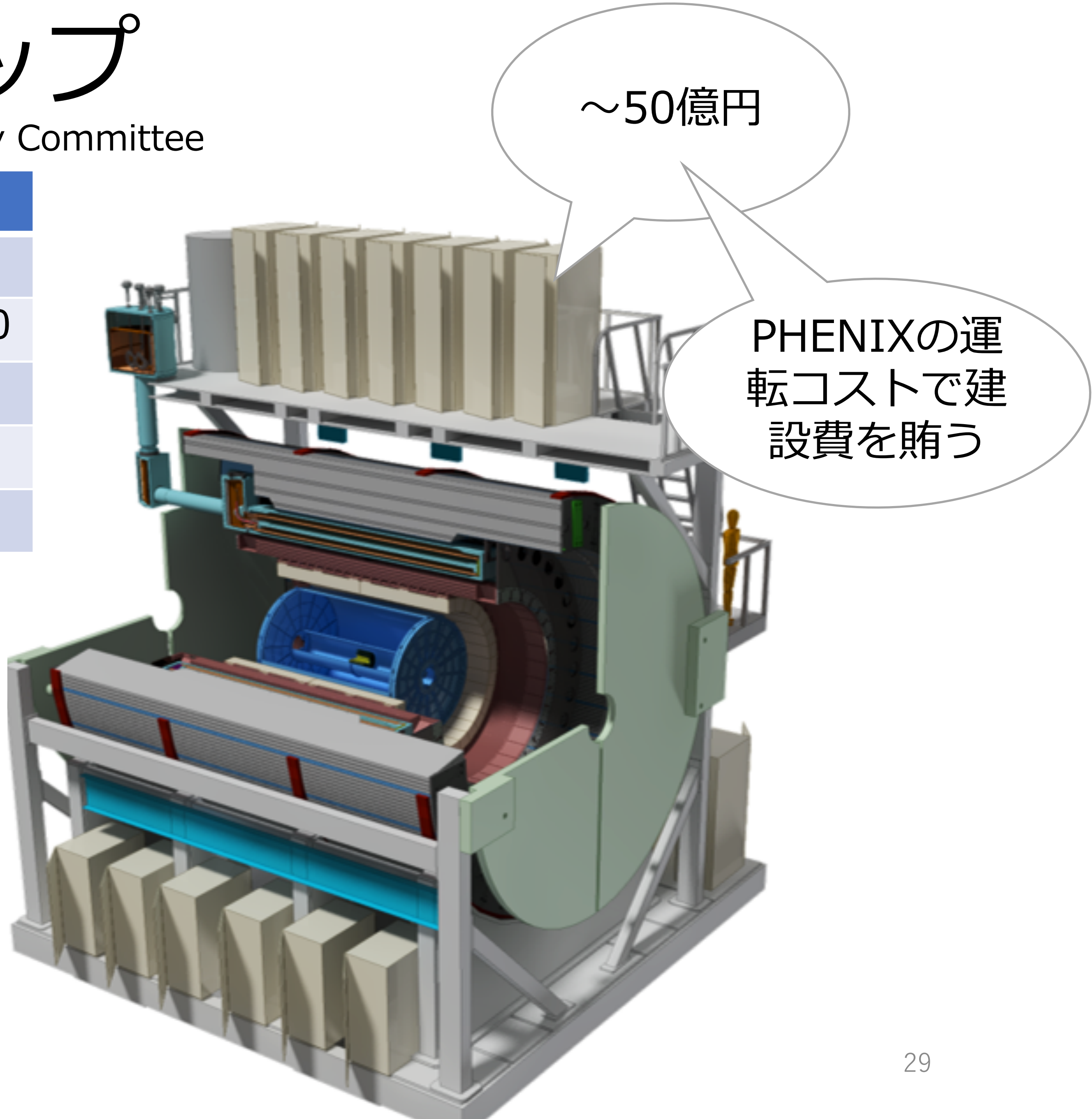
潮目が変わったのはSLACから1.5TのBaBar
実験電磁石を無償で譲り受けたこと

sPHENIXロードマップ

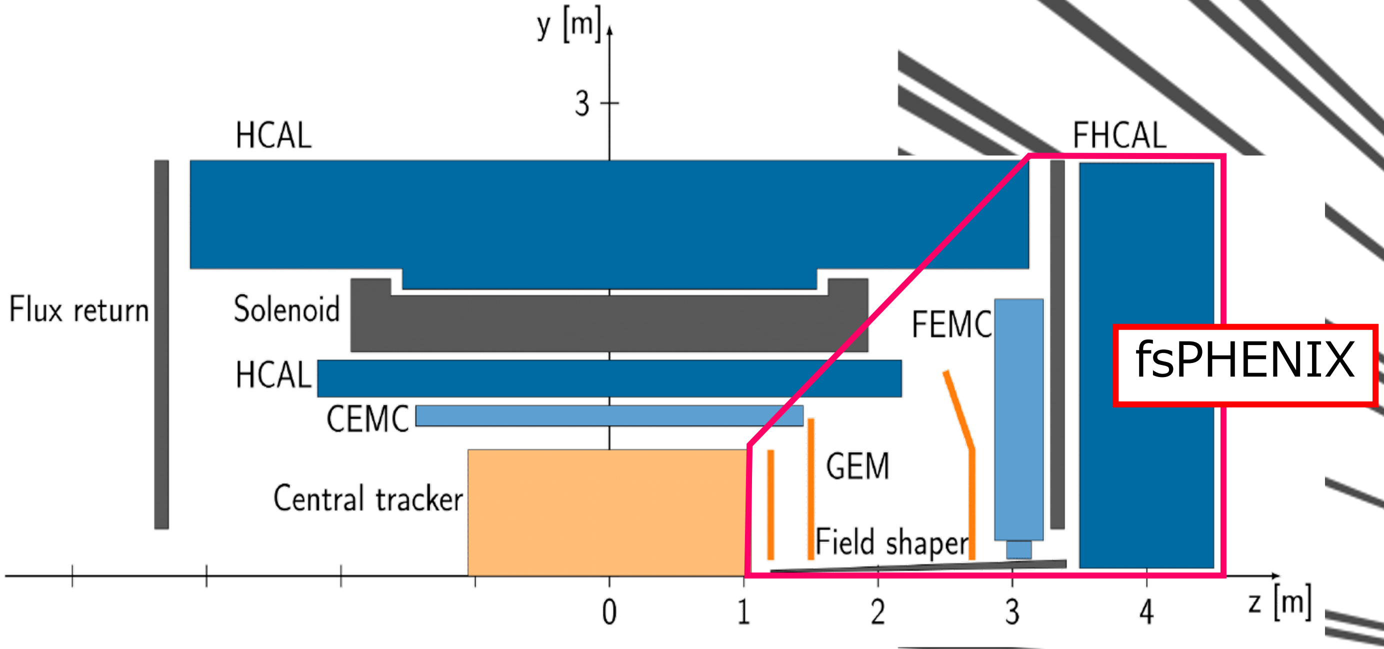
*National Science Advisory Committee

西暦	ステージ
2015年	NSAC*で高い評価
2016年	PHENIX 実験終了・CD0
2018年8月	CD1/CD3
2019年	PD2/3
2023年	実験開始

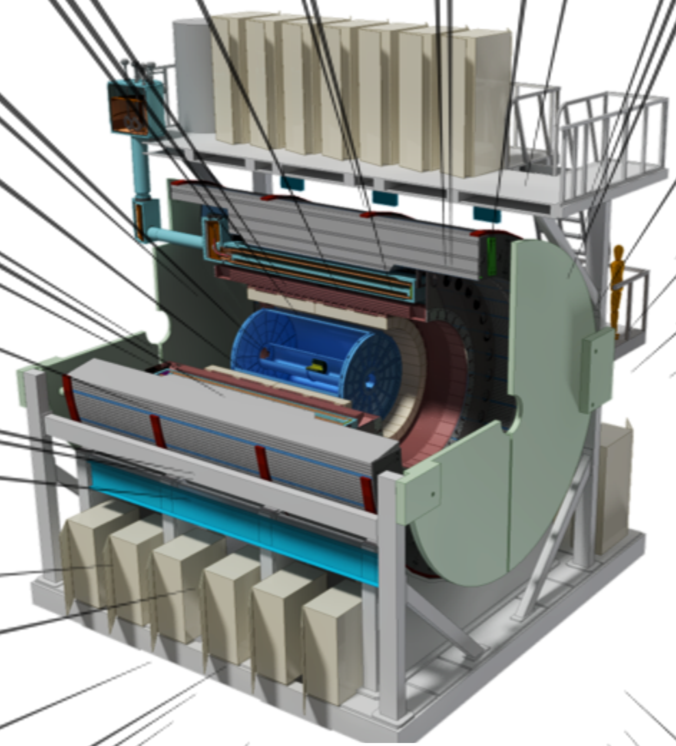




sPHENIX計画の選択と集中



当時のsPHENIXデザイン



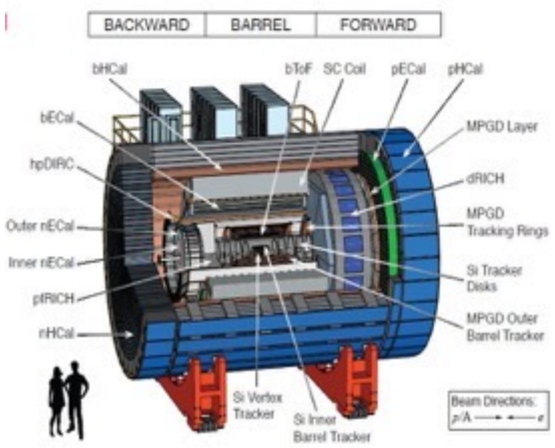
前方検出器は断念してバレルのみに

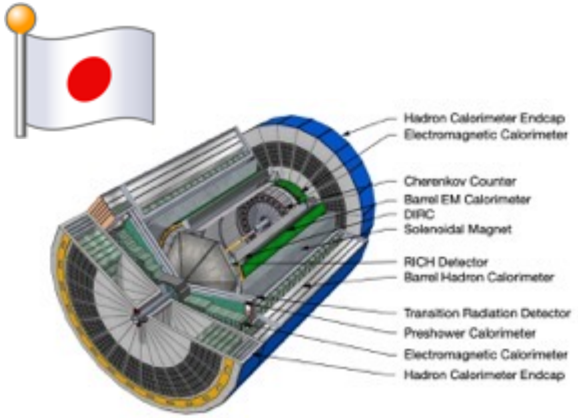
EIC Detector/Technology Choice

	ATHENA	ECCE	CORE
Magnet	New 3T, ca 1.6m inner radius, ~4m length	**BaBar 1.5T**, ca 1.4m radius, 3.9m length	New 3T, 1m radius, 2.5m length
Central Tracking	3+2 MAPS(ITS3), Mircromegas	3+2 MAPS, 2 mRWell, AC-LGAD	3+3 MAPS
FW /BWTracking	5 discs , GEM, mRWell	4/5 discs, AC-LGAD	6 discs, mRWell
Hadron PID (BW/Cent/FW)	Aerogel/AC-LGAD+DIRC/dRICH	AC-LGAD+Aerogel/AC- LGAD+DIRC/AC-LGAD+dRICH	AC-LGAD TOF/DIRC/dRICH
EMCALS	PbW04/AstroPix Si+PbSciFi/W SciFi	PbWO4/SciGlass/PBSciFi Shashlik	PbW04/W Shashlik
HCALS	FeSci/FeSci/FeSci	-/FeSci/ Longitudinally separated	-/-/STAR FCS KLM only

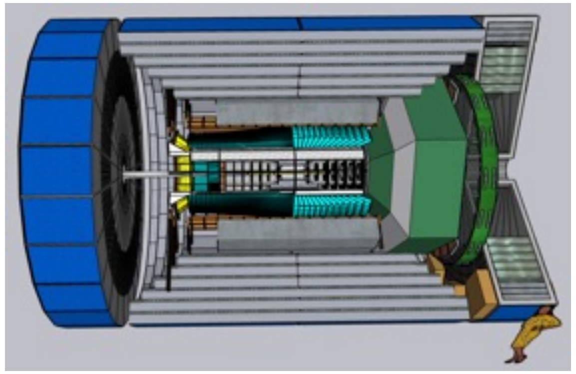
2021年末の段階で候補は３つ

この中でDOE予算で建設される"Detector-1"は一つのみ

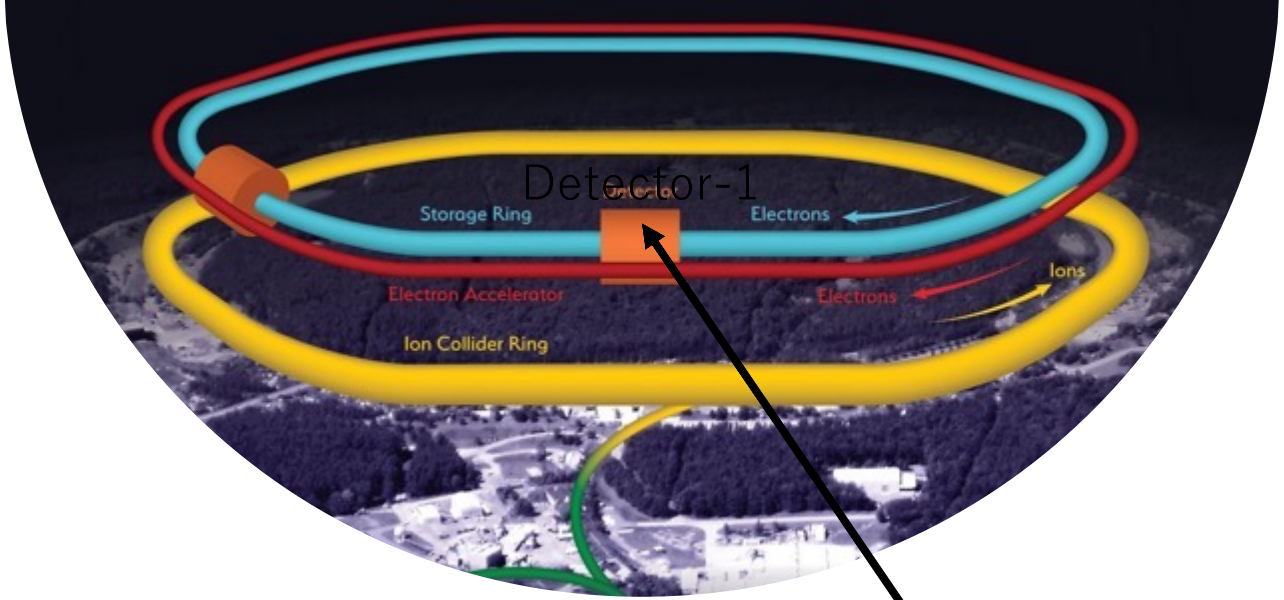




(ePHENIX)



Detector Choice (Decision)

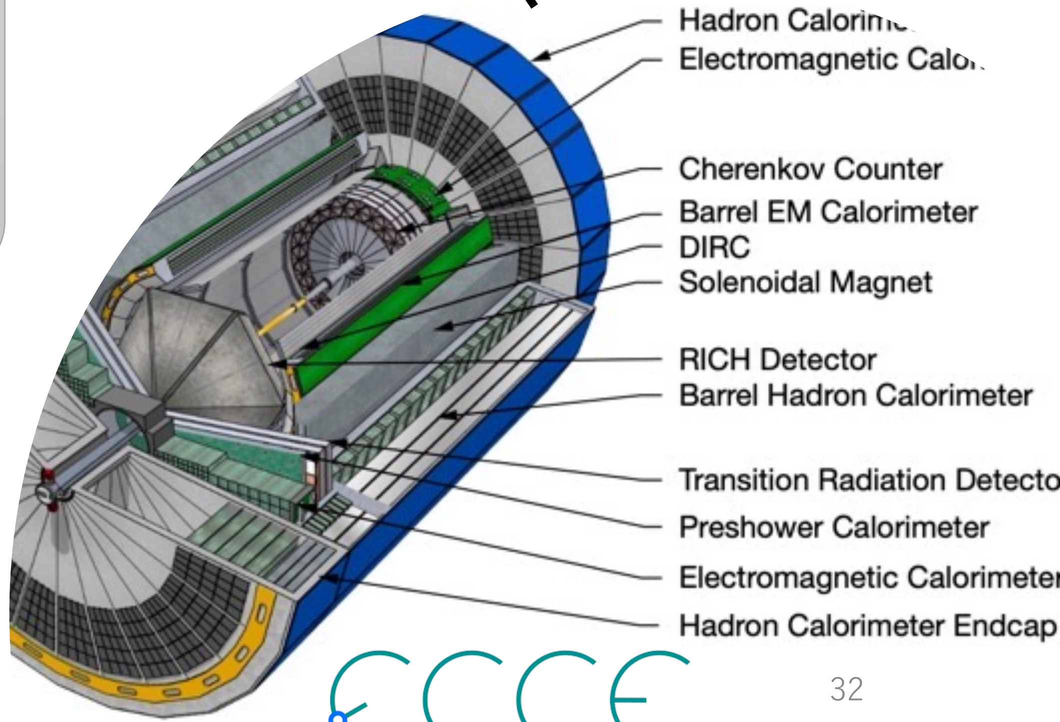


Detector Proposal Advisory Panel

- **Co-chairs**
  - Rolf Heuer (CERN)
  - Patty McBride (FNAL)
- **Members**
  - Sergio Bertolucci (INFN Sezione di Bologna)
  - Daniela Bortoletto (Oxford University)
  - Markus Diehl (DESY)
  - Ed Kinney (University of Colorado, Boulder)
  - Fabienne Kunne (CEA)
  - Andy Lankford (University of California, Irvine)
  - Naohito Saito (KEK)
  - Brigitte Vachon (McGill University)
- **Scientific Secretary**
  - Tom Ludlam (BNL)
- \+ EIC Detector Advisory Committee (ongoing detector R&D)

満場一致でECCEを
Detector 1として推奨する

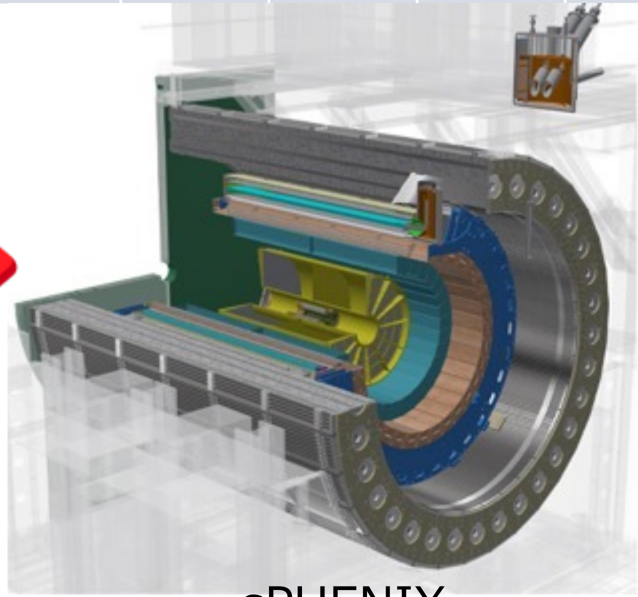
2022/3/8



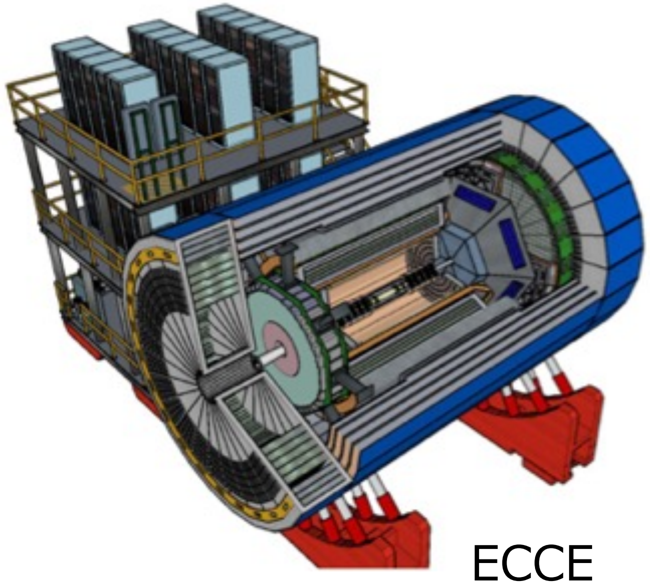
ECCE

sPHENIXとEICの予定

PHENIX



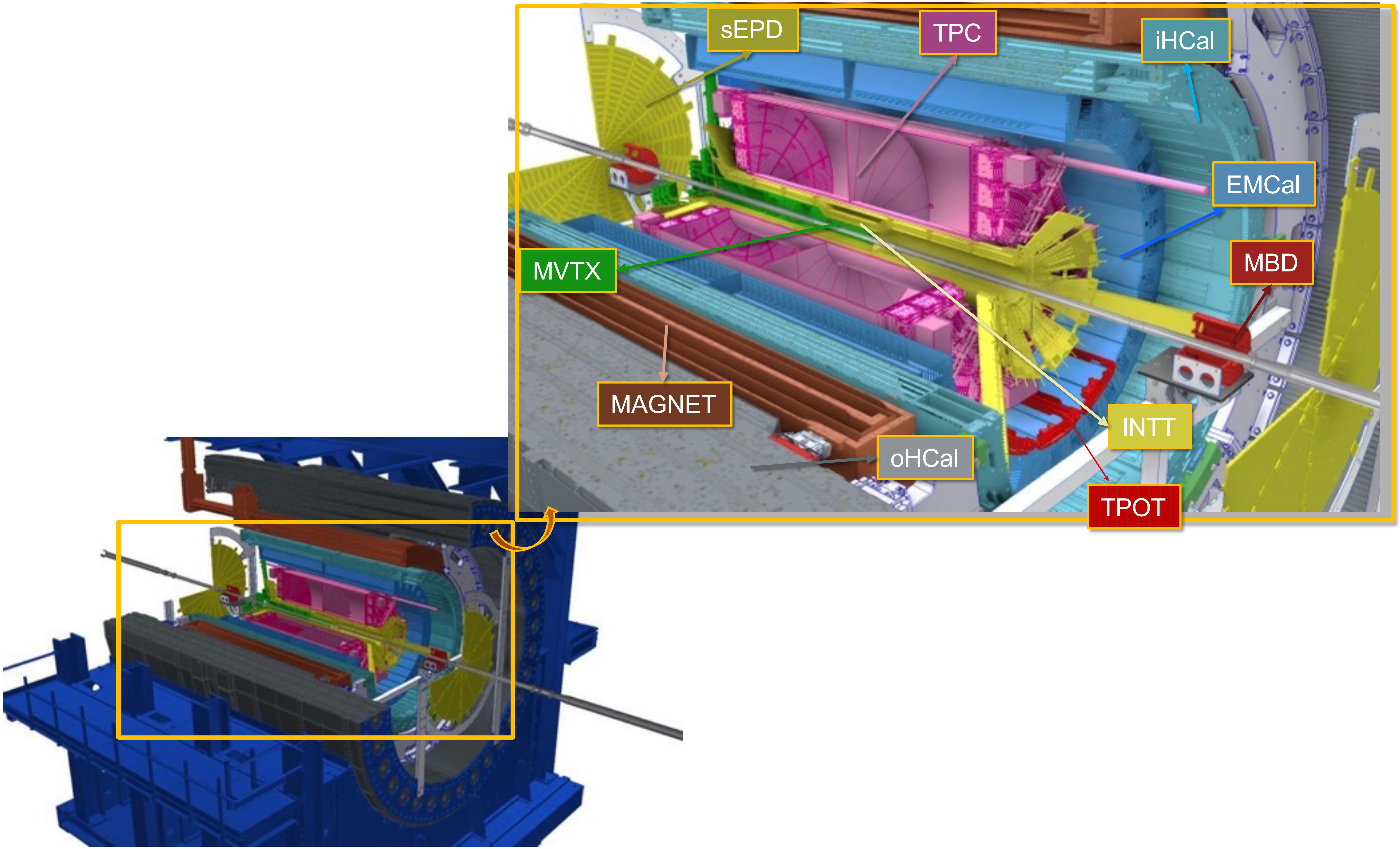
sPHENIX



ECCE

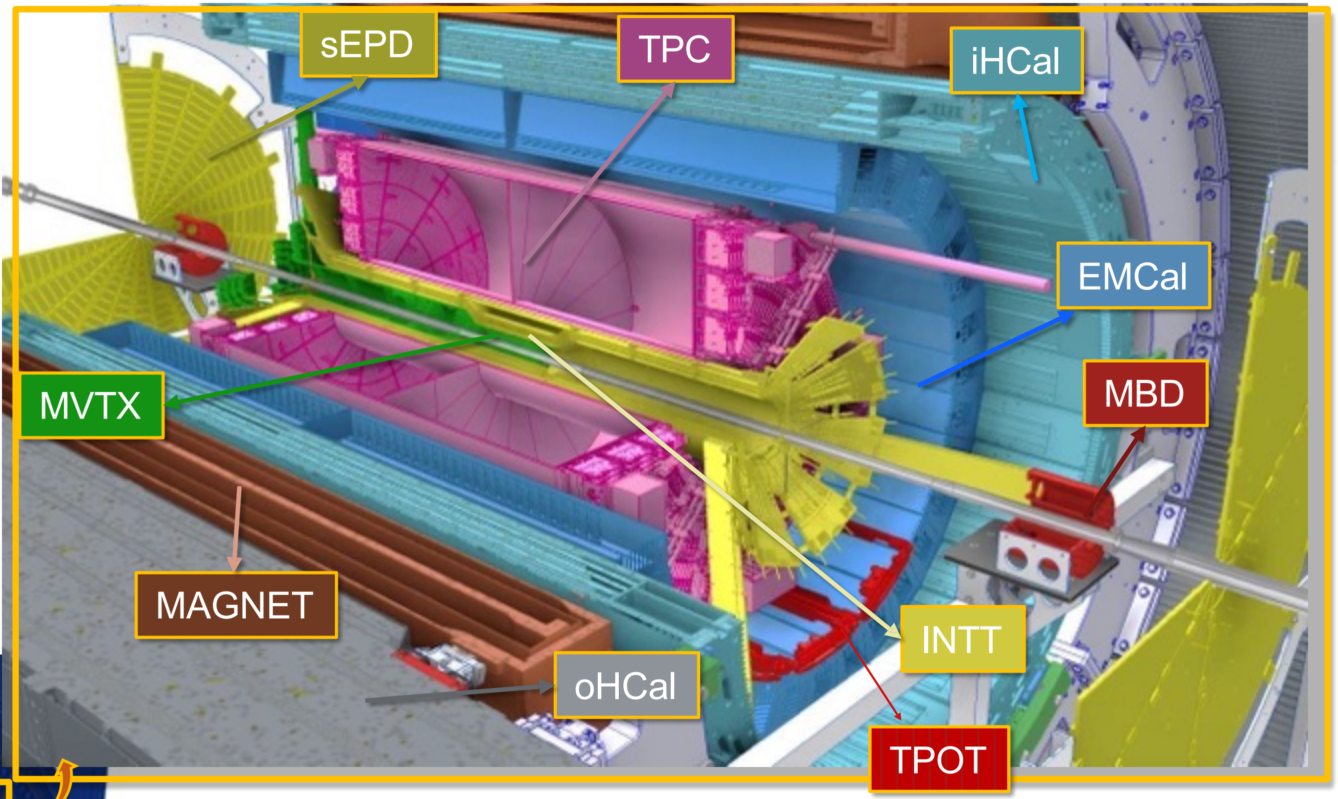
sPHENIX検出器の構成

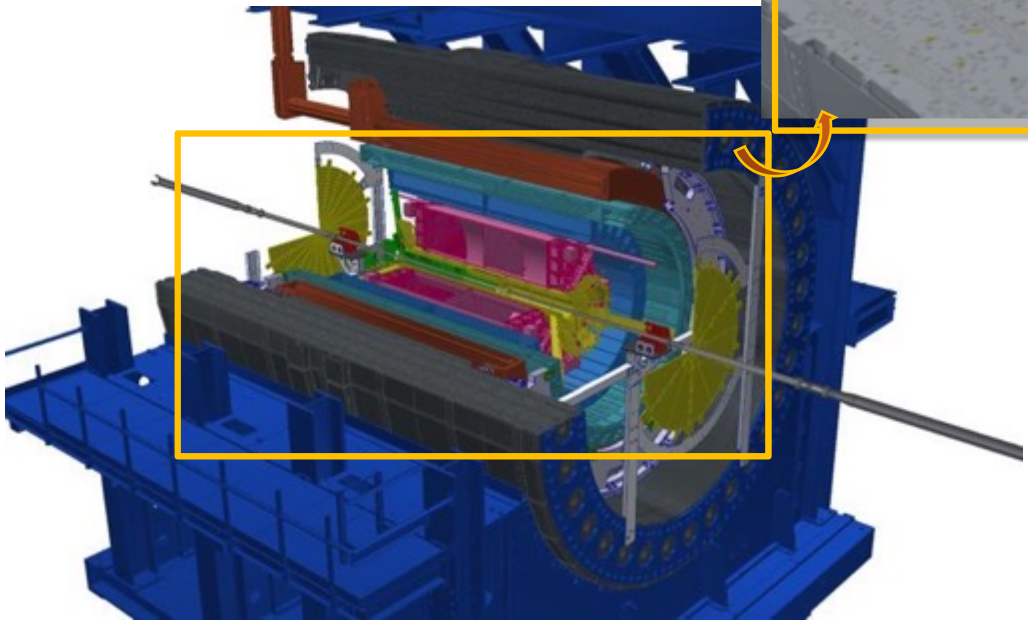
sPHENIX Detector

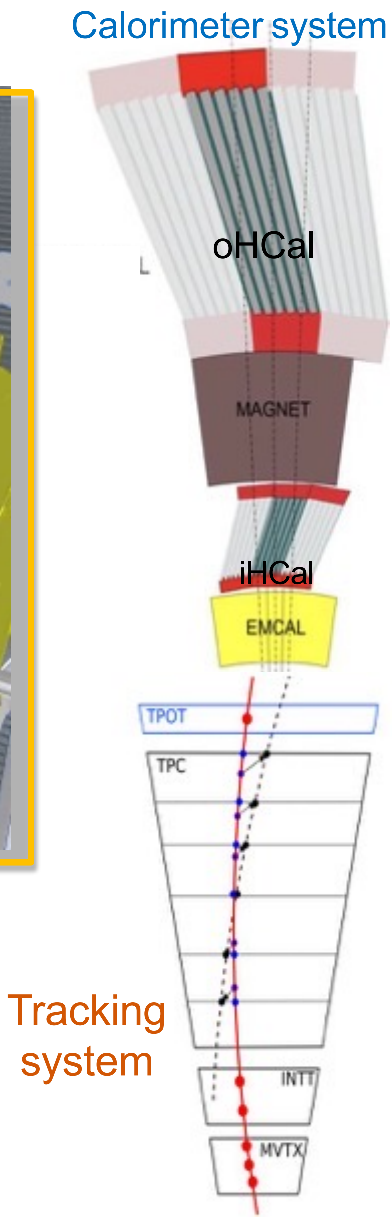


sPHENIX Detector

- BaBar 実験の1.4テスラソレノイド電磁石
- Hermetic coverage:
- |η|<1.1, 2π in φ
- 大立体角をトラッカー＆ EM+ハドロンカロリメータで覆う
- 15 kHz の高データ収集レート
- トラッキングシステムはストリーム読み出し







sPHENIX Detector

- BaBar 実験の1.4テスラソレノイド電磁石
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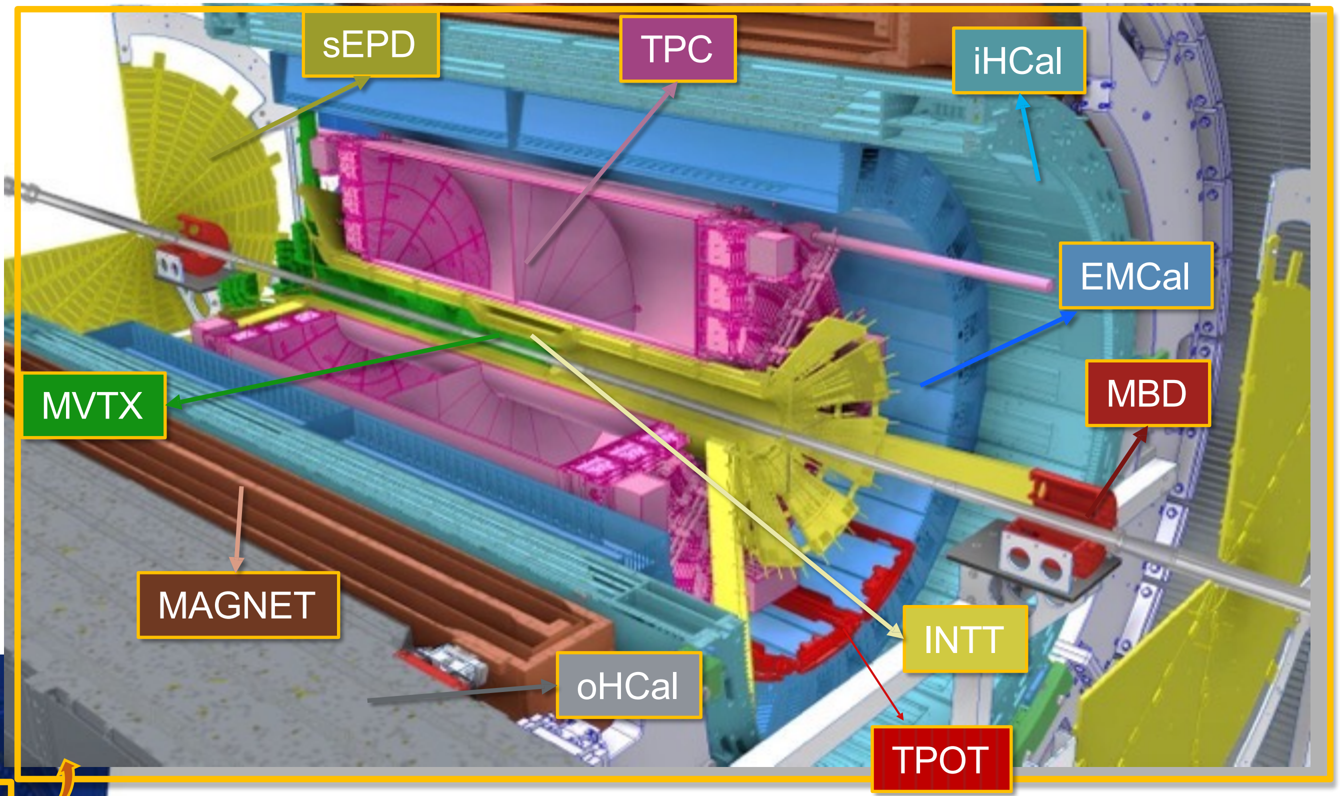
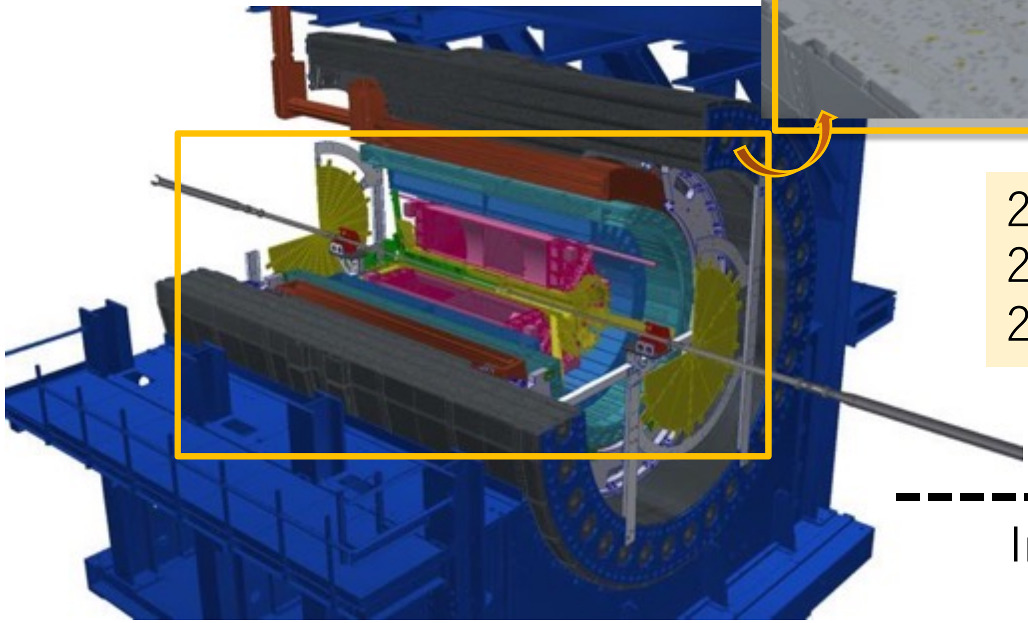
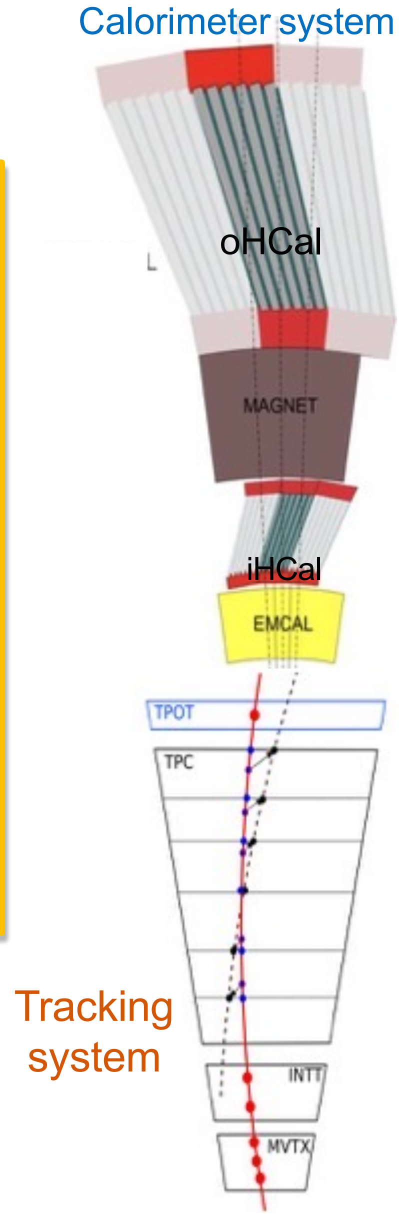






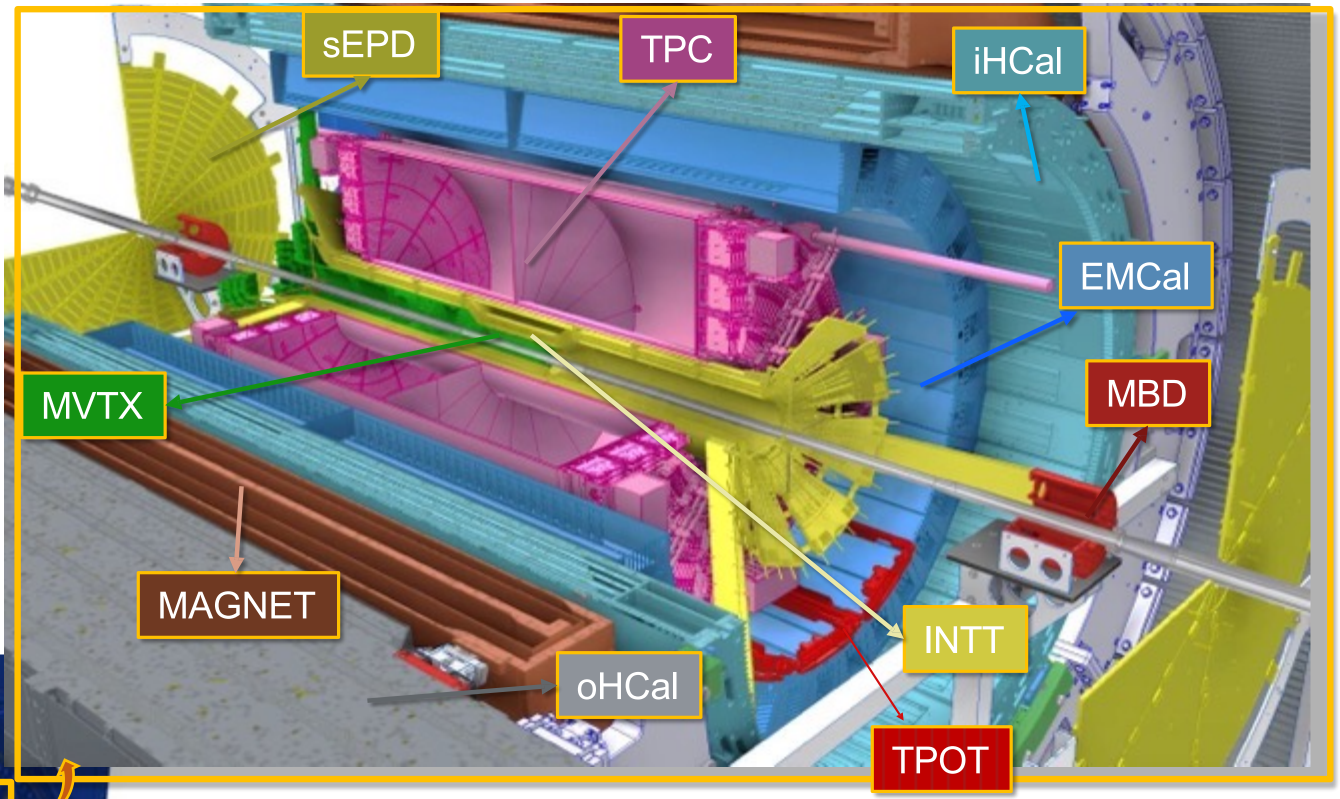
2023 : Commissioning Au+Au
2024 : p+p
2025 : Au+Au

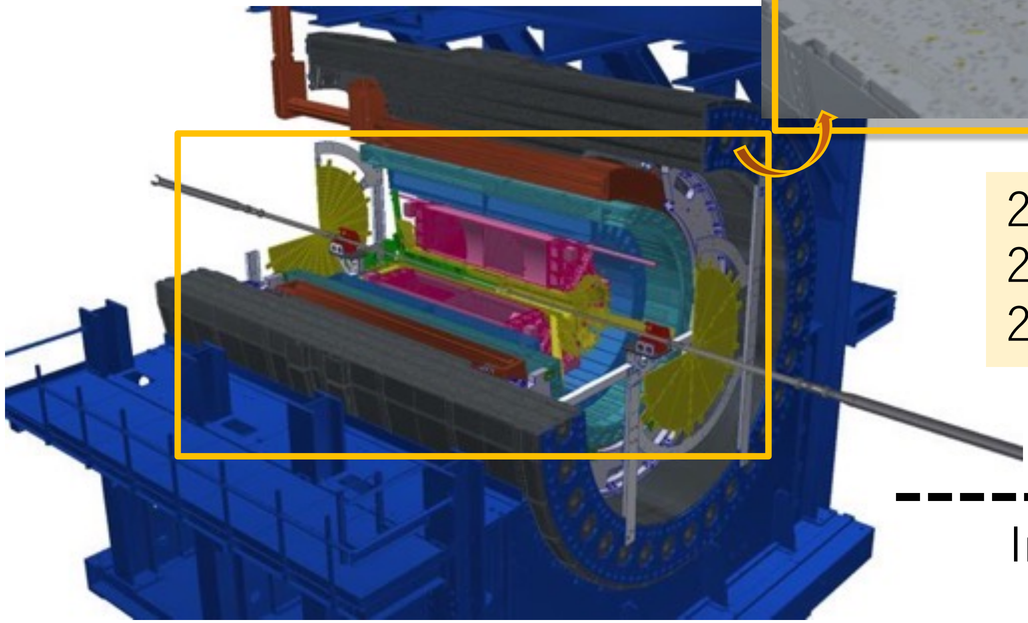
$\sqrt{s}$ =200GeV

2023 Jan	May	Aug	Oct
Install	Beam Commissioning		Physics

sPHENIX Detector

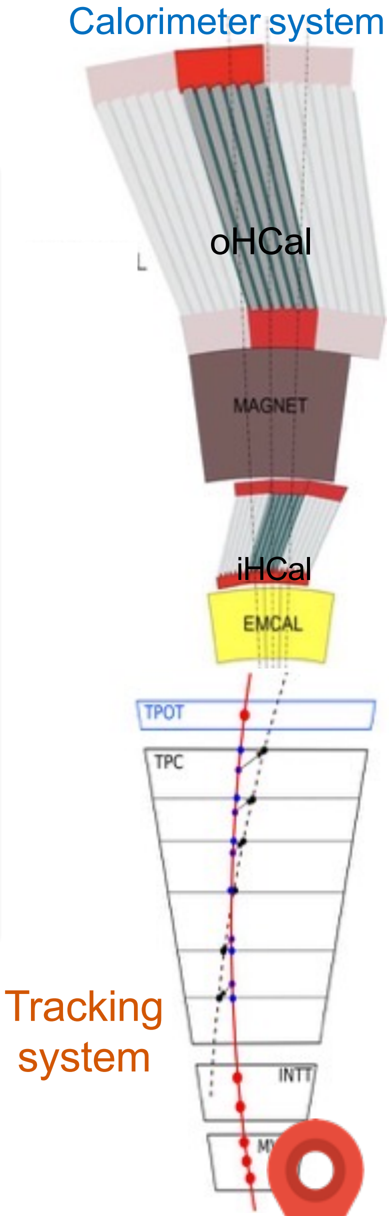
- BaBar 実験の1.4テスラソレノイド電磁石
- Hermetic coverage:
- |η|<1.1, 2π in φ
- 大立体角をトラッカー＆ EM+ハドロンカロリメータで覆う
- 15 kHz の高データ収集レート
- トラッキングシステムはストリーム読み出し





2023 : Commissioning Au+Au
2024 : p+p
2025 : Au+Au

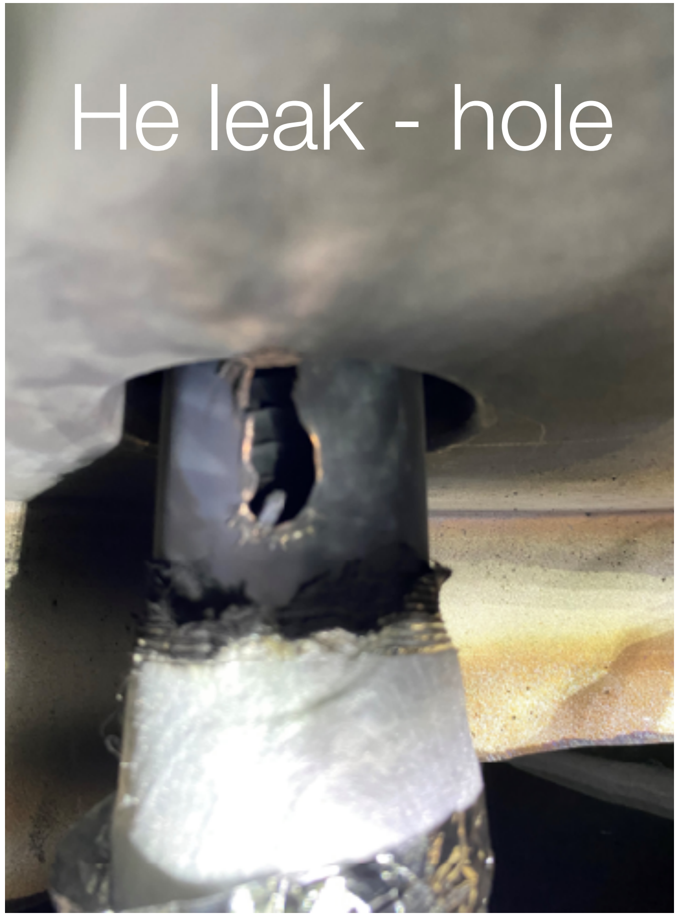
$\sqrt{s}$ =200GeV



2023 Jan — May — Aug — Oct

Install — Beam Commissioning — Cosmic

2023年ランの予期せぬ終了

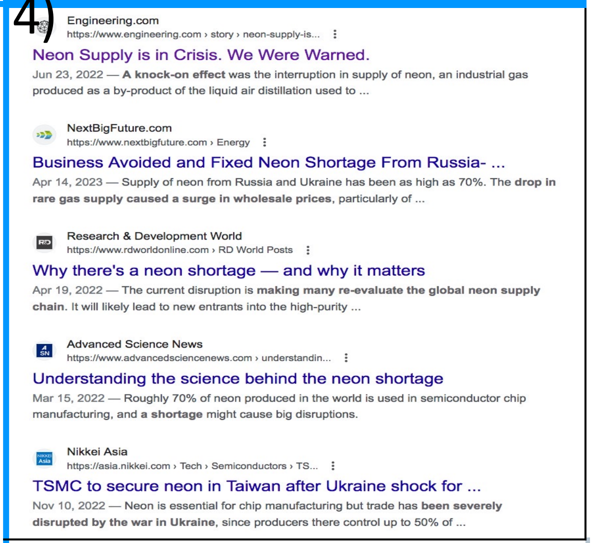


RHICの超電導冷却システムの故障によりビーム運転維持が困難になった。短期的な修理が見込めず、やむを得ず2023年のランは終了。

sPHENIX 苦難の行進

Despite the many success of sPHENIX, we had our own set of challenges, including:

1) The COVID pandemic shutdown BNL as well as many collabora;ng ins;tu;ons for months followed by periods where only 25–50% of the lab workforce was allowed on site.
2) The supply-‐chain crisis delayed many key sPHENIX components by months, especially electronics chips and circuit boards
3) Our beam pipe was lost in a UPS warehouse fire. Fortunately STAR had a spare that we used.
4) The TPC gas was planned to be Ne/CF4. Interna;onal conflict created a huge shortage of neon. We switched to Ar/CF4 mix with similar gain and drim proper;es
5) RHIC Run2023 ended 8 weeks early due to significant damage to a cryo feed through in a valve box.


4)

Engineering.com
https://www.engineering.com › story › neon-supply-is...
Neon Supply is in Crisis. We Were Warned.
Jun 23, 2022 — **A knock-on effect** was the interruption in supply of neon, an industrial gas produced as a by-product of the liquid air distillation used to ...

NextBigFuture.com
https://www.nextbigfuture.com › Energy
Business Avoided and Fixed Neon Shortage From Russia- ...
Apr 14, 2023 — Supply of neon from Russia and Ukraine has been as high as 70%. The **drop in rare gas supply caused a surge in wholesale prices**, particularly of ...

Research & Development World
https://www.rdworldonline.com › RD World Posts
Why there's a neon shortage — and why it matters
Apr 19, 2022 — The current disruption is **making many re-evaluate the global neon supply chain**. It will likely lead to new entrants into the high-purity ...

Advanced Science News
https://www.advancedsciencenews.com › understandin...
Understanding the science behind the neon shortage
Mar 15, 2022 — Roughly 70% of neon produced in the world is used in semiconductor chip manufacturing, and a **shortage** might cause big disruptions.

Nikkei Asia
https://asia.nikkei.com › Tech › Semiconductors › TS...
TSMC to secure neon in Taiwan after Ukraine shock for ...
Nov 10, 2022 — **Neon is essential for chip manufacturing but trade has been severely disrupted by the war in Ukraine**, since producers there control up to 50% of ...

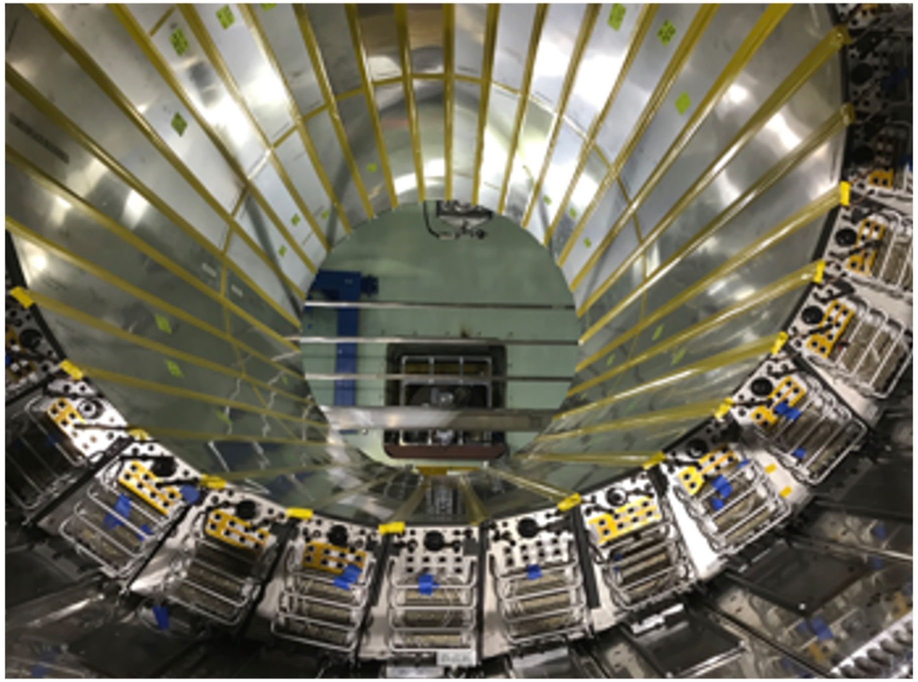
E. O'brien @ sPHENIX QM2023

建設とコミッショニングの現状

Hadron and EM Calorimeters

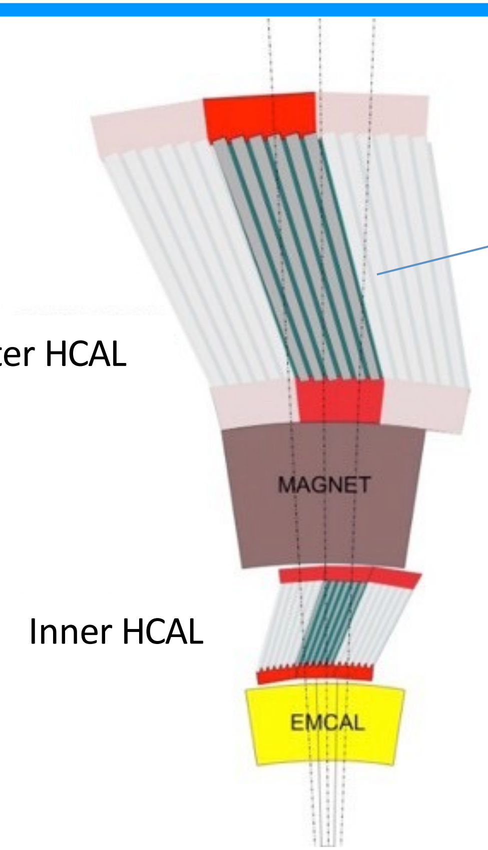
Inner HCal Installation

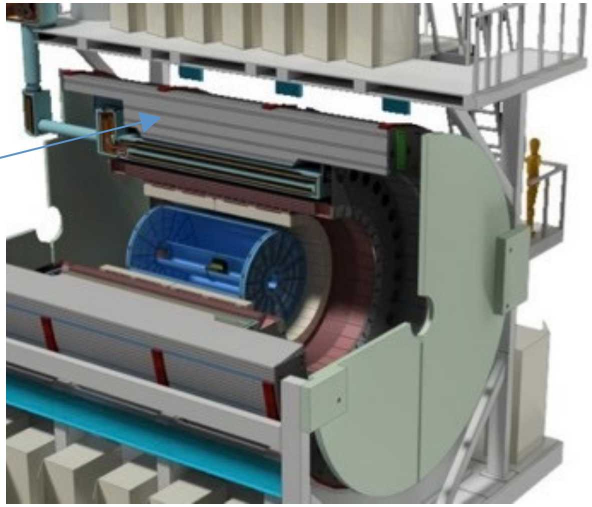
EMCal in position



sPHENIX will have kinematic reach out to ~ 70 GeV for jets, kinematic overlap with the LHC.

Hadronic Calorimeters





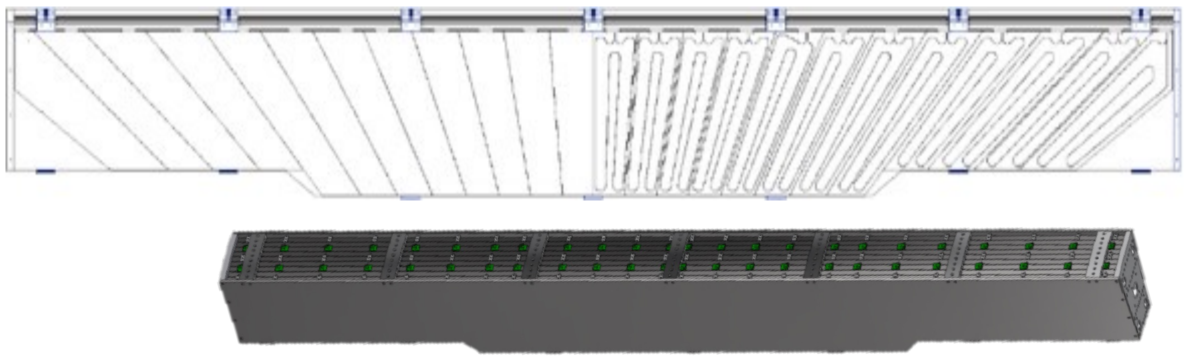
- HCAL steel and scintillating tiles with wavelength shifting fiber
  - **Outer HCal (outside the solenoid)**
  - **Inner HCal (inside the solenoid)**
  - **$\Delta\eta \times \Delta\phi \approx 0.1 \times 0.1$**
  - **1,536 readout channels each**
- SiPM Readout

- Outer HCAL $\approx 3.5\lambda_I$
- Magnet $\approx 0.31\lambda_I$
- IHCal $\approx 0.25\lambda_I$
- EMCal $\approx 18X_0 \approx 0.7\lambda_I$

HCAL performance requirements driven by jet physics in HI collisions

- Uniform fiducial acceptance $-1<\eta<1$ and $0<\phi<2\pi$
  - Extended coverage $-1.1<\eta<1.1$ to account for jet cone
- Absorb >95% of energy from a 30 GeV jet **(4.76 λ_I)**
- Hadronic energy resolution of *combined* calorimetry:
  - Jet resolution performance goal: $\frac{\sigma}{E} < \frac{150\%}{\sqrt{E}}$ (in central Au+Au collisions)
  - Gaussian response (limited tails)
- OHCAL also serves function of barrel magnetic flux return

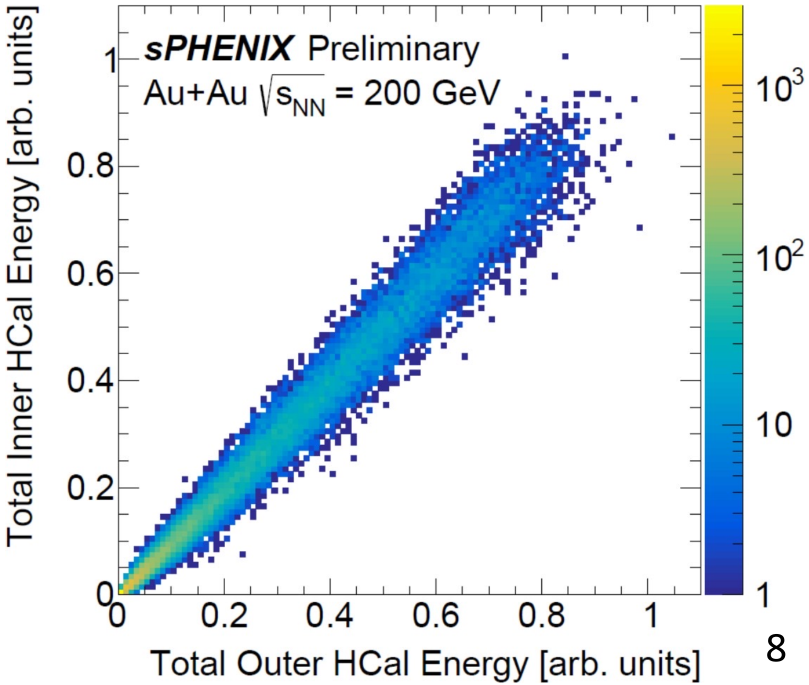
Hadronic Calorimeters



- **Outer HCal Sectors double as barrel magnet flux return**
- Absorber/mechanics tapered steel plates, thickness 26-42 mm each
- 32 sectors assembled into 2π barrel (inner radius = 1.9m, outer radius =2.6m)
- **Completed sector is 6.3m long, 13.5 tons**

Other parameters:

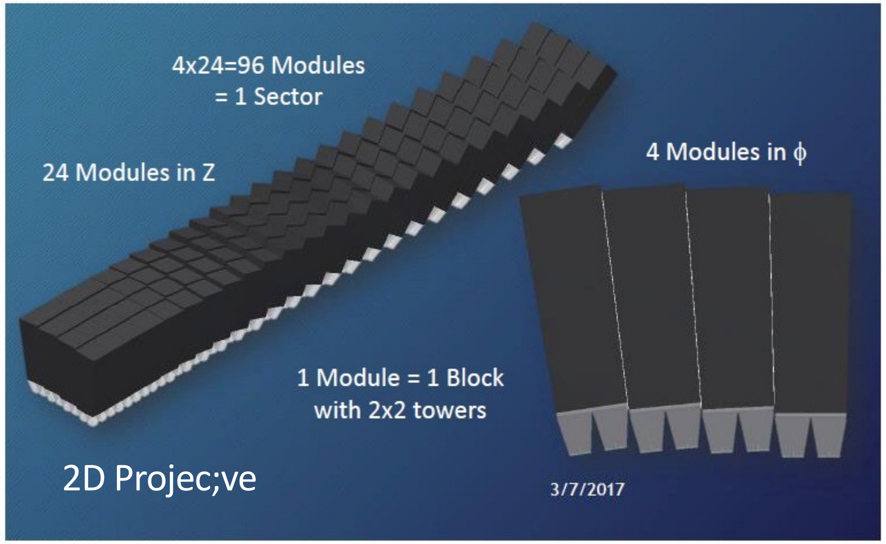
- 10 rows of 8mm scint. tiles (24 tiles per row), 12° tilt angle
- 5 scintillators/tower
- 48 towers per sector
- 32 sectors;
- 1536 channels (7680 SiPMs)



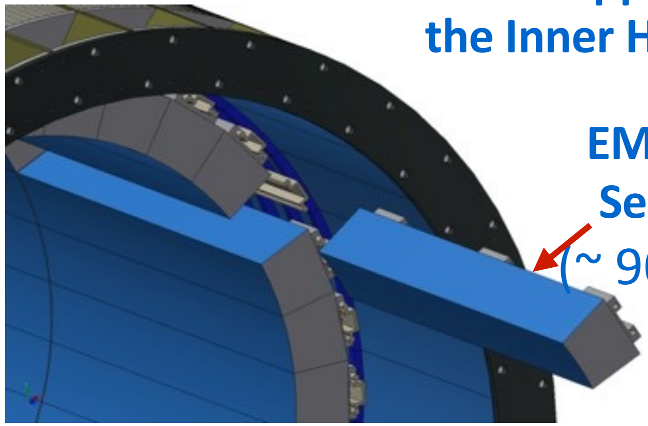
Electromagnetic Calorimeter (EMCal)

$2(\pm\eta) \times 32\ (\phi) = 64$ Sectors

Electromagnetic calorimeter covering ± 1.1 in η and 2π in ϕ

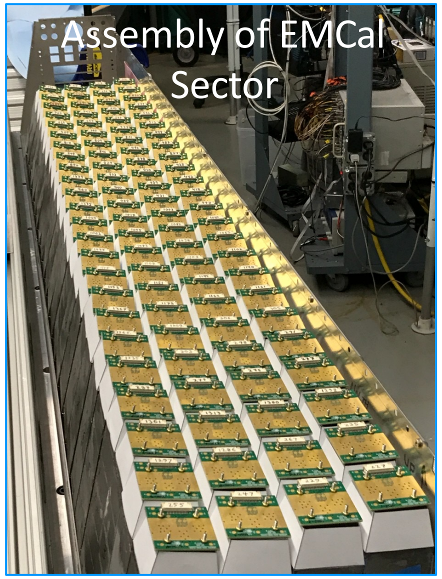


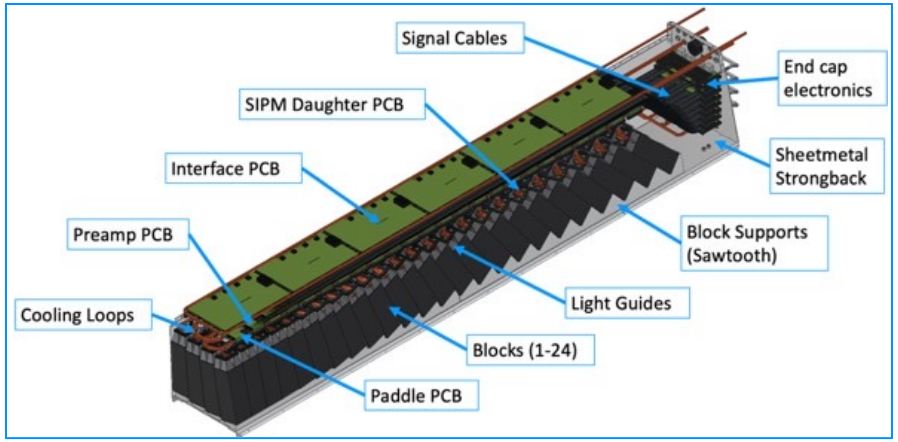
Sector are supported off the Inner HCAL

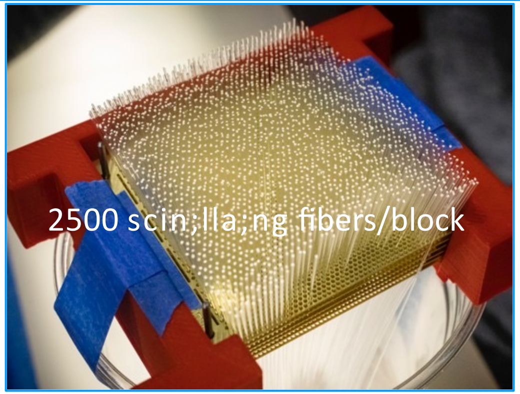


EMCAL Sector
(~ 900 lbs)

- Blocks made of tungsten-powder/epoxy composite encasing ~2500 scintillating fibers/block.
- Aluminum support mechanics and shroud
- Sectors and blocks are approximately projective and tilted in η and ϕ



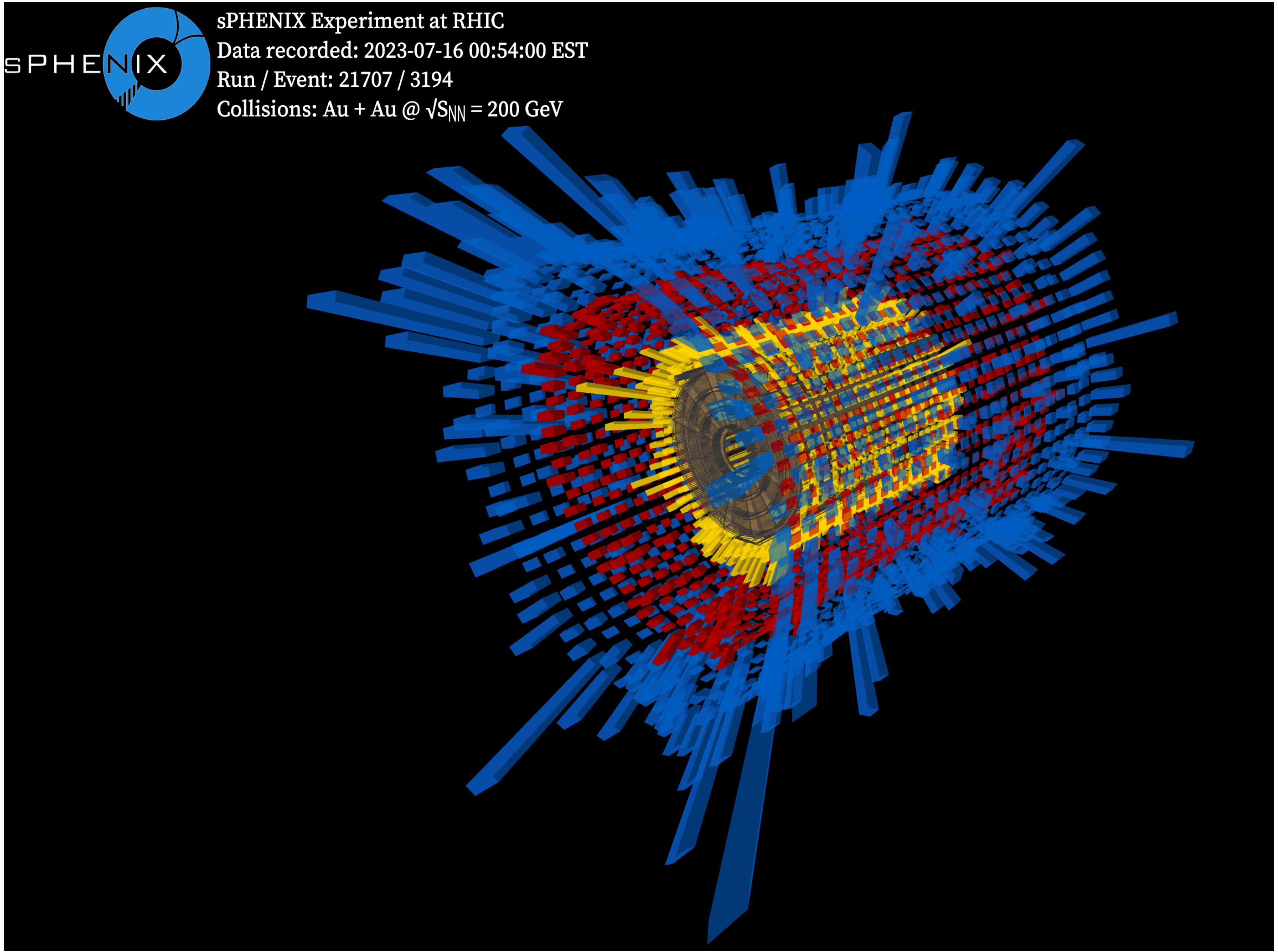




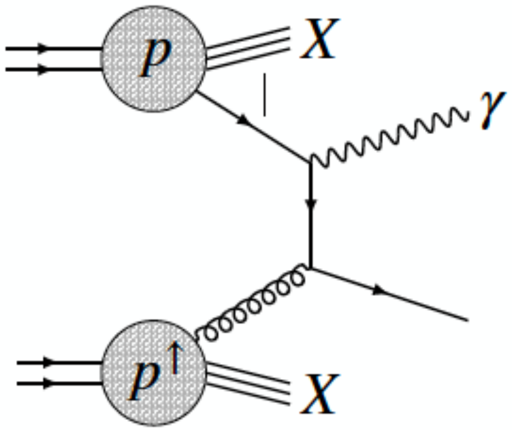
sPHENIX EMCalの性能

	PHENIX	STAR	sPHENIX
Rapidity Coverage	-0.35 < η < 0.35	-1 < η < 1	-1.1 < η < 1.1
Azimuthal Coverage	π	2π	2π
Segmentation $\Delta\eta \times \Delta\phi$	0.008 × 0.008 (0.011 × 0.011)	0.05 × 0.05	0.024 × 0.024
Molier Radius [mm]	30 ~ 40		15
Shower Max	No	Yes	No

Hadron and EM Calorimeters

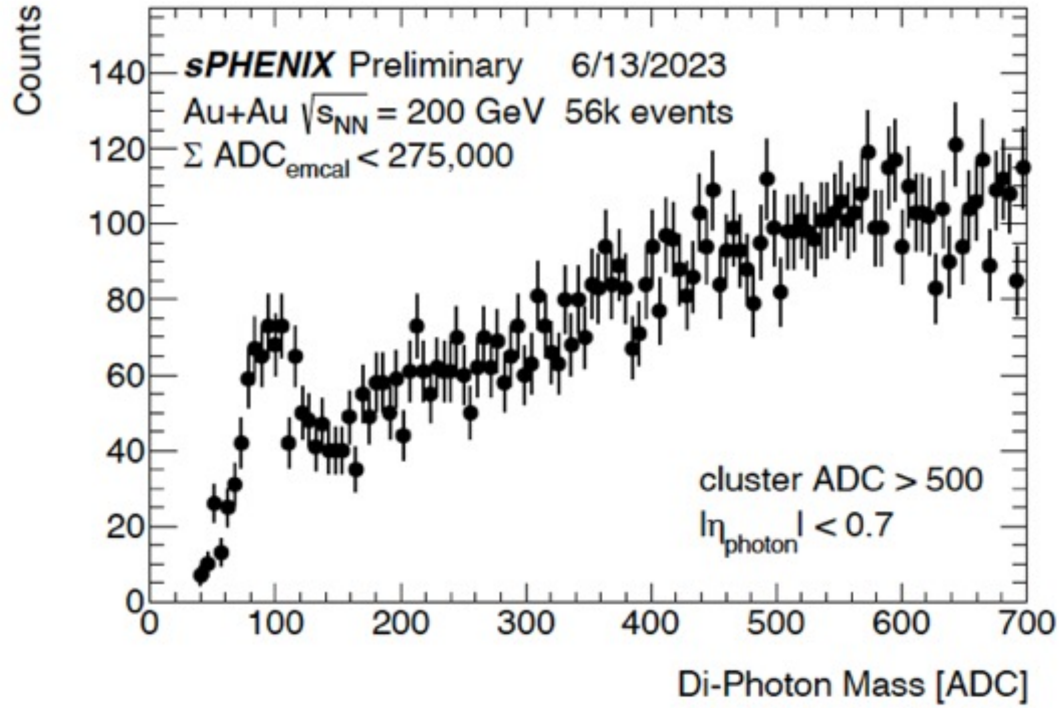


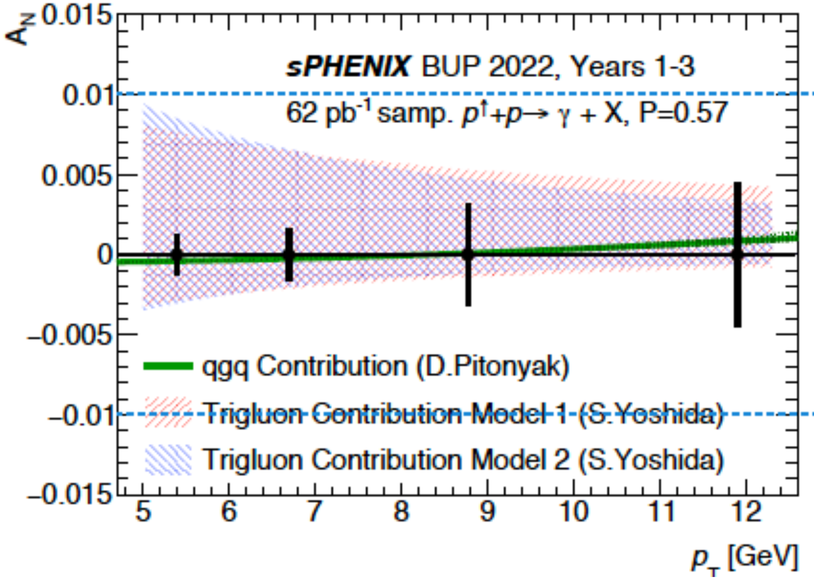
Gluon TMD by Direct-γ

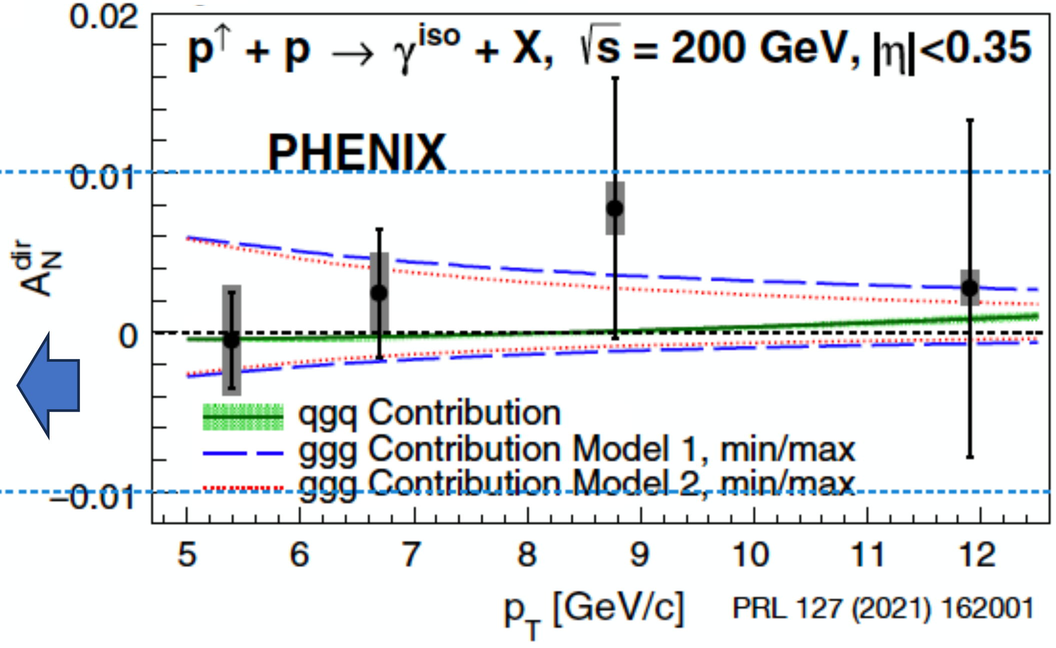


TMD: Transverse Momentum Dependence

$$p^{\uparrow} + p \to \gamma + X$$

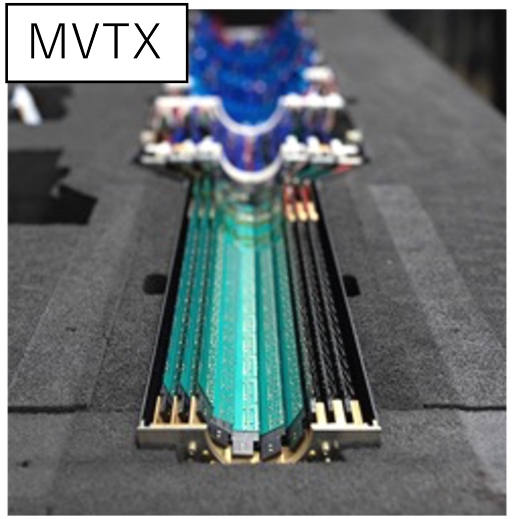




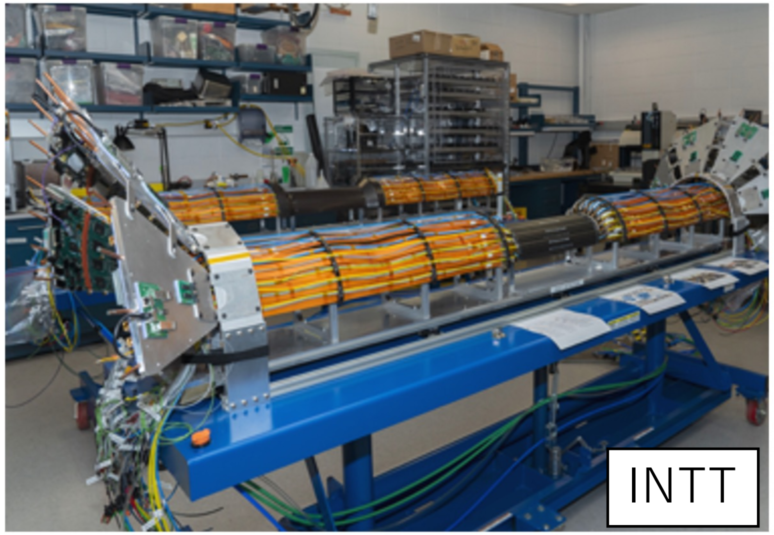


Much improved direct photon TSSA -> gluon TMD

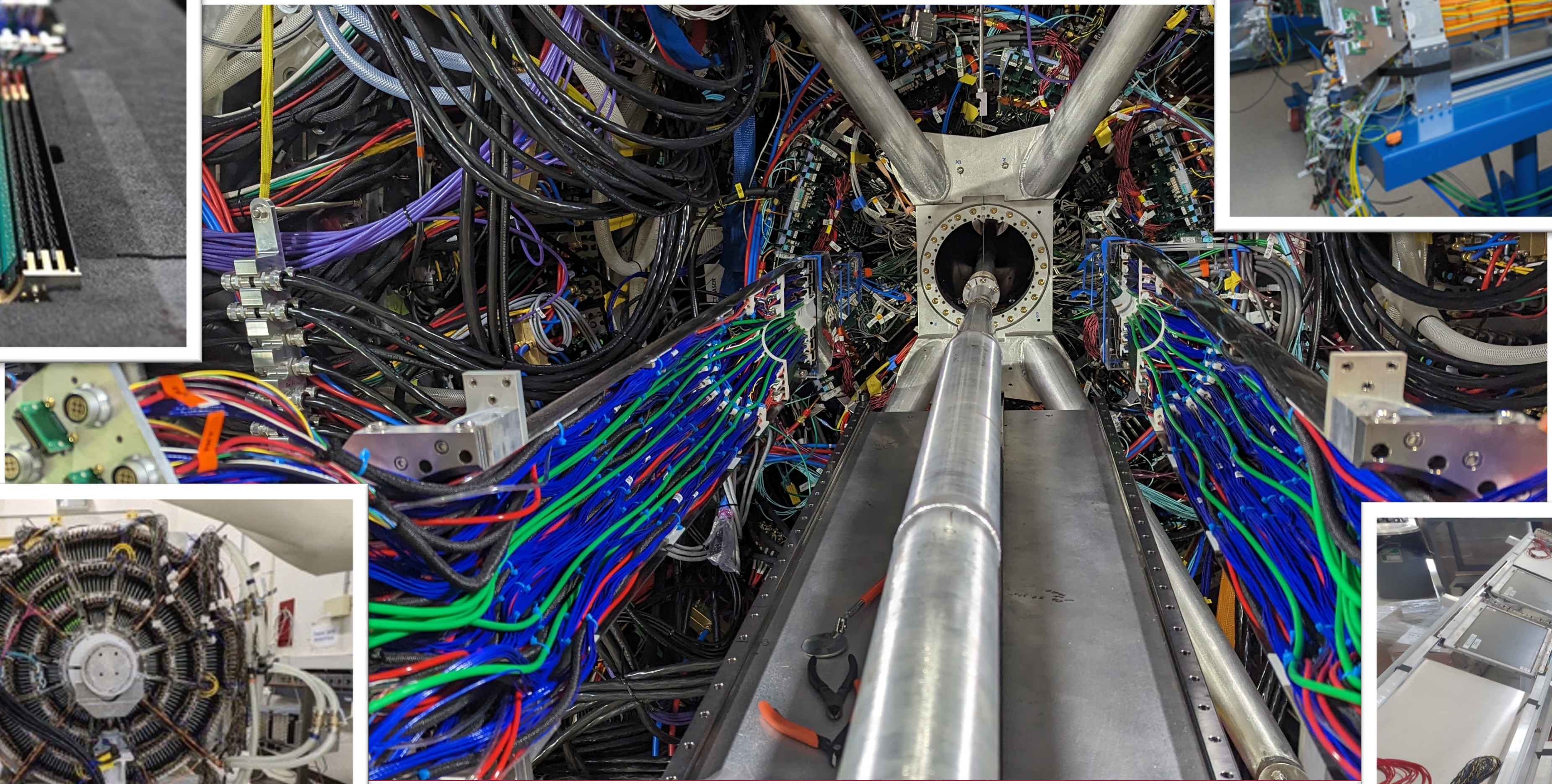
Tracking Detectors



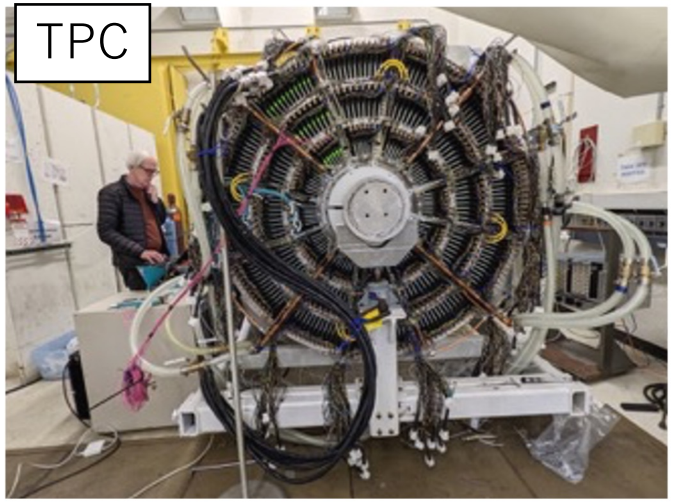
MVTX



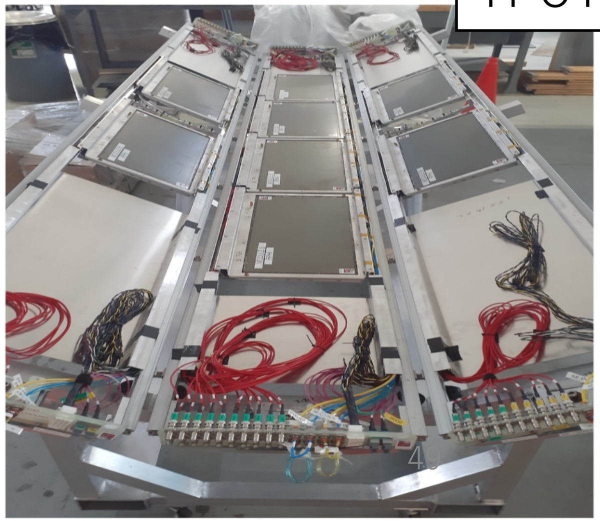
INTT



All Trackers installed in Position (March 30th, 2023)



TPC



TPOT

Tracking System

Silicon pixel detector (MVTX)

- 29 um x 27 um, pixels
- 2.5 cm < R < 4.5cm
- 20 BLCK integration time

Silicon strip detector (INTT)

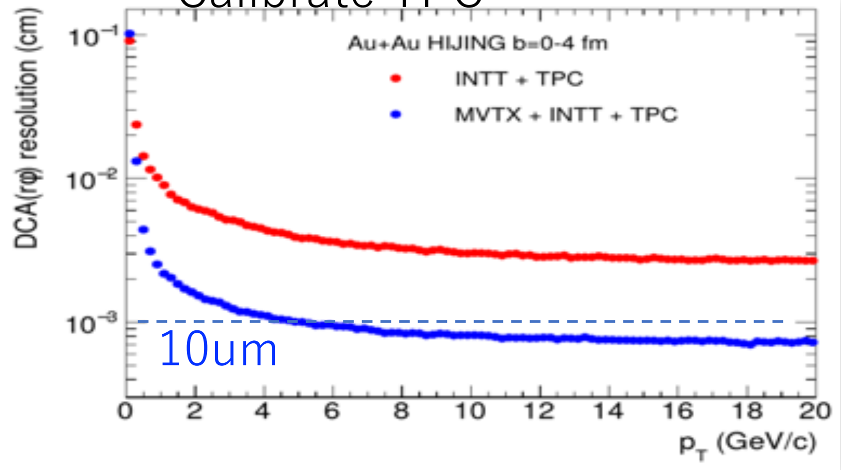
- 78um, strip sensors
- 7cm < R < 11cm
- 1 BCLK timing resolution

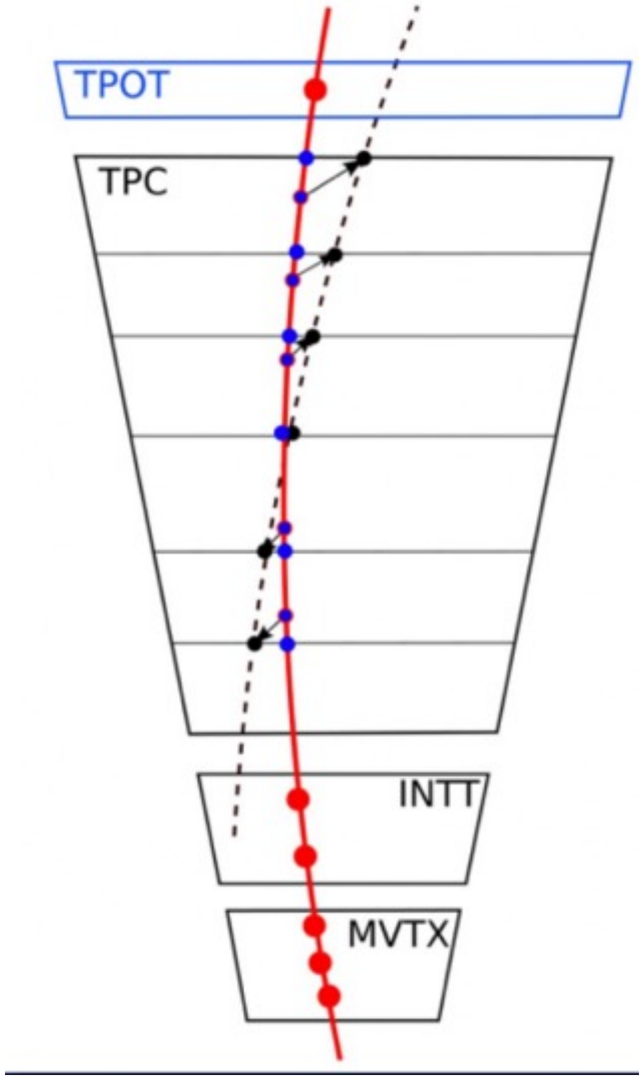
Time projection Chamber (TPC)

- 20cm < R < 78cm
- Spatial resolution, ~100um
- Long drift time, ~13us

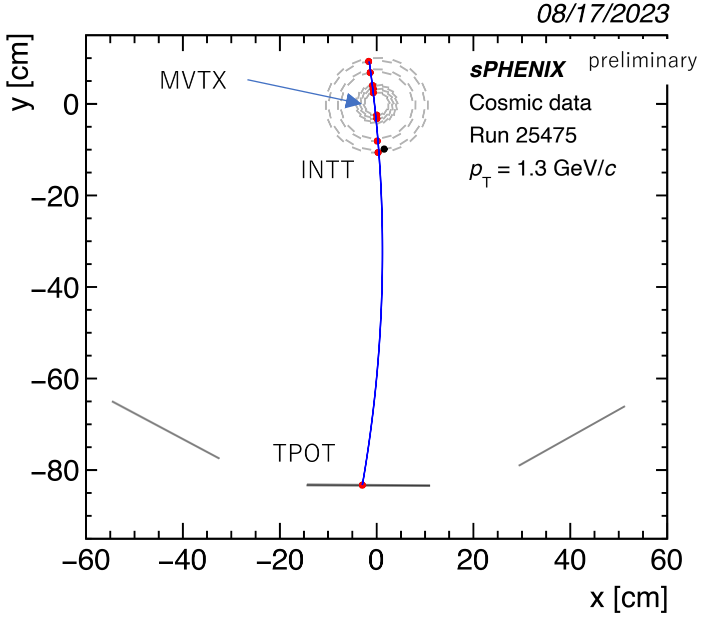
TPC Outer Tracker (TPOT)

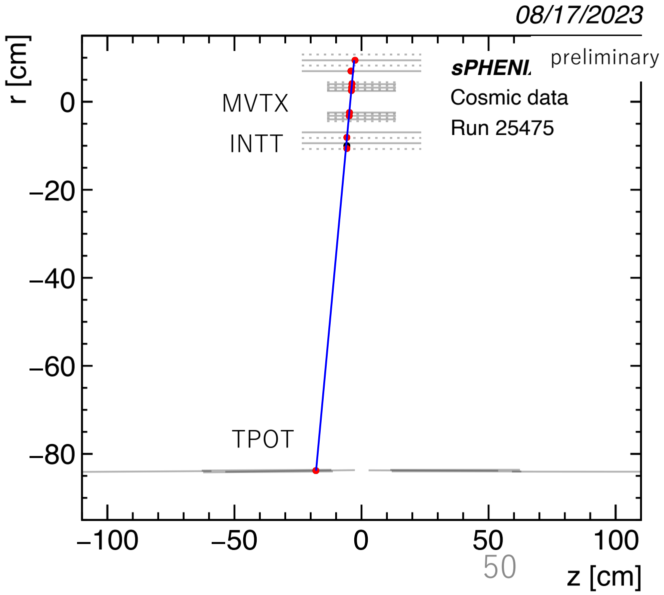
- Calibrate TPC



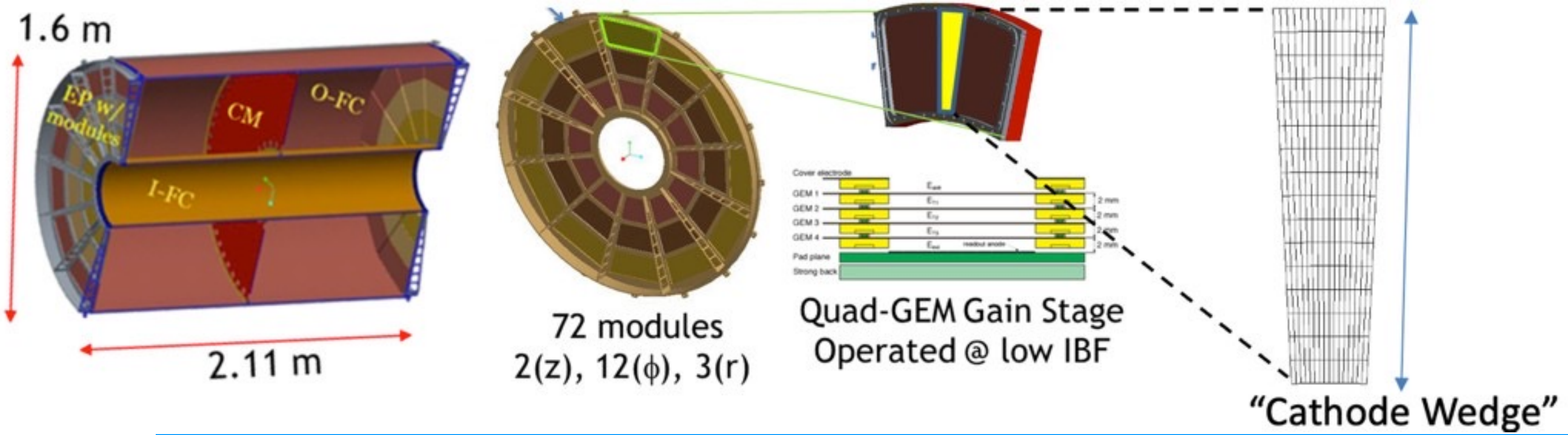


Cosmic Ray Track Reconstruction



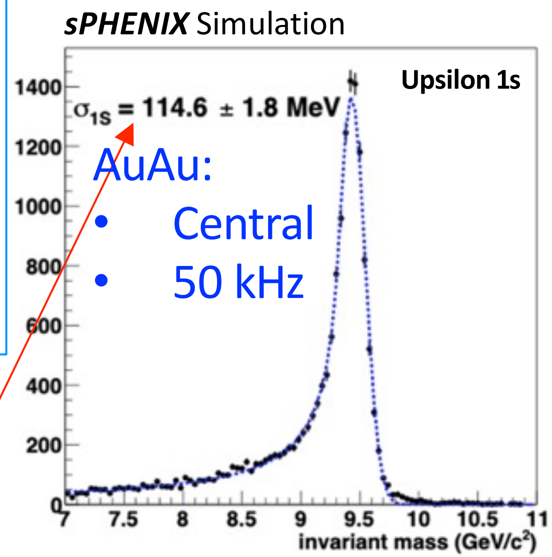


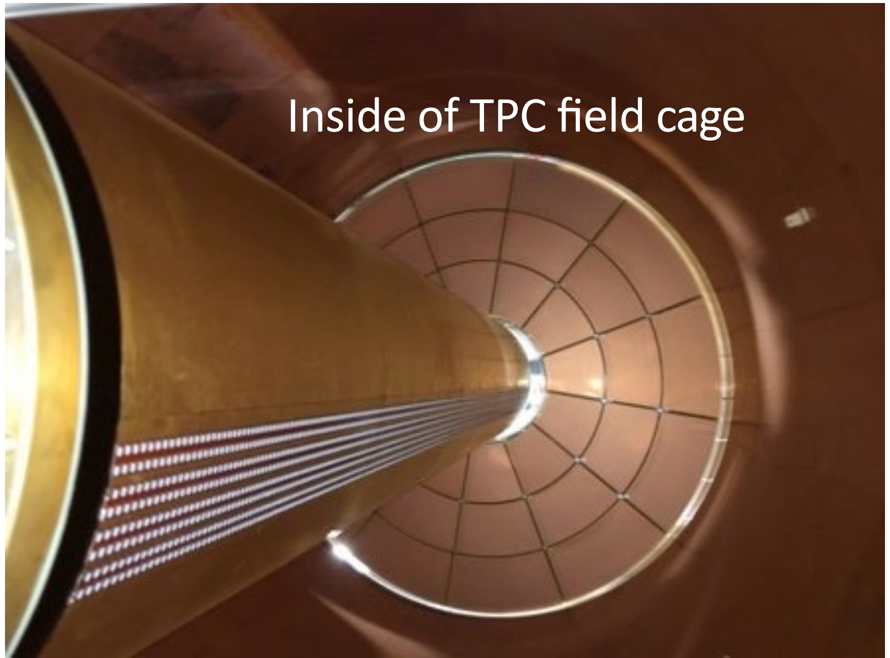
Time Projection Chamber (TPC)



A next–genera;on TPC operated in con;nuous readout mode using Gas–Electron Mul;plier (GEM) avalanche w/ low Ion Back Flow (IBF).

- Field cages are Kapton--carbon fiber
- End caps are aluminum
- Central membrane is G–10–honeycomb sandwich
- Internal chamber volume is filled with Ar–CF4 60/40 gas (4 m^3 gas volume)
- Electronics readout on each end
- ASIC modified SAMPA chip from ALICE



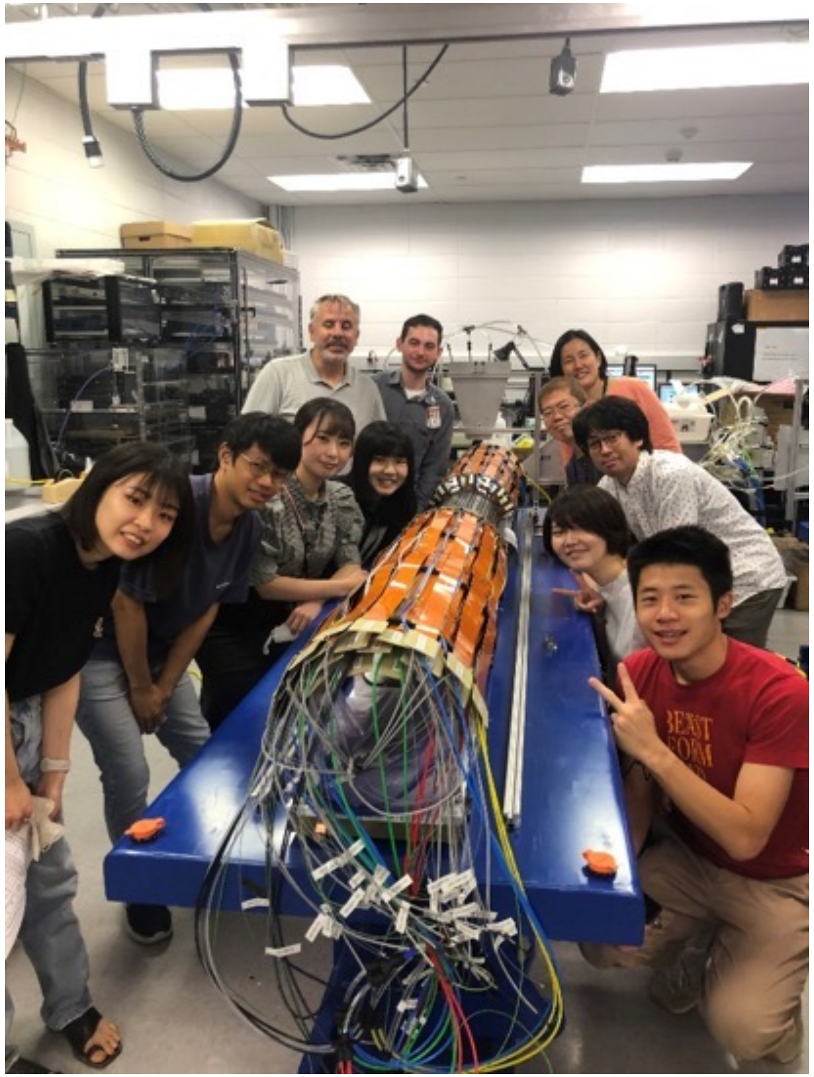


Charged Tracking in sPHENIX:
TPC provides momentum--resolu;on

sPHENIX Intermediate Tracker (INTT)

Two--layer silicon--strip detector.

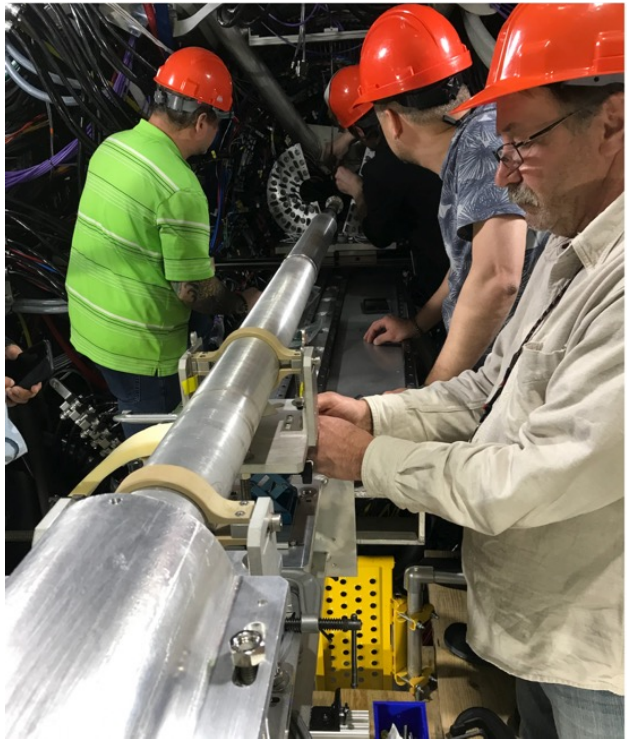
Read Out Cards reused from PHENIX forward silicon detector

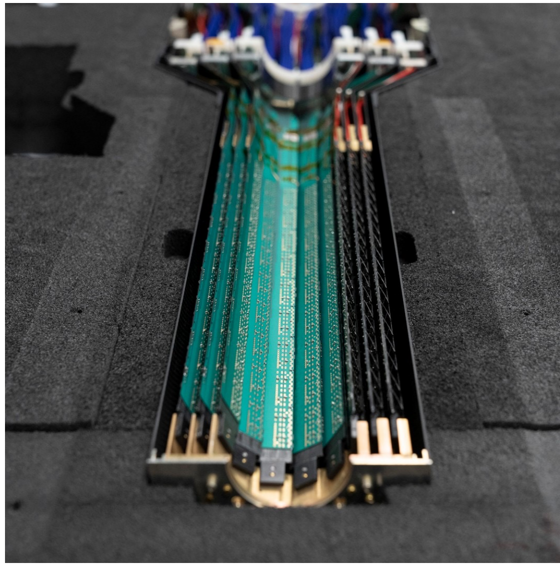


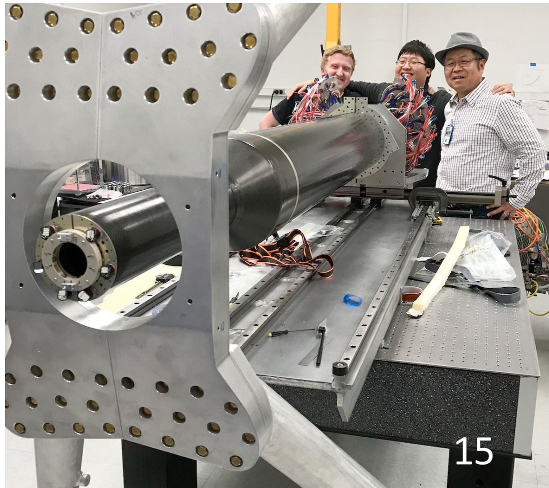
E. O'brien @sPHENIX QM2023

Monolithic Ac;ve Pixel Vertex Detector (MVTX)

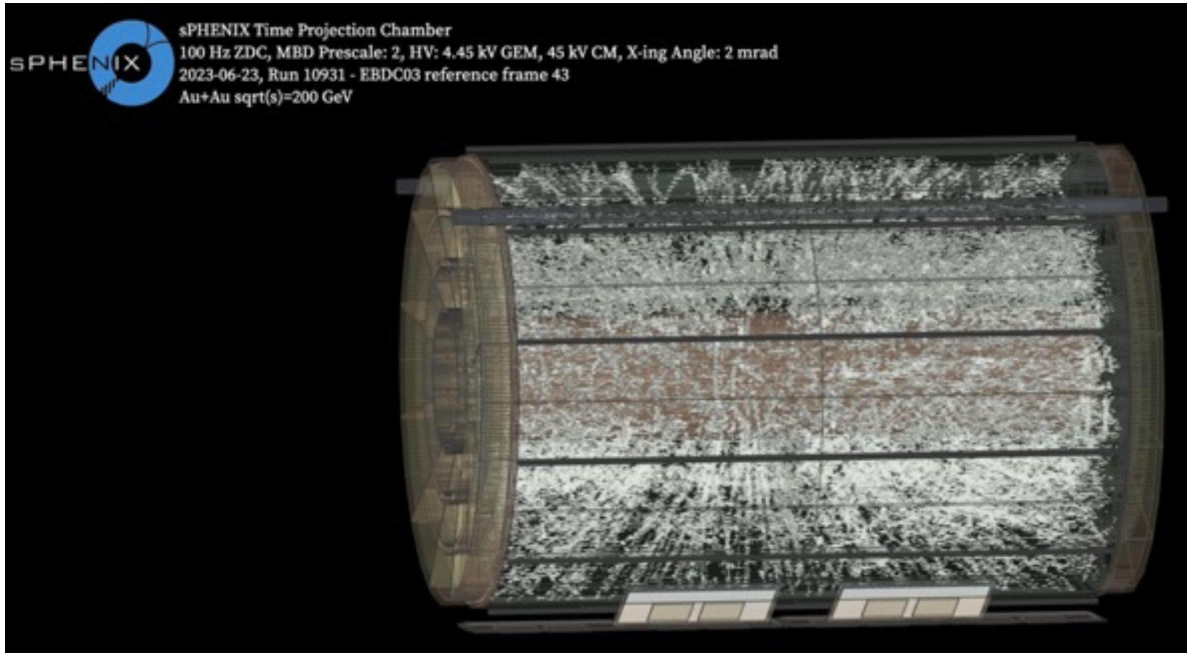
- The MVTX is a 230M channel, 3–layer MAPS--based pixel detector
- The MVTX is a copy of inner 3 layers of the ALICE ITS w/ a custom design of service supports to meet sPHENIX needs
- Staves and Readout Units produced at CERN w/ par;cipa;on from sPHENIX collaborators

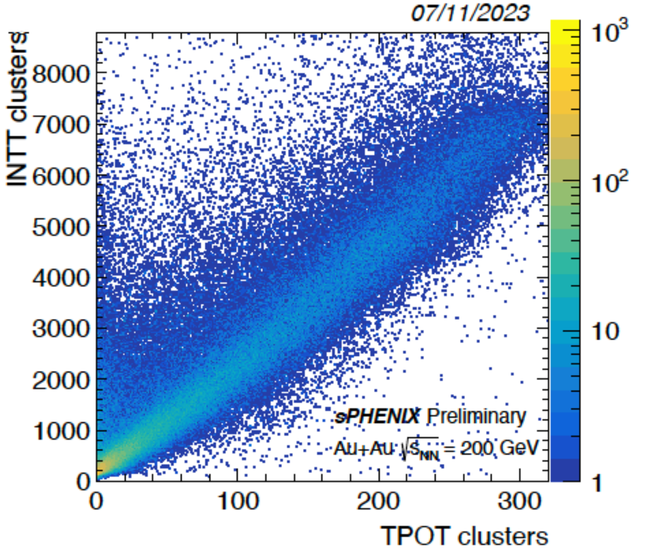


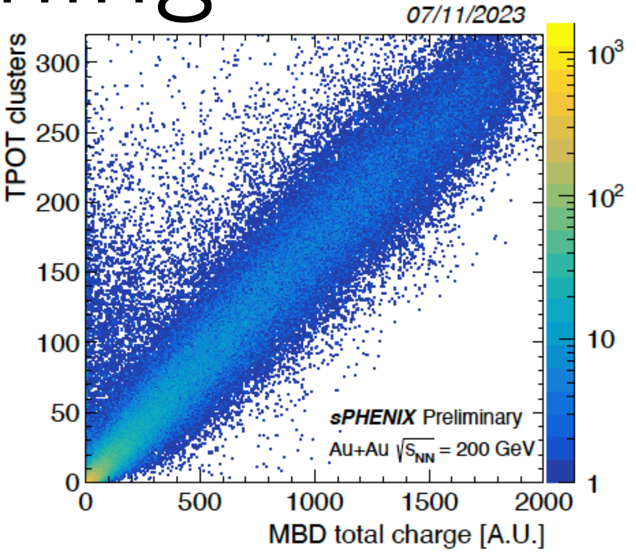




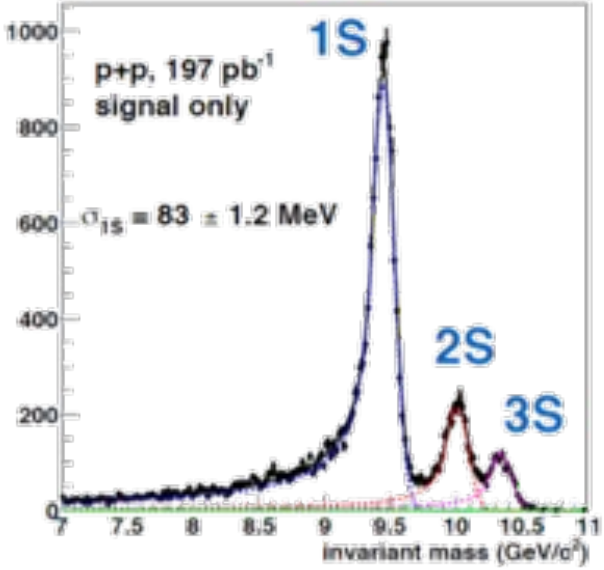
Tracking Detector Commissioning





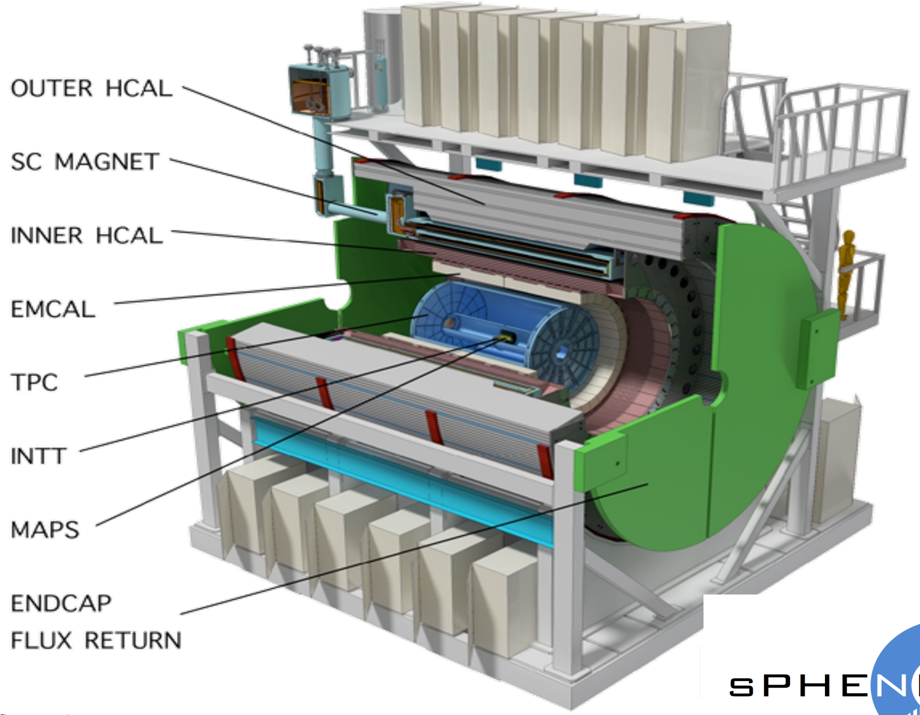


sPHENIX Simulation



- TPC Event Display in Au+Au @ 200GeV
- Multiplicity correlations between MBD-INTT-TPOT
- MVTX correlation between different layers
- More correlation hits in Zhaozhong Shi’s talk on Thursday 08/24

Clear separation between 2S and 3S states

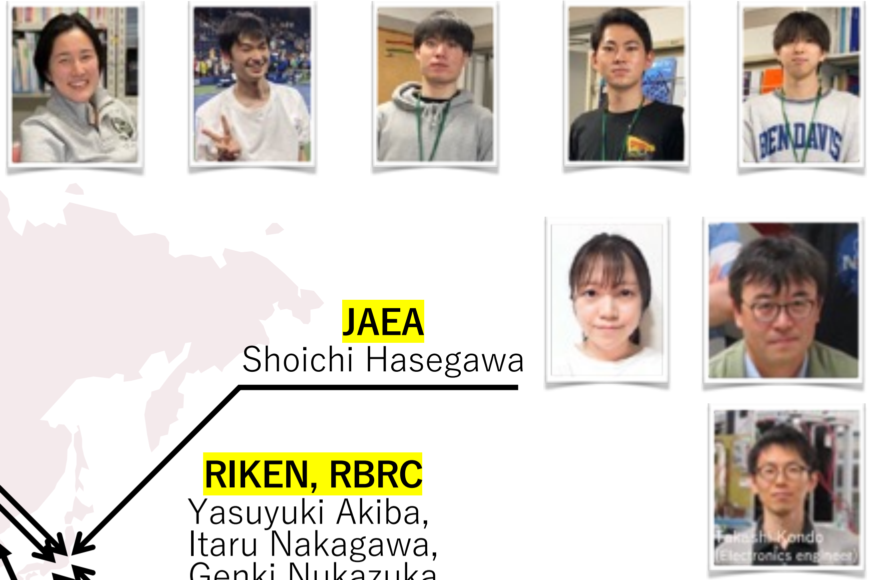


sPHENIX

日本グループの貢献

INTTシリコンストリップ検出器

INTT共同研究者



TIRI
Takashi Kondo

BNL
Rachid Nouicer,
Dan Cacace, Raul Cecato,
Donald Pinelli, Robert Pisani,
Nick Seberg, Steven Andrade,
Antonio Vederosa, Stephen Boose

Rikkyo Univ.
Kazuma Fujiki
Hikaru Imai,
Tomoya Kato,
Ryota Shishikura,

Purdue Univ.
Wei Xie,
Milan Stojanovic,
Joseph Bertaux,
Han-Sheng Li
(former member)

JAEA
Shoichi Hasegawa

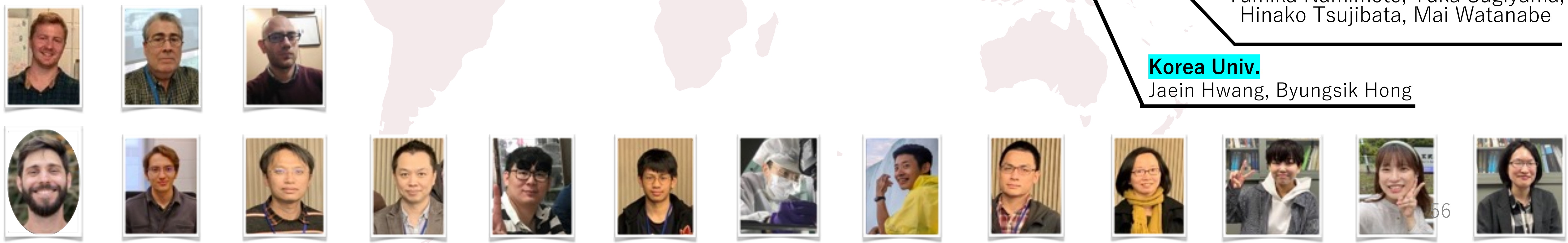
RIKEN, RBRC
Yasuyuki Akiba,
Itaru Nakagawa,
Genki Nukazuka

National Taiwan Univ.
Rong-Shyang Lu, Jenny Huang,
Lian-Sheng Tsai, Ou-Wei Cheng

National Central Univ.
Chia-Ming Kuo, Kai-Yu Cheng,
Cheng-Wei Shih, Wei-Che Tang

Nara Women's Univ.
Manami Fujiwara, Takashi Hachiya,
Misaki Hata, Maya Shimomura,
Runa Takahama, Mai Kano,
Yumika Namimoto, Yuka Sugiyama,
Hinako Tsujibata, Mai Watanabe

Korea Univ.
Jaein Hwang, Byungsik Hong

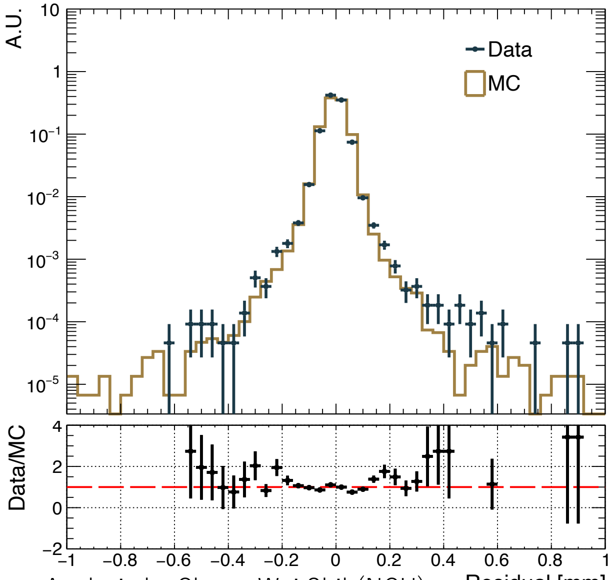


INTTシリコンラダー

パフォーマンス

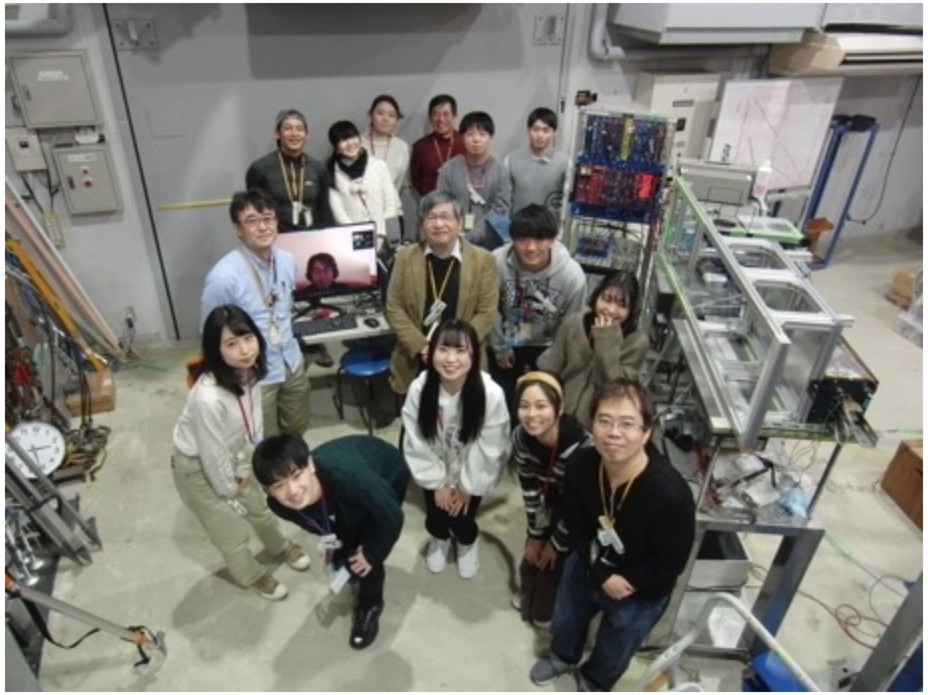
- 1ビームクロック以下の時間分解能を確認。
- 2021年ビームテストで検出効率(>99%) を確認
- 宇宙線測定@奈良女でアクセプタンス中検出効率の勾配がないことを確認。
- ほぼ設計通りのパフォーマンス。
- シミュレーションモデルでResidual分布を完璧に再現

ビームテスト
Residual分布

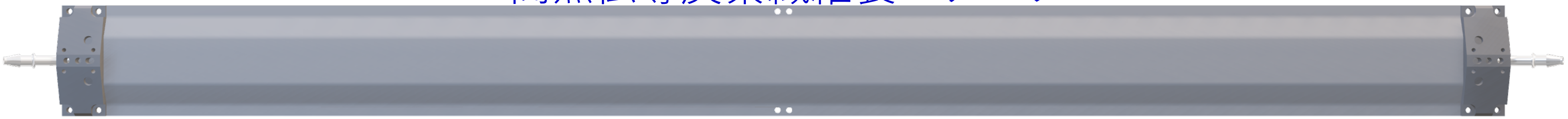


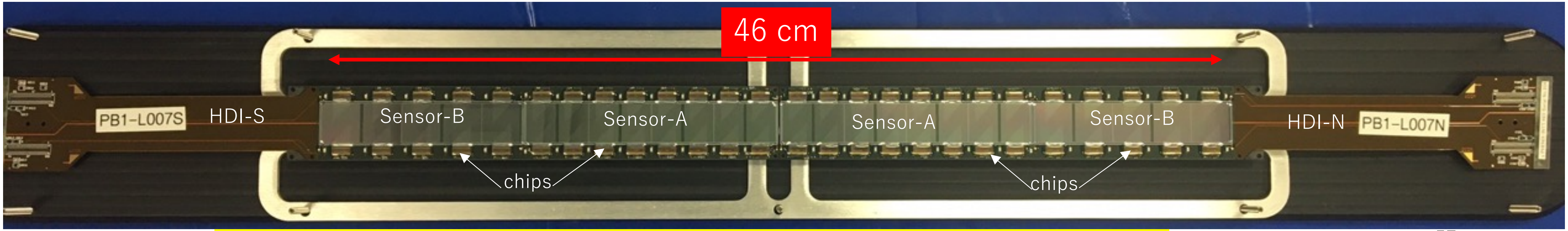
Analysis by Cheng-Wei Shih(NCU)

2021年12月ビームテスト@東北大ELPH



高熱伝導炭素繊維製ステーブ

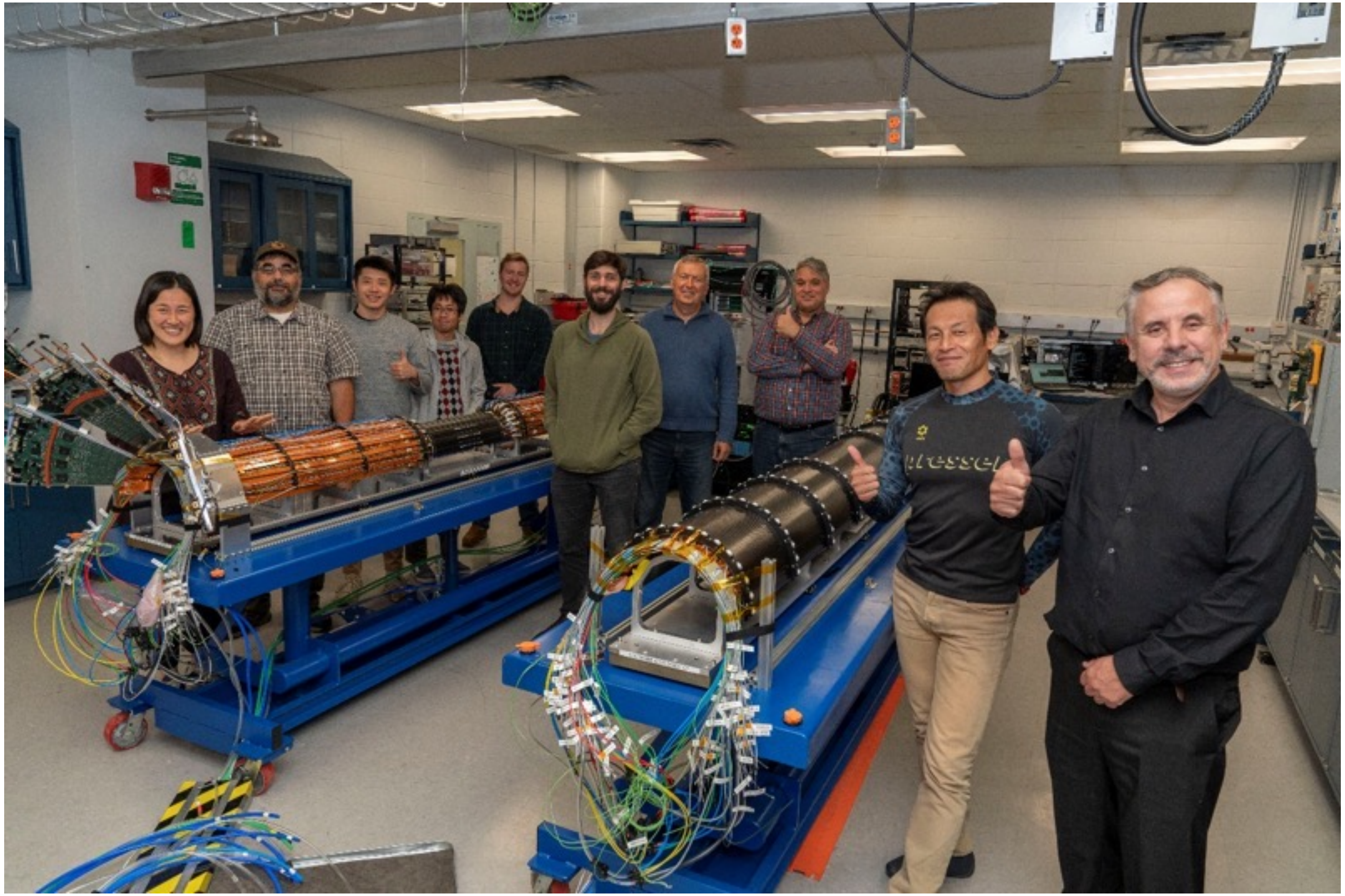


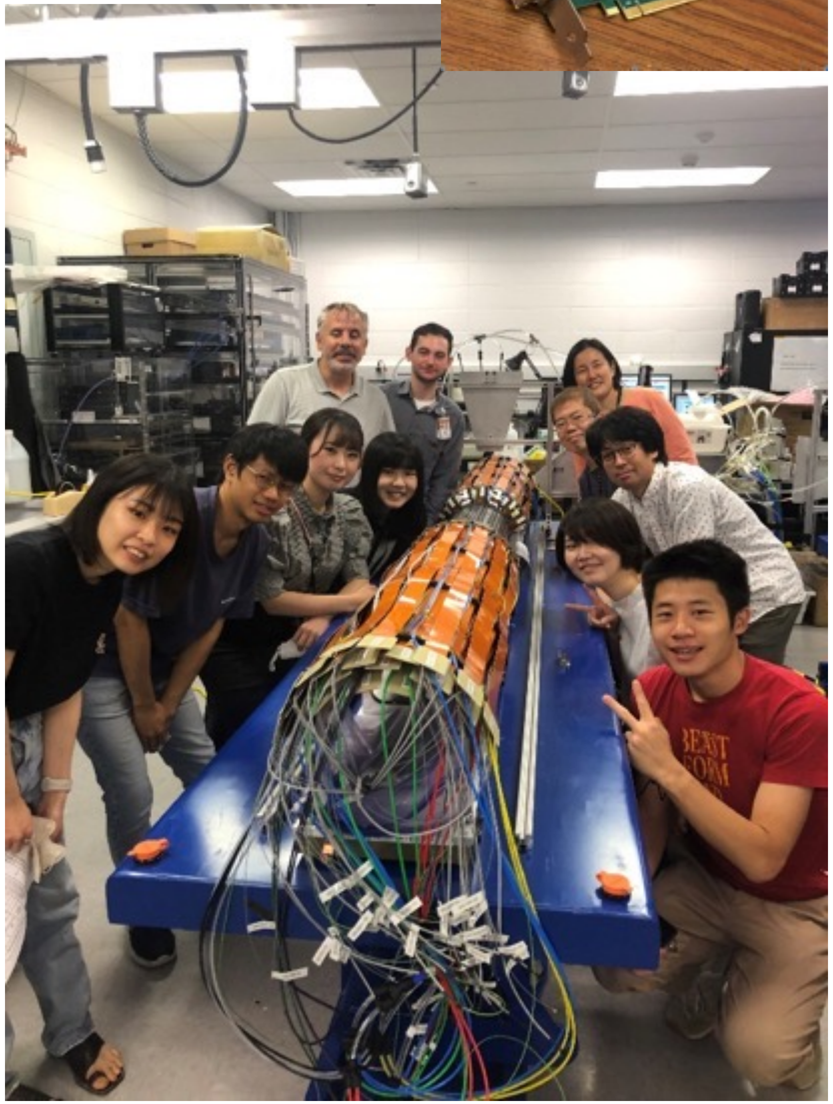


120ラダーの量産は2022年の3月にBNL+台湾にて完了

INTTバレル

Felix読み出しボード



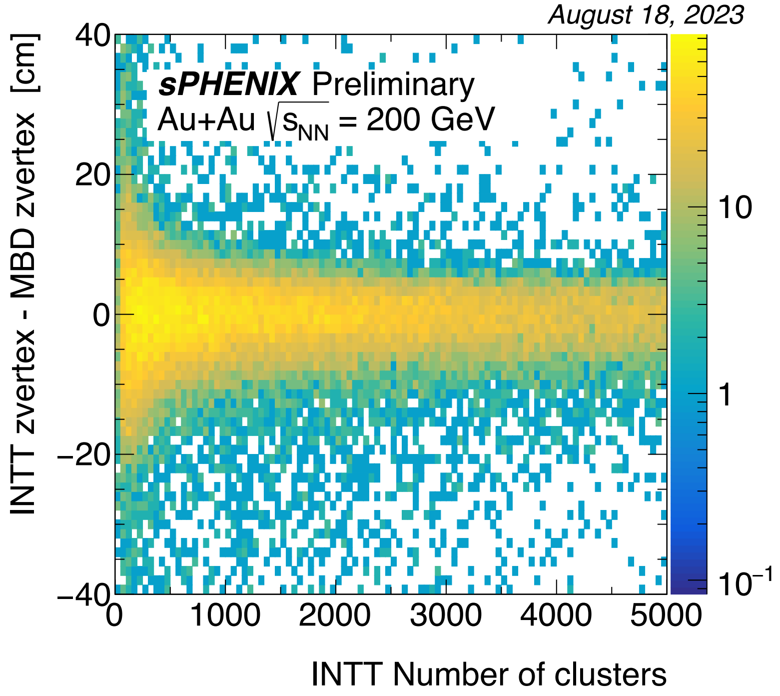


ATLASのFelix読み出しボードベースのデータ収集。
2年目のランでsPHENIX飛跡検出器群はDeadtimelessのストリーム読み出しを目指す。

Vertex Reconstruction & Centrality

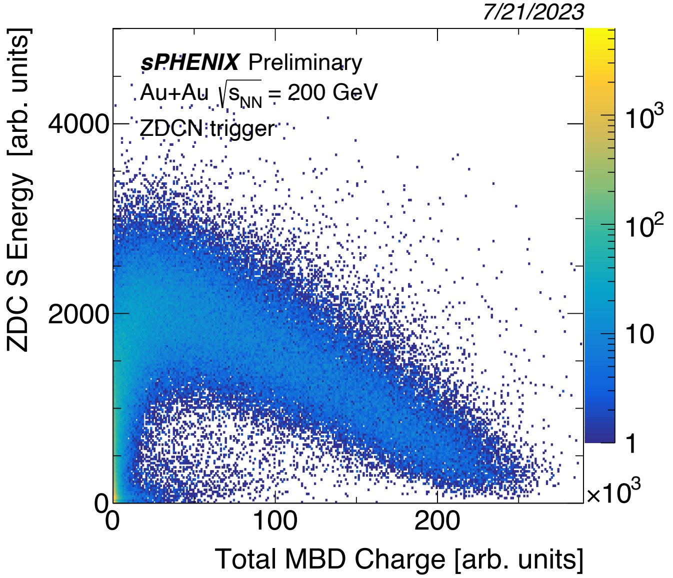
sPHENIX Simulation

INTT-MBD Z-vertex Reconstruction

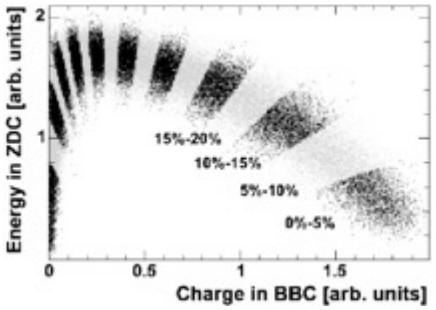


Confirmed fairly consistent z-vertex reconstruction between two independent detectors

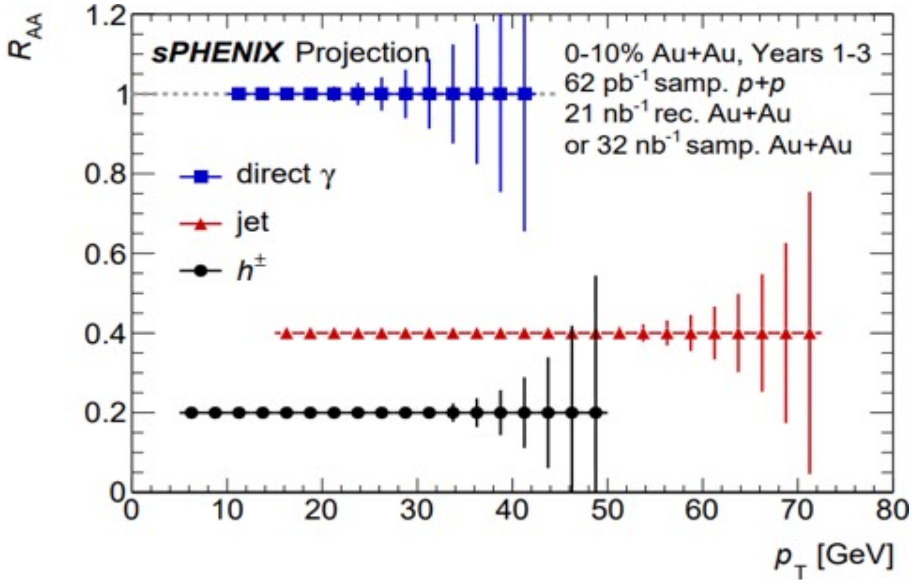
MBD-ZDC Centrality

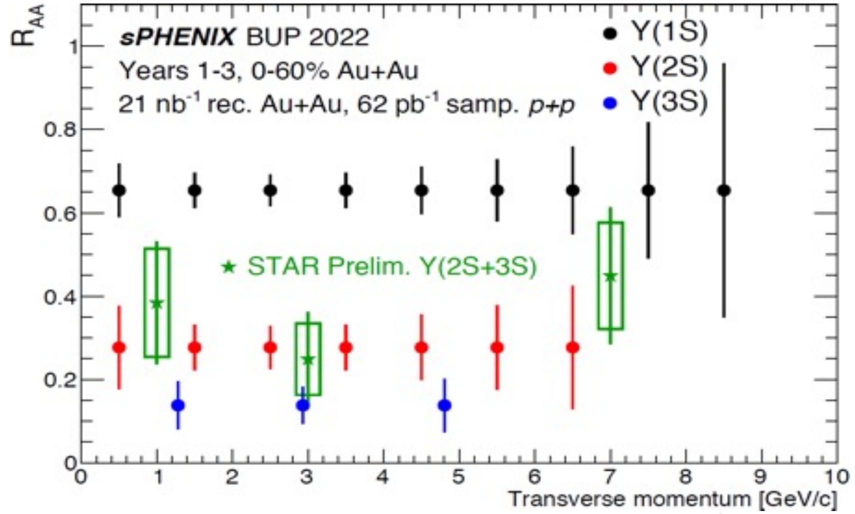


Phys. Rev. C **71**, 034908 (2005)



Published Centrality plot in PHENIX





sPHENIXの文献（日本語）

草分け

sPHENIX 実験 – a state-of-the-art jet detector at RHIC –

山口　頼人

理研 BNL 研究センター

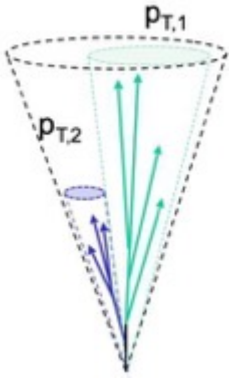
クォーク・グルオン・プラズマ(QGP)はクォークとグルオンがハドロンの閉じ込めから解放された超高温高密度 QCD 物質です。以前は QGP 存在検証が主目的であった QGP の実験的研究は RHIC と LHC という 2 つの強力な加速器が稼働したことでその存在は疑いようのないものとなり、今では実際の QGP はどういうものか詳しく調べる新たな局面を迎えています。RHIC や LHC の実験からは生成 QGP の粘性が非常に小さいという驚くべき結果が報告されました。この粒子間相互作用が強い“強相関 QGP”の性質を詳しく調べるためにはより核心に迫るプローブを駆使した測定が必要です。本稿では RHIC で 2023 年開始予定の新実験である sPHENIX 実験が明らかにする QGP の性質および、実験準備の状況について紹介します。

原子核研究第63巻1号(2018)

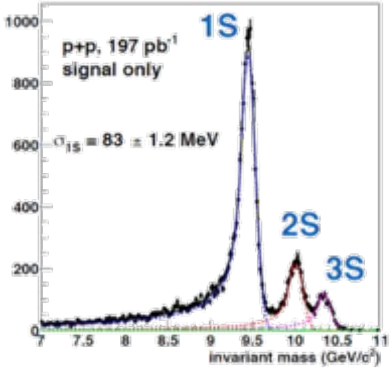
日経サイエンス2023年6月号

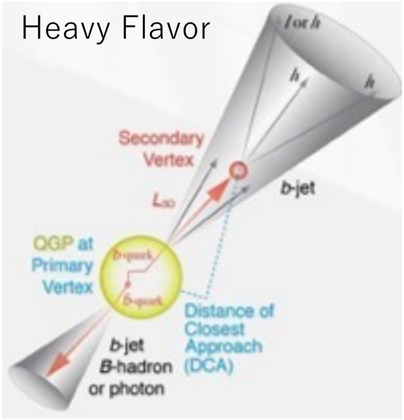
sPHENIX Summary

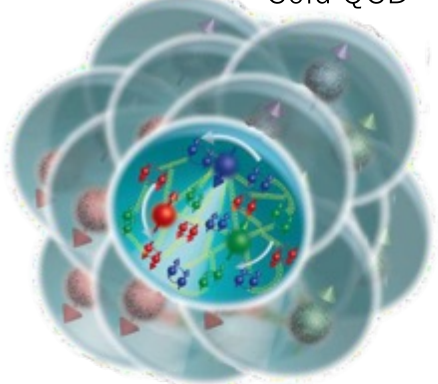
- Large and hermetic EM and hadronic calorimetry.
- Highly precise tracking.
- 15kHz trigger rate and stream readout for trackers.
- Wide range of physics covered in sPHENIX
- A lot of progress in 2023 commissioning with Au+Au Collision at $\sqrt{s}$ =200GeV and getting ready for 2024 Run.
- Will address on cold QCD in 2024!



Jet Physics

Quarkonium spectroscopy


Heavy Flavor


Cold QCD


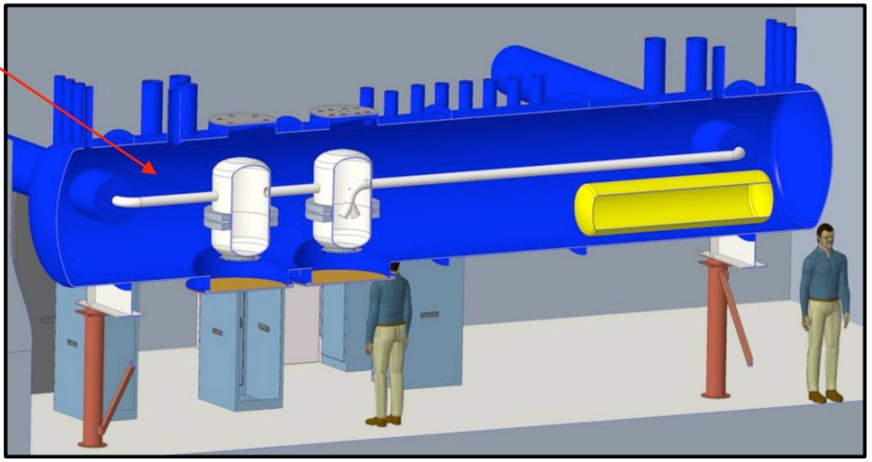
WIN-WIN-WINのシナリオ

Backup Slides

1004B Blue Ring Valve Box

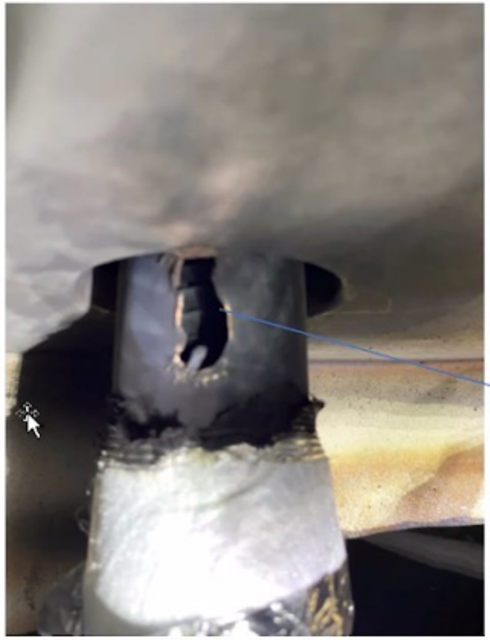
M-Line

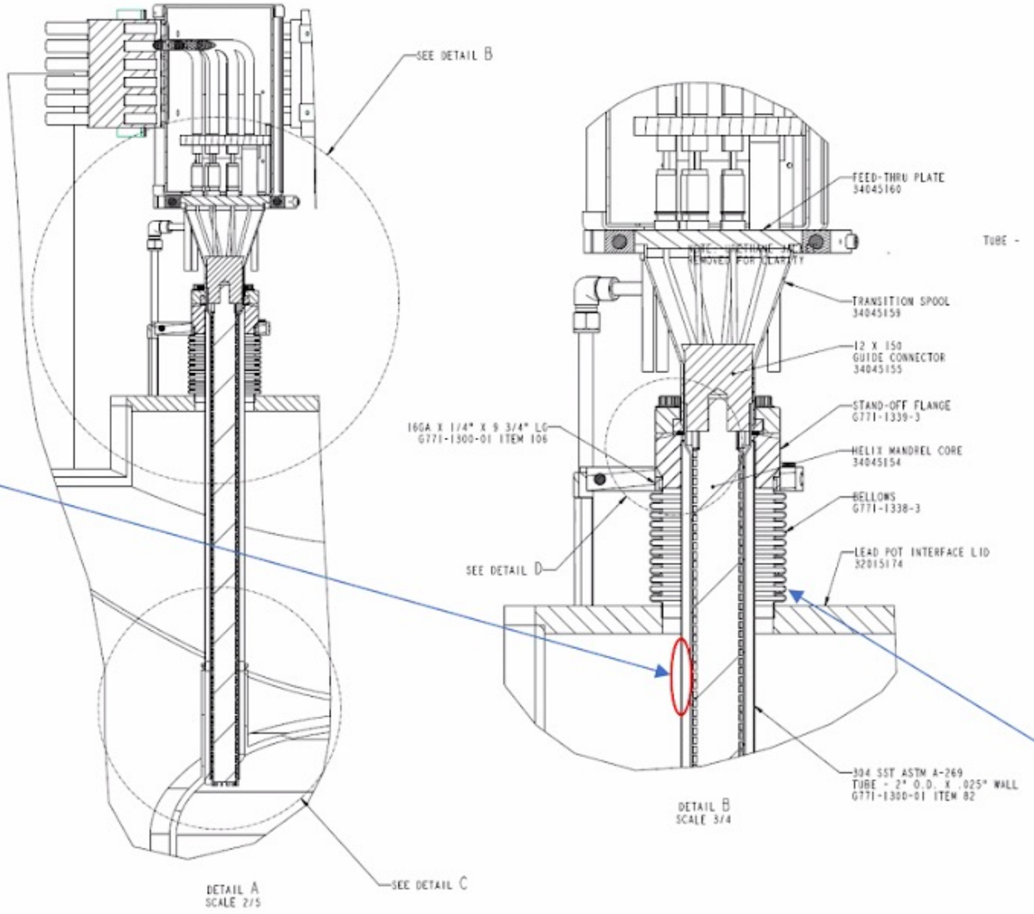
Magnet cooling line, contains all SC busses



- electrical tests acquired under “as-is” (e.g. cold) conditions indicate failure is localized to inside the valve box vessel
  - Main Blue dipole circuit shorted to ground, believe to have ruptured M-Line pipe (as evidenced by Helium in vacuum vessel)
  - Remaining 4 cryo circuits in valve box vessel (not shown) are intact
- in progress
  - careful warm-up of sector 4 magnet string (expected completion end of this week)
  - work planning, pre-inspection, preparation for initial opening and inspection
  - assembly of foreseen materials for repair: superconducting bus cable (special process spares), magnet line flex lines (re-inforced bellows assemblies for pressure systems), piping, fittings, gas-cooled leads, splice material, insulation
- repair plan development the week of August 28th
- length of repair is TBD

Feedthrough tube rupture



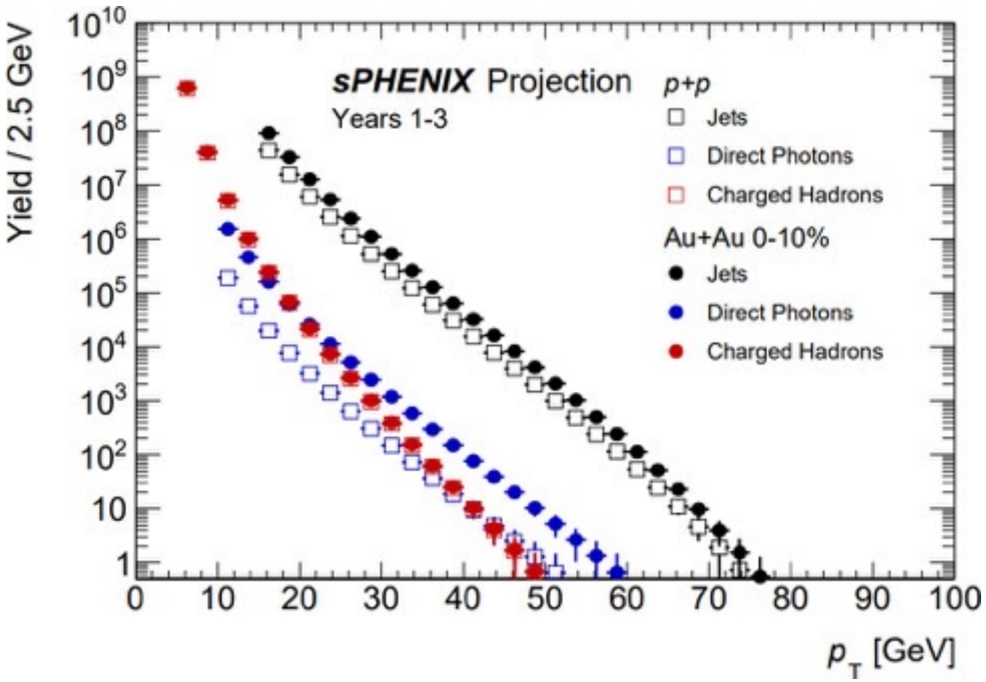


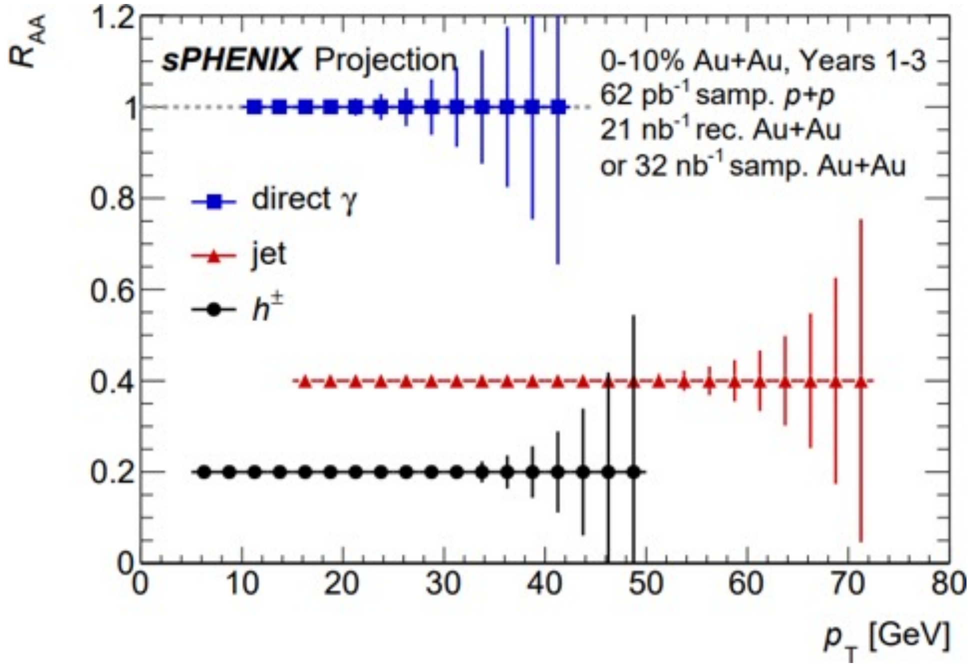
Charred 150 amp feedthrough

Feedthrough bellows rupture

Jet Physics

Probing the QGP with precise jet, direct photon, and hadron measurements



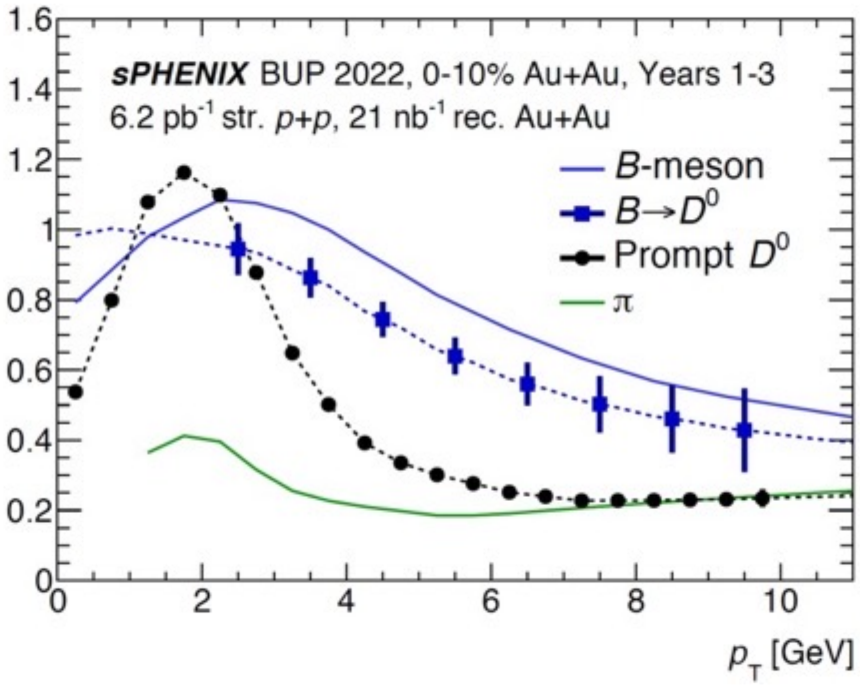


✓High data rates & hermetic EMCal+HCal offer wide p_T range for jet reconstruction.

✓sPHENIX can precisely measure the low p_T region, which is challenging at the LHC.

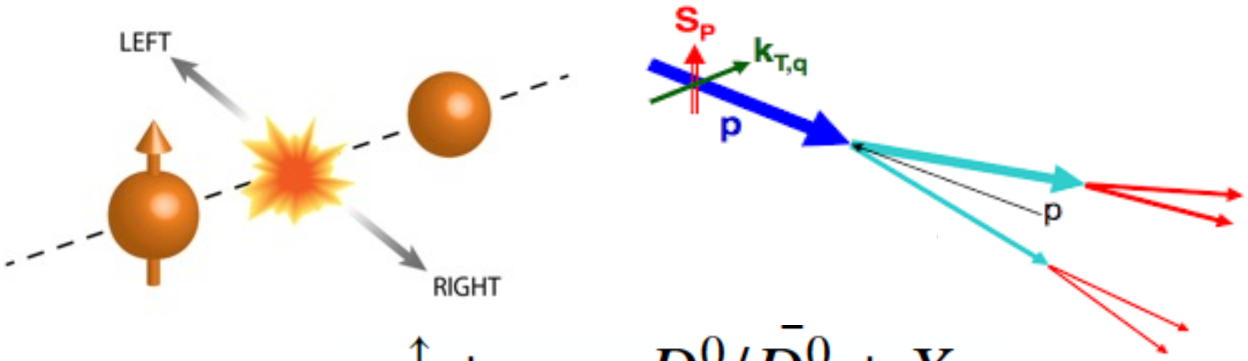
✓sPHENIX will have kinematic reach out to ~ 70 GeV for jets, kinematic overlap with the LHC.

Heavy Flavor

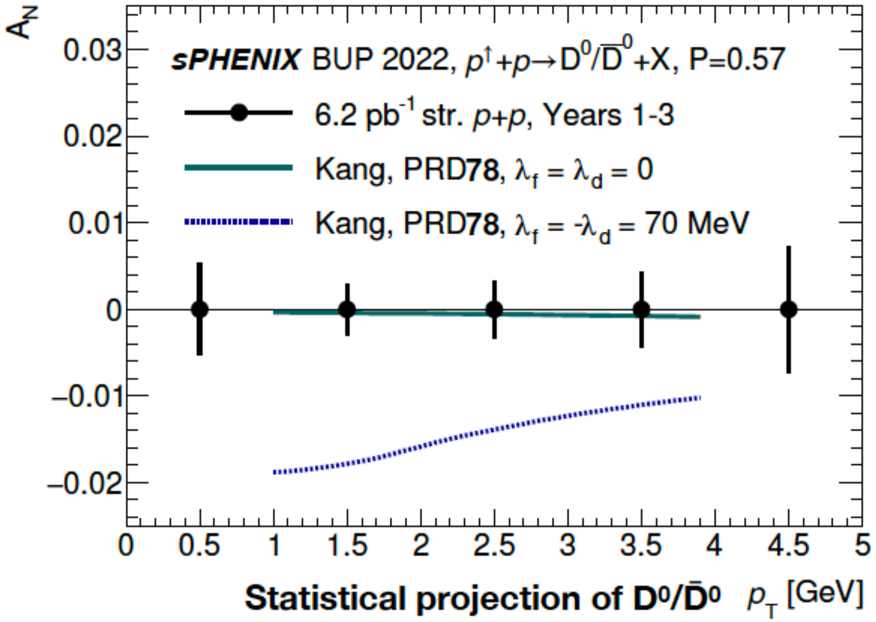


- ✓ Cleanly separate open bottom via DCA.
- ✓ Study mass dependence of energy loss and collectivity.
- ✓ Bottom quarks and light quarks are expected to be different for R_{AA} and v_2 for $p_T \lesssim 15$ GeV.

Polarized single spin asymmetry



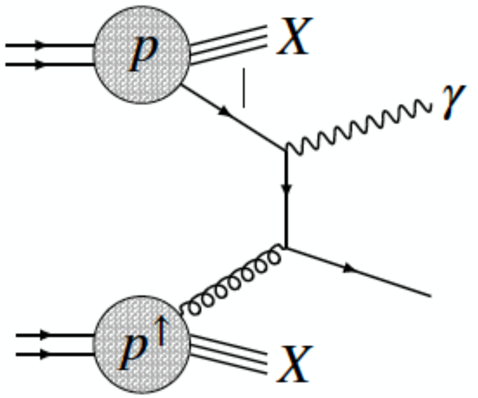
$$p^{\uparrow} + p \rightarrow D^0/\bar{D}^0 + X$$



Statistical projection of D⁰/D̄⁰ measurement at sPHENIX.

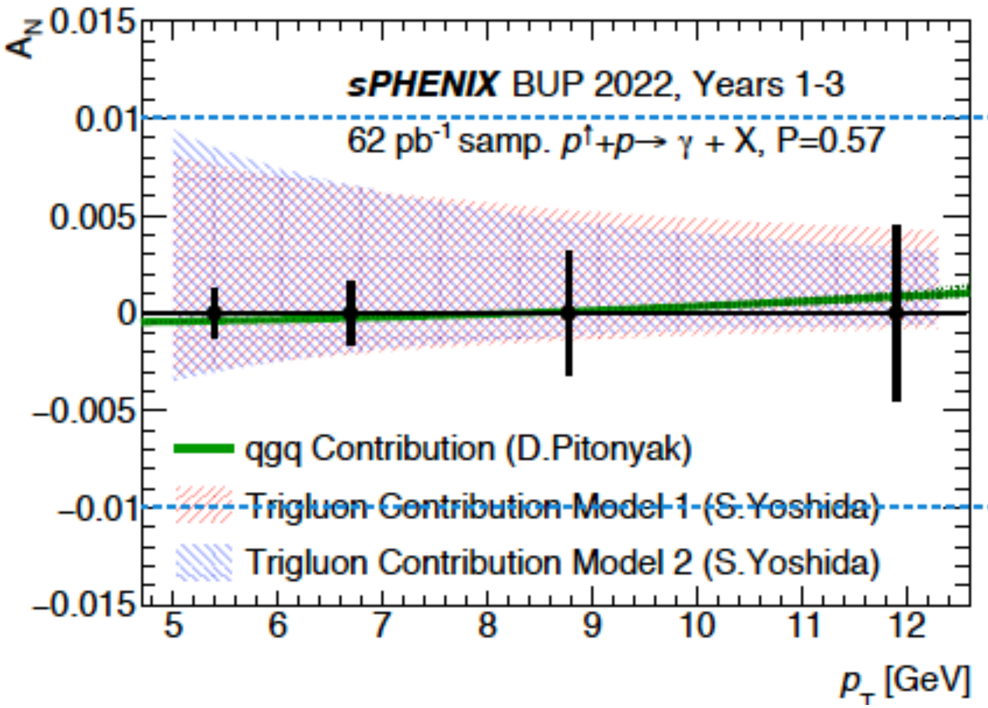
Explores gluon spin contribution to proton spin

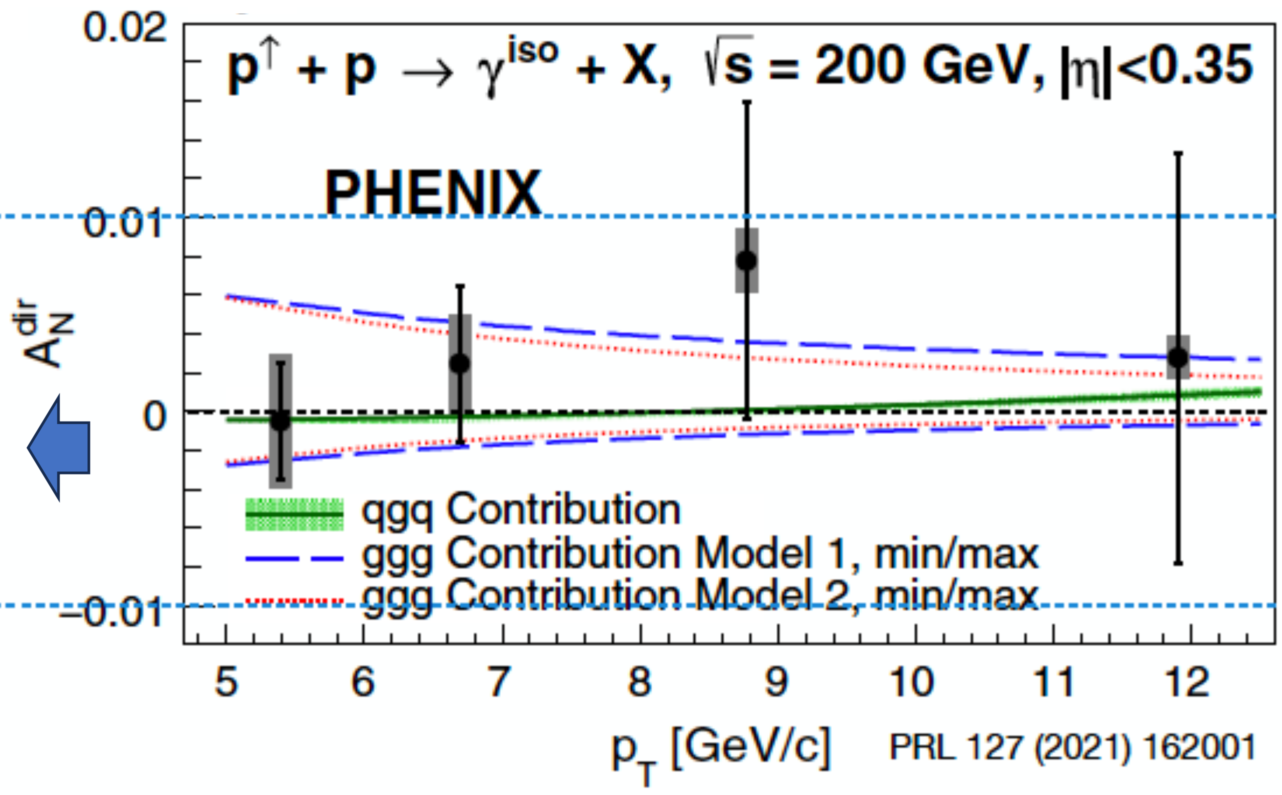
Cold QCD : Gluon TMD with Direct photons



$$p^{\uparrow} + p \rightarrow \gamma + X$$

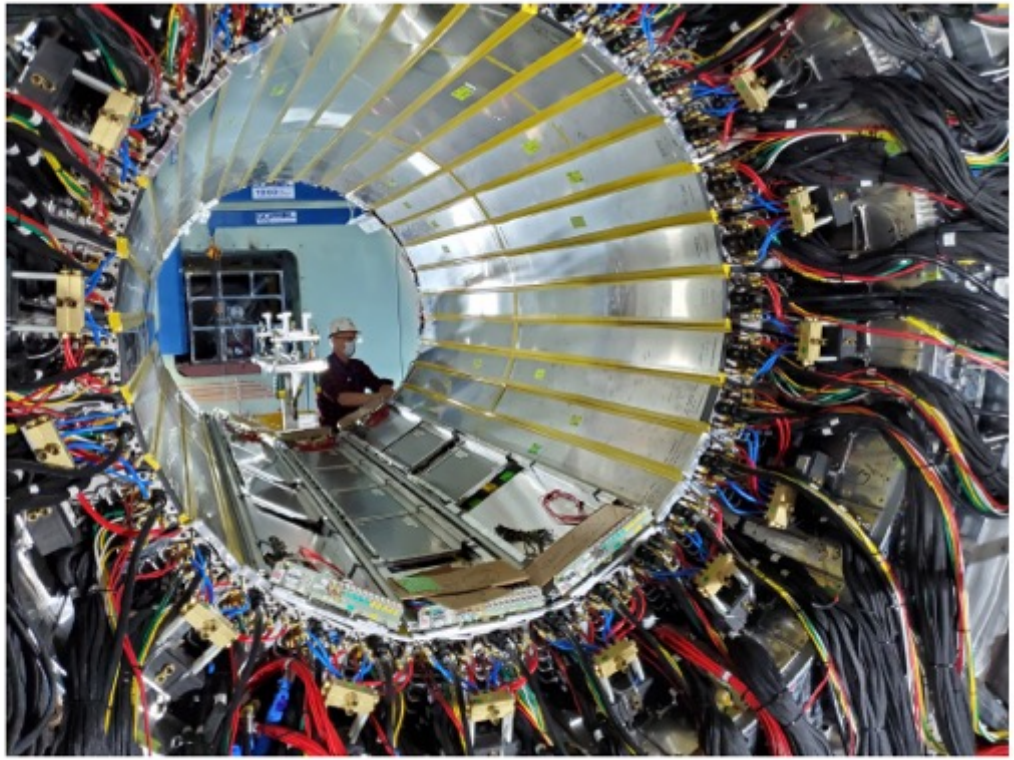
Much improved direct photon TSSA -> gluon TMD

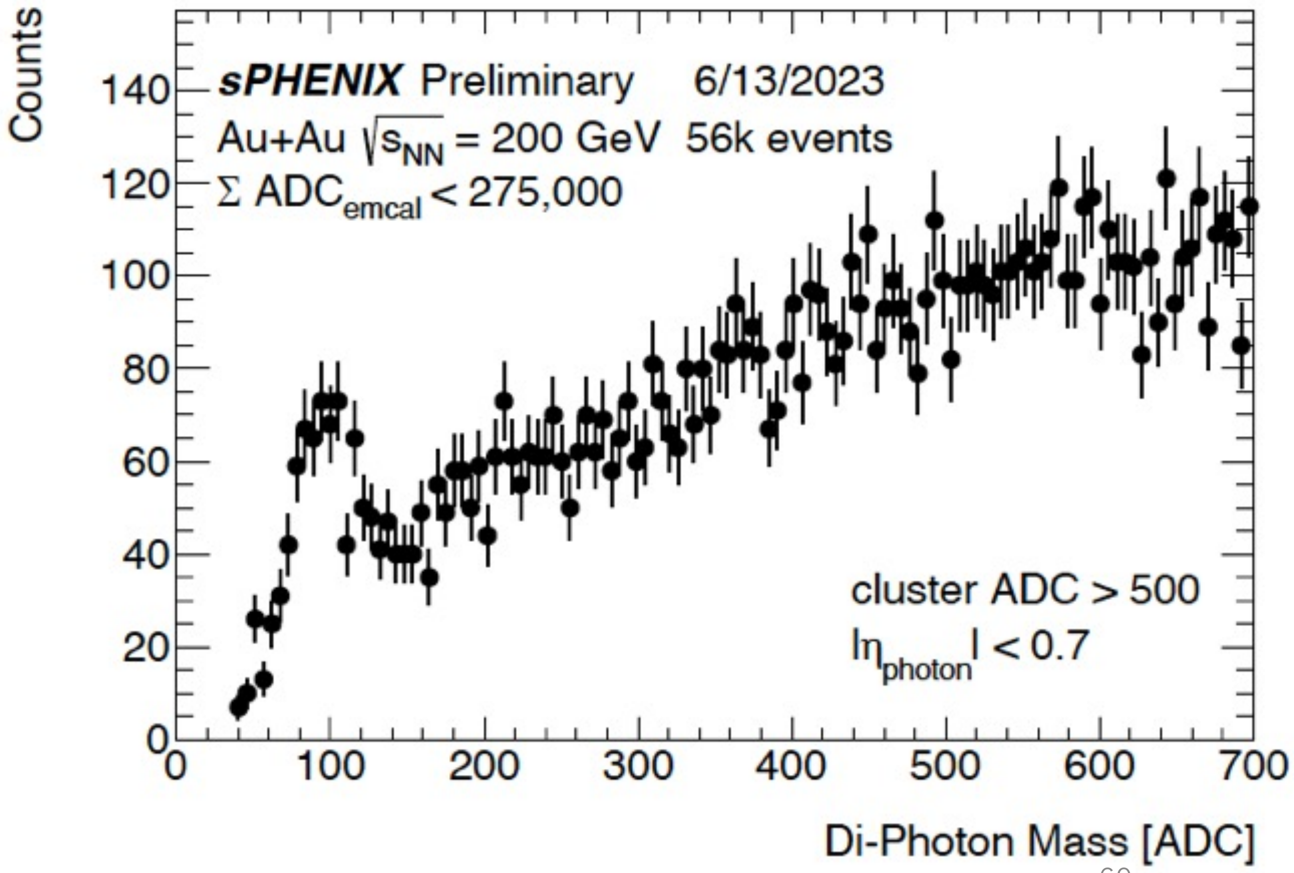




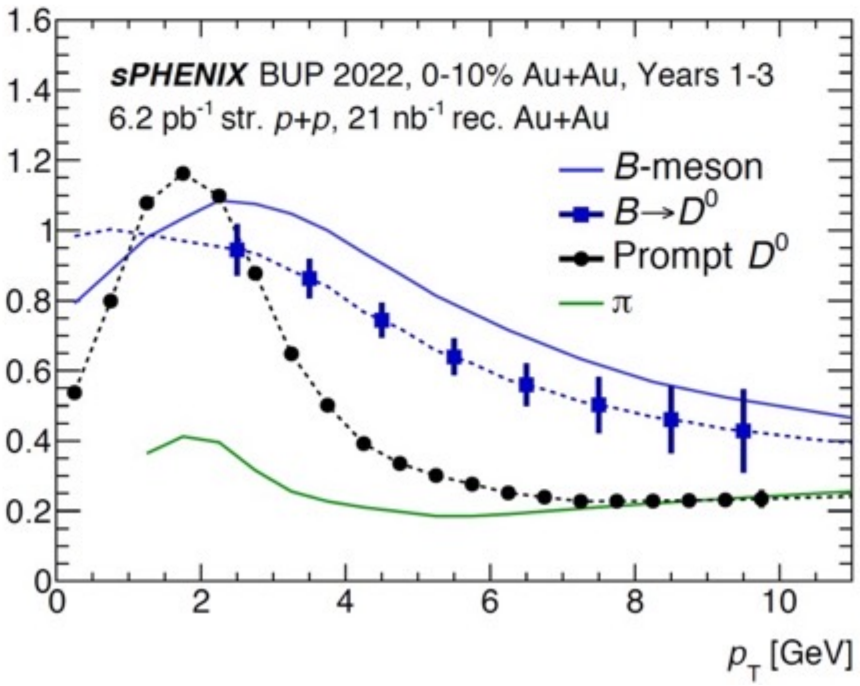
First Data from Commissioning: EMCal

- Clear pi0 peak seen in the di-photon invariant mass spectrum





Heavy Flavor



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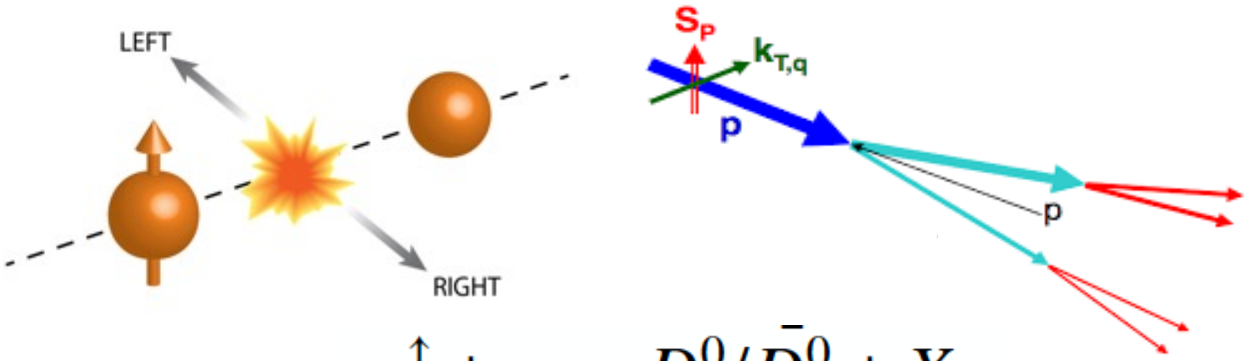
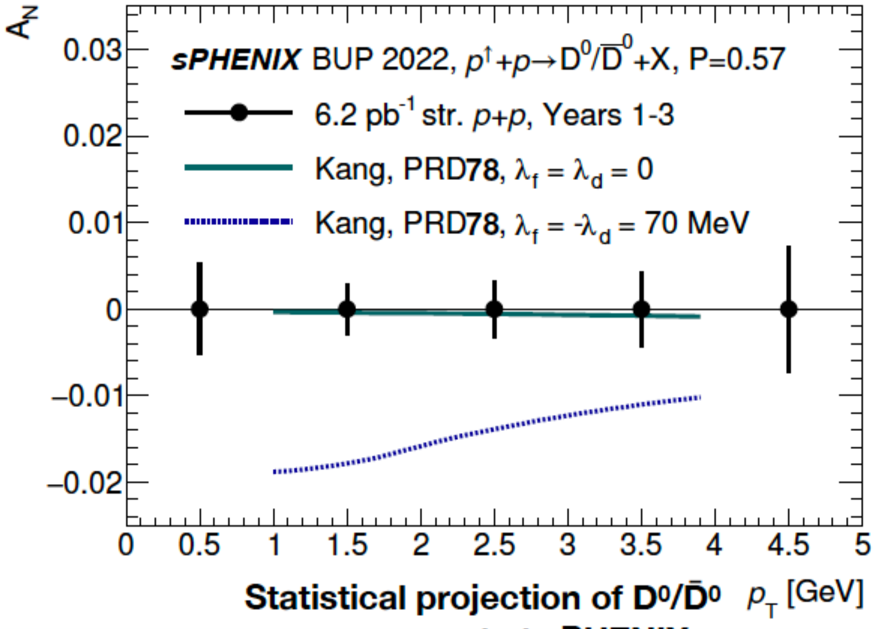
- ✓ Study mass dependence of energy loss and collectivity.
- ✓ Bottom quarks and light quarks are expected to be different for R_{AA} and v_2 for $p_T \lesssim 15$ GeV.

Polarized single spin asymmetry



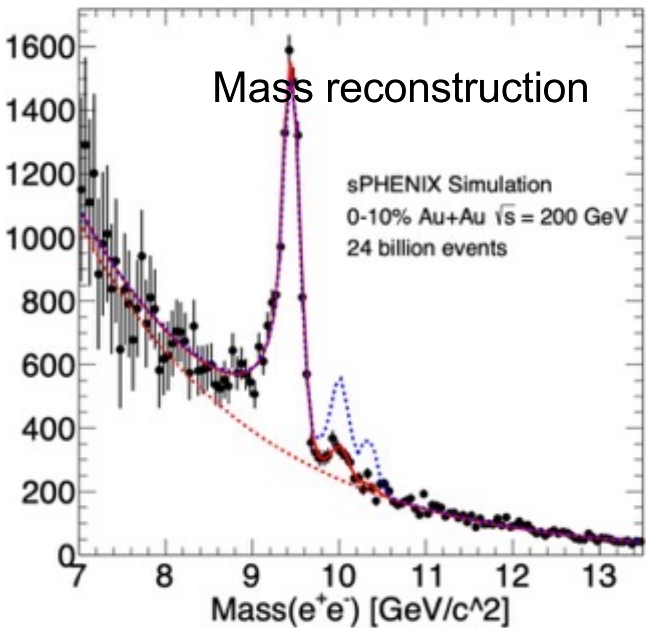
$$p^{\uparrow} + p \rightarrow D^0/\bar{D}^0 + X$$

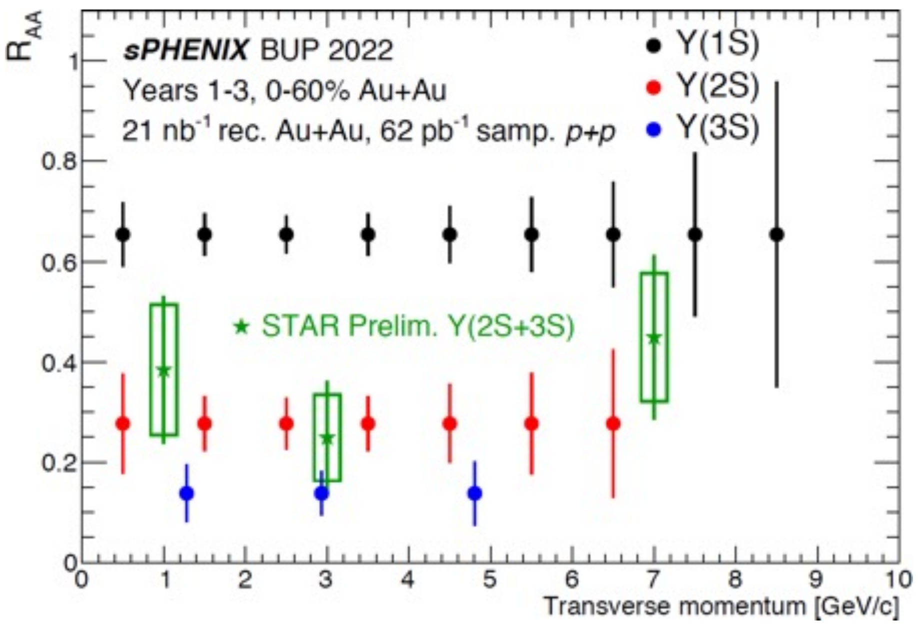


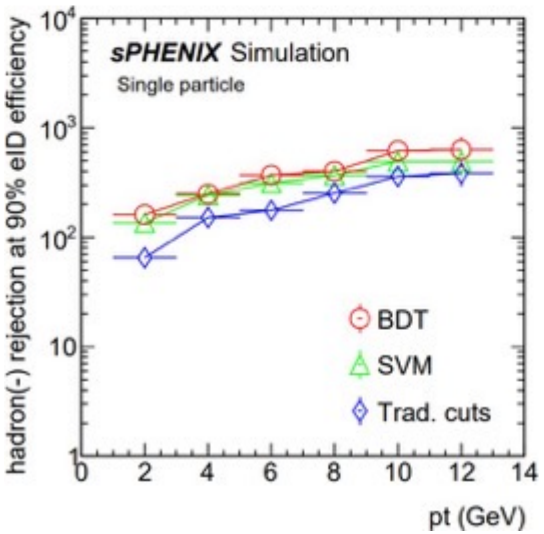
Statistical projection of $D^0/\bar{D}^0$ measurement at sPHENIX.

Explores gluon spin contribution to proton spin

Quarkonium spectroscopy

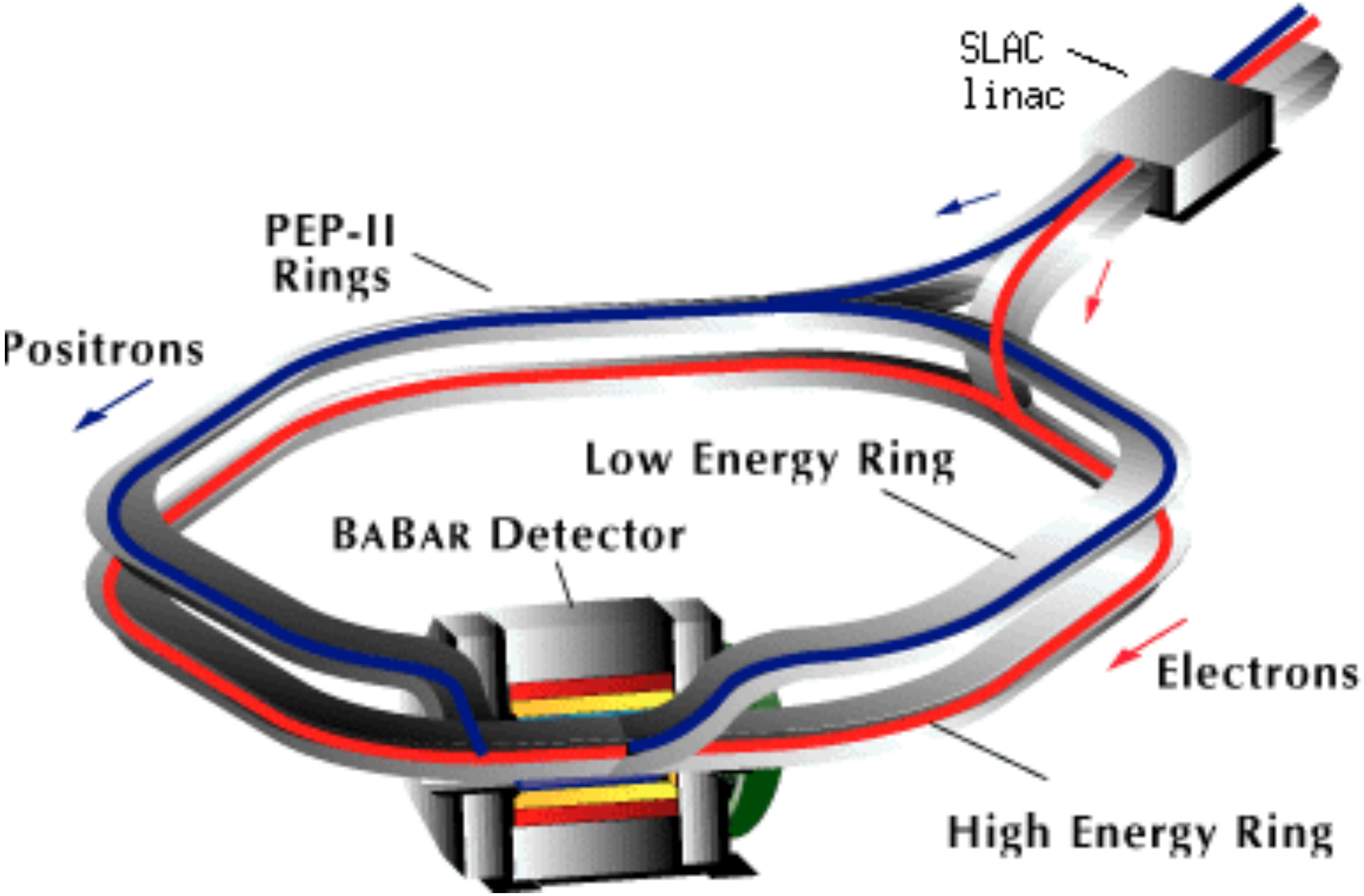


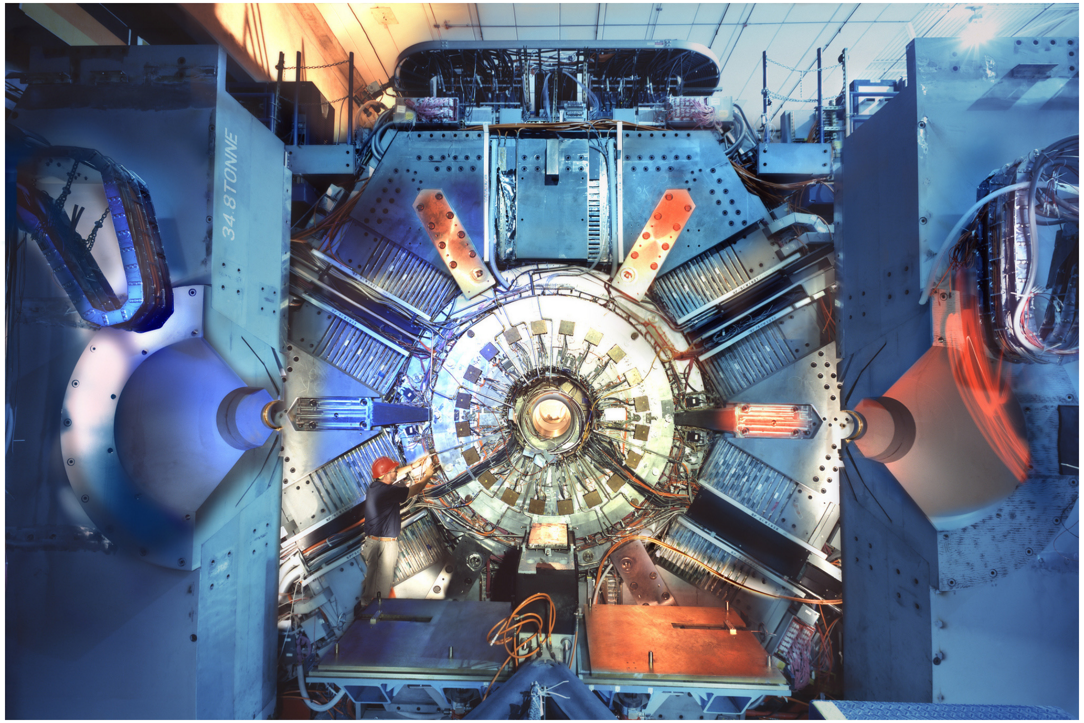


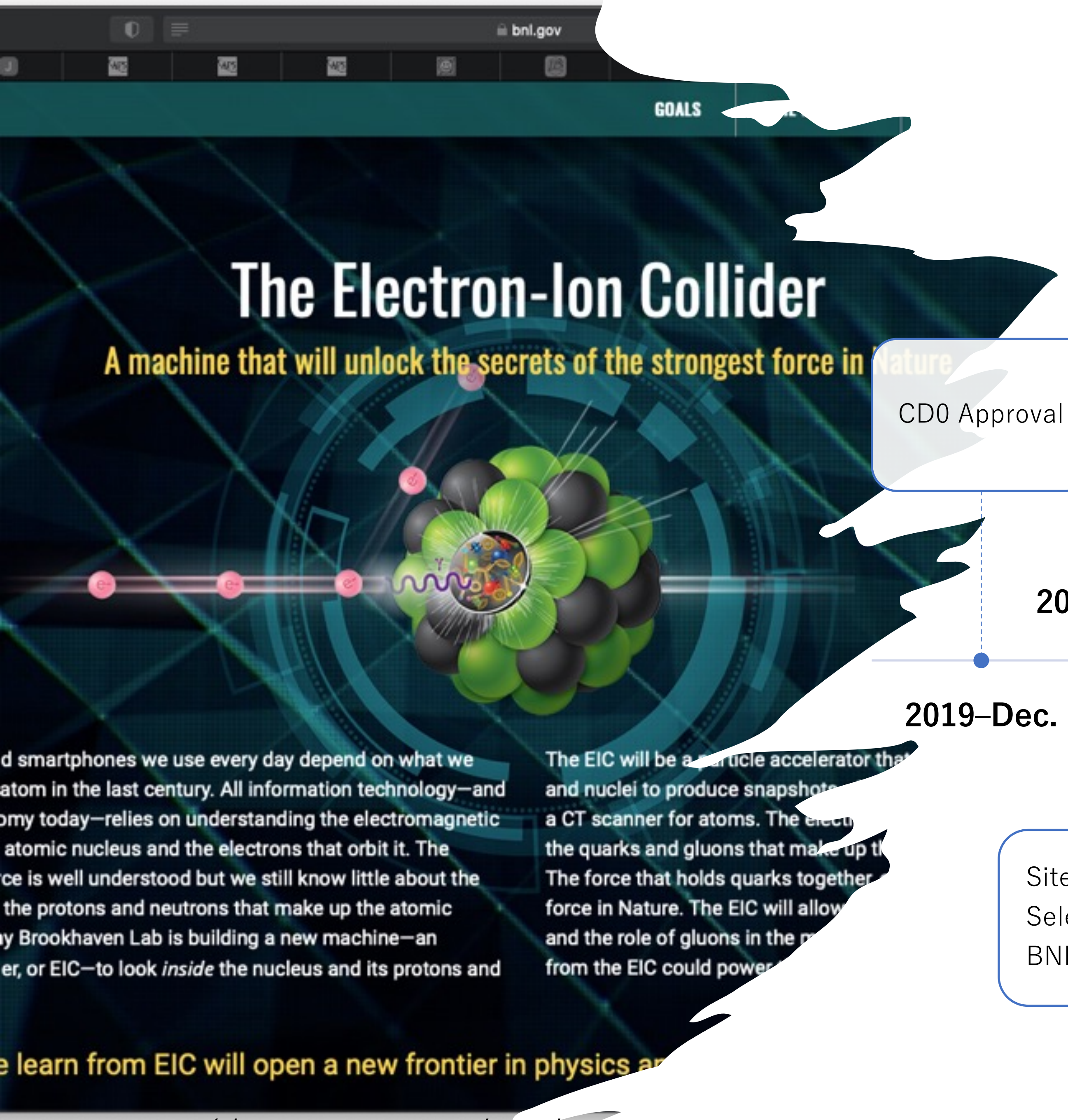


- ✓ Suppression with clear distinction of three Upsilon states. Color dipoles probing the QGP at three length scales.
- ✓ The centrality dependence and particularly the p_T dependence are critical measurements for comparison between RHIC and the LHC.
- ✓ Signal enhancement with ML tools (BDT) is expected.

BABAR


SLAC
linac
PEP-II
Rings
Positrons
Low Energy Ring
BABAR Detector
Electrons
High Energy Ring





https://www.bnl.gov/eic/

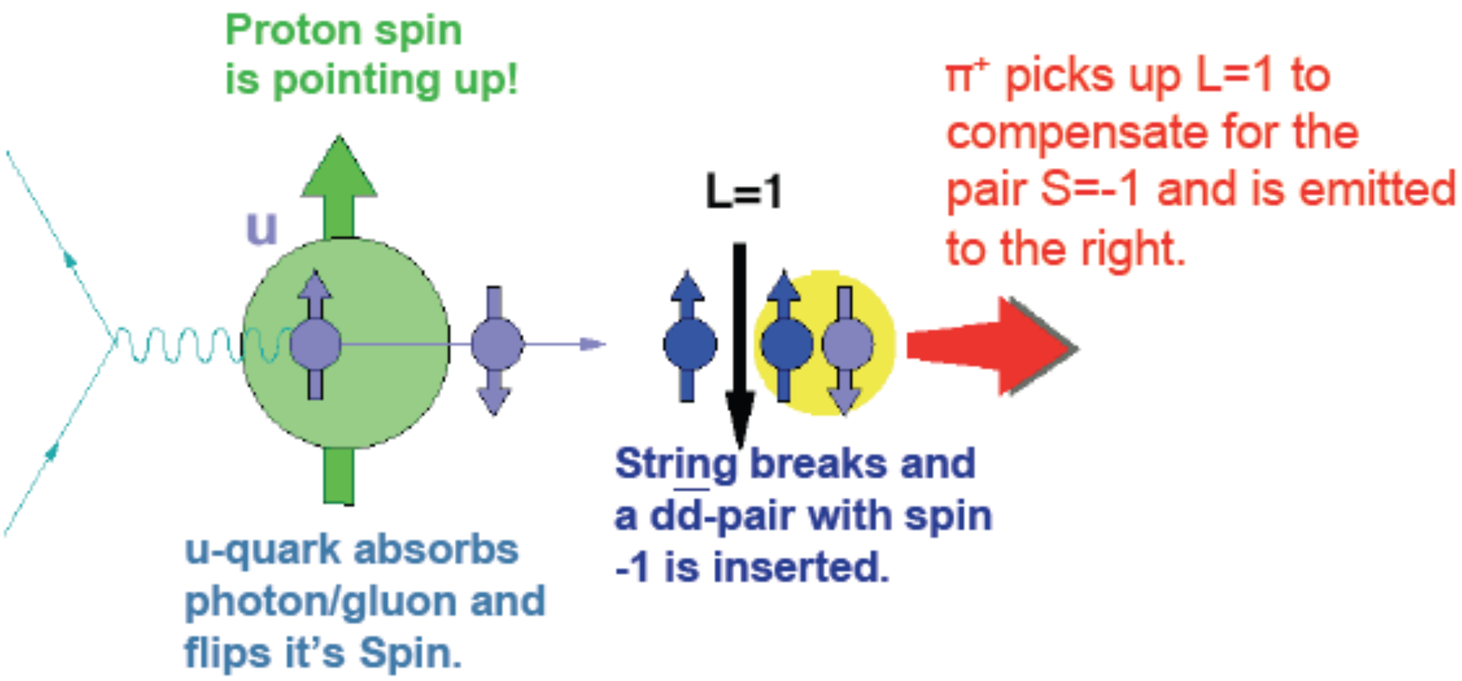
EIC スケジュール

- 2019–Dec.: CD0 Approval
- 2020–Jan.: Site Selection at BNL
- 2020: EICUG Yellow Report (physics/Detector)
- 2020–Nov.: Expression of Interest
- 2021: 3 Call for Detector Proposal
  - ATHENA
  - ECCE
  - CORE
- 2021–July: CD1 Approval
- 2021–Mar.: Decision on Detector(s)
- 2023: CD2?
- 2024: CD4?

スピンBackup

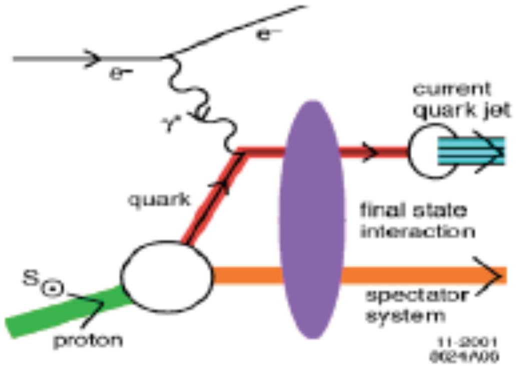
The Collins Effect in the Artru Fragmentation Model

A simple model to illustrate that spin-orbital angular momentum coupling can lead to left right asymmetries in spin-dependent fragmentation:

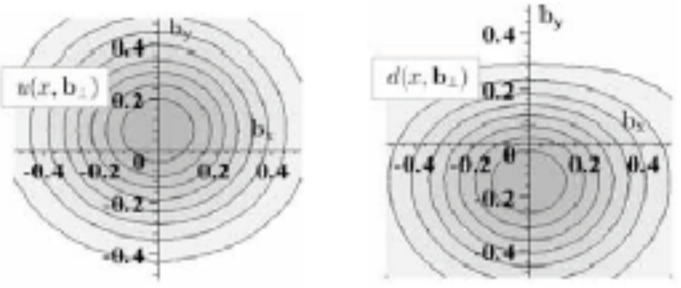


Naïve Sivers Interpretation

Sivers effect is an interference with a final state interaction of quark with spectator system.



(Int.J.Mod.Phys.A18:1327-1334,2003)
M. Burkardt



(Nucl.Phys. A735 (2004) 185-199)

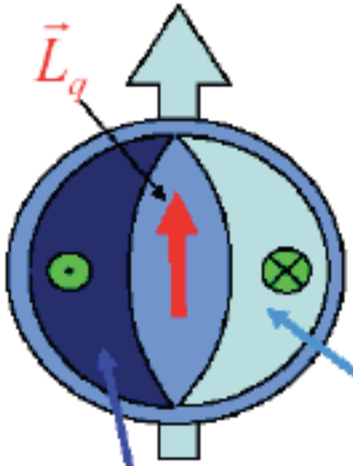
Can be understood as soft-gluon exchange in final state.

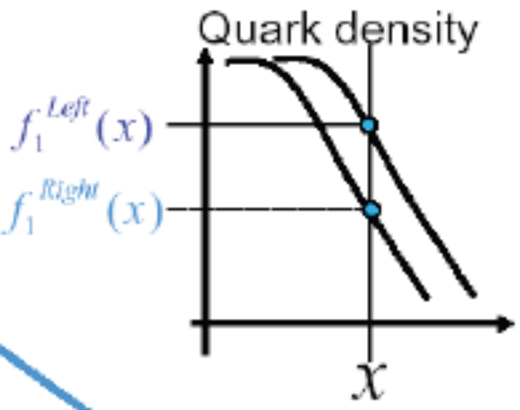
Sivers effect generates single spin asymmetries scattered off transversely polarized target.

Sivers effect and Orbital Angular Momentum

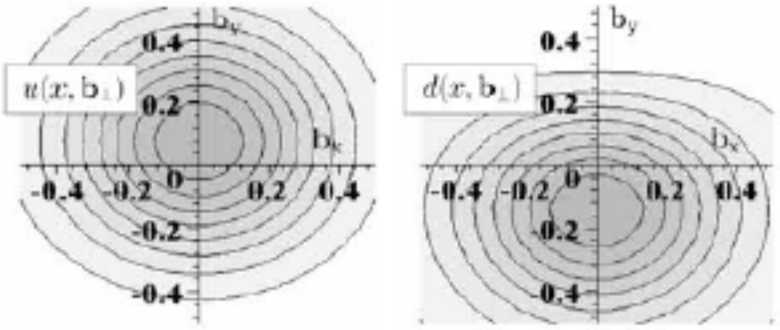
Semi-classical picture :

If quarks have L_q , probability to find quark which carries momentum fraction of “x” is different between left & right sides in the nucleon (viewed from virtual photon).





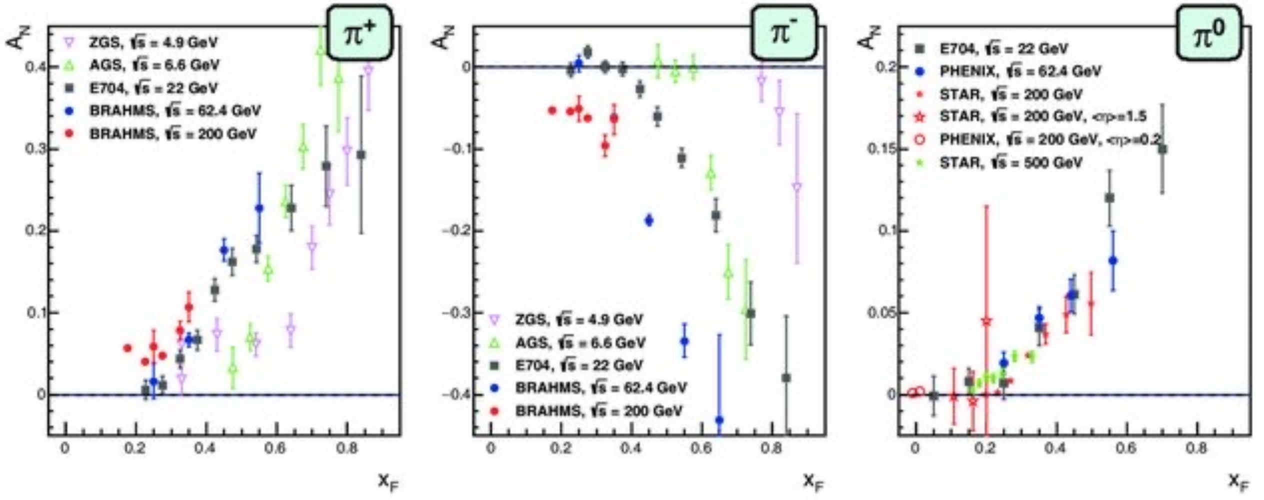
$$\boxed{f_1^{Left}(x)} < \boxed{f_1^{Right}(x)}$$

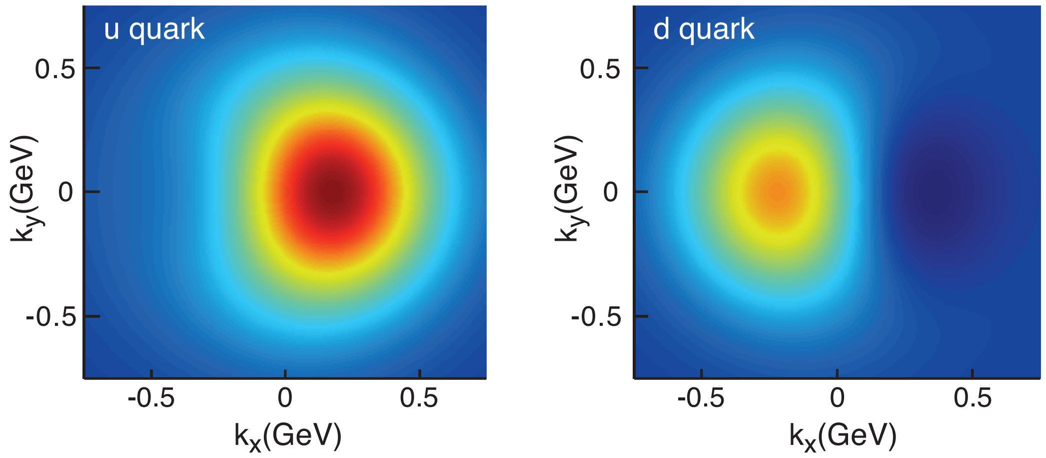


M. Burkardt
(Nucl.Phys. A735 (2004) 185-199)

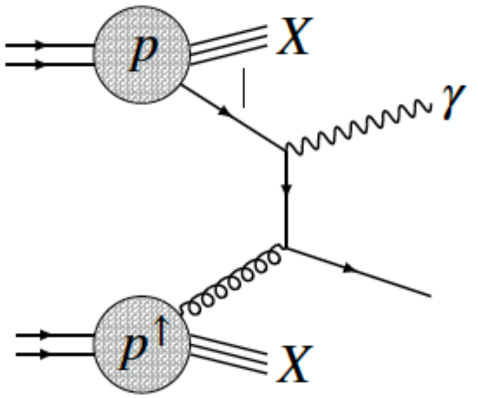
→ Sivers function can be viewed an impact-parameter dependent PDF.

Single Spin Asymmetry



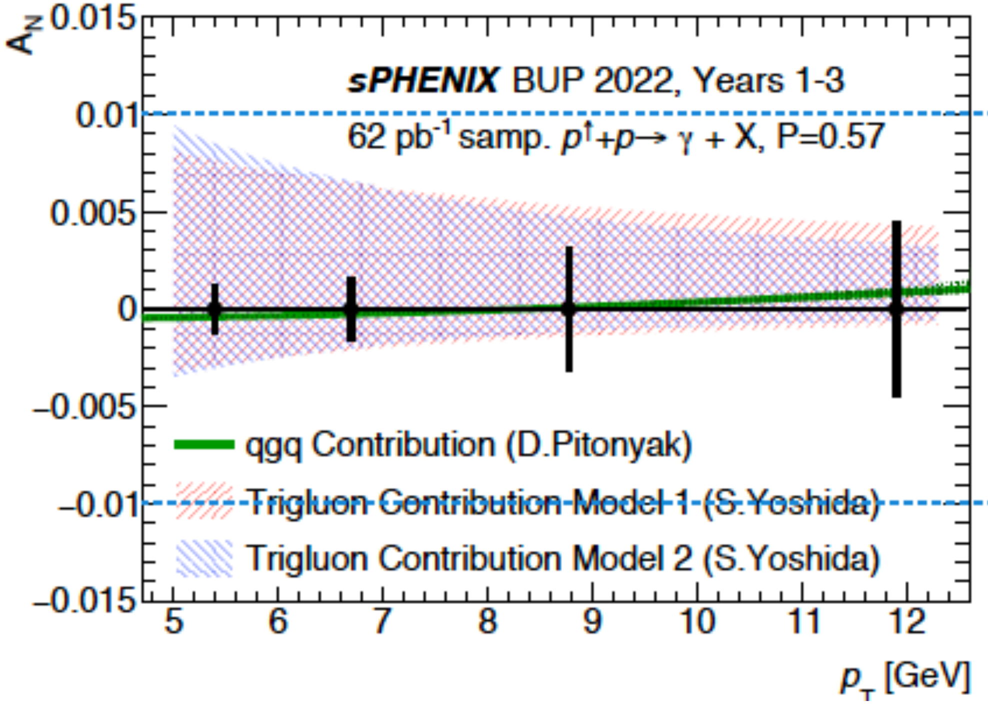


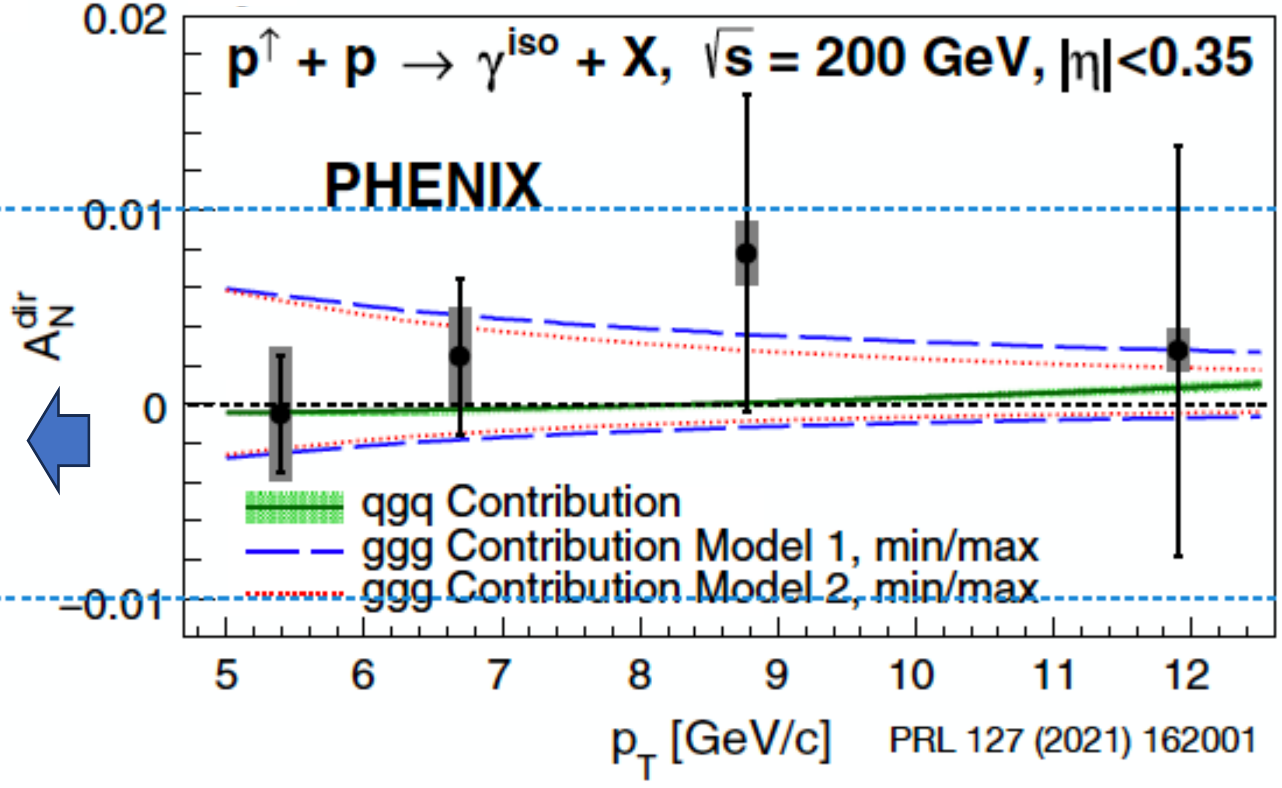
Cold QCD : Gluon TMD with Direct photons



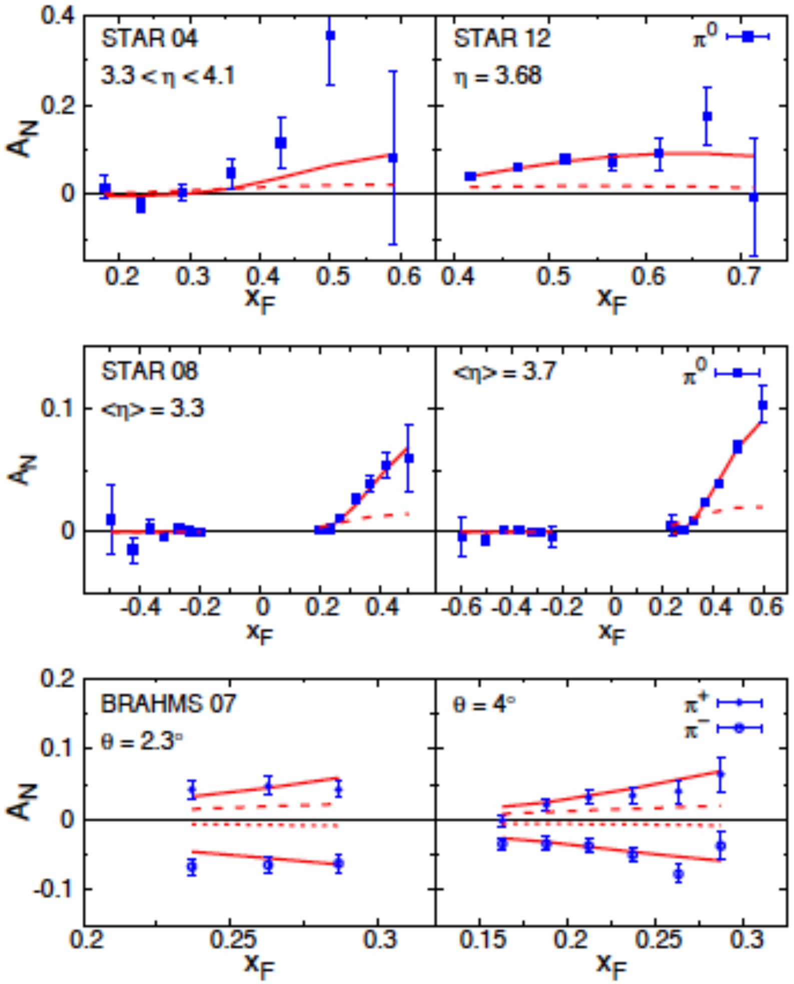
$$p^{\uparrow} + p \rightarrow \gamma + X$$

Much improved direct photon TSSA -> gluon TMD





Collins dominate?



A_N from twist-3 fragmentation functions (Kanzawa, Koike, Metz, Pitoniak, arXiv:1404.1033)

Describes data well !