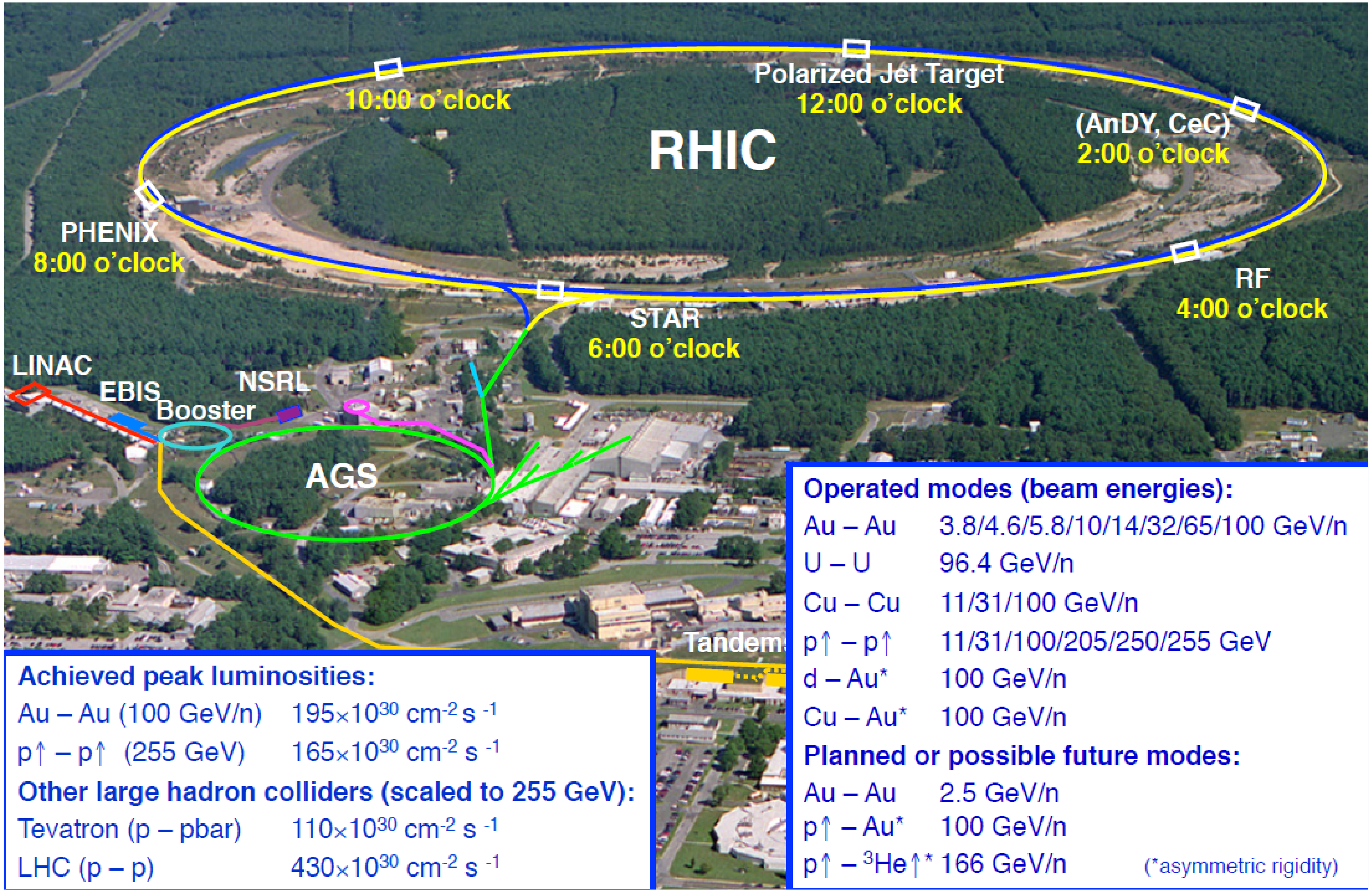
RHIC加速器の状況

ゼロ度粒子生成ミニ研究会
＠理研仁科ホール
２０１２年１０月３日（水）

後藤雄二（理研）

RHIC加速器

RHIC – a High Luminosity Polarized Hadron Collider

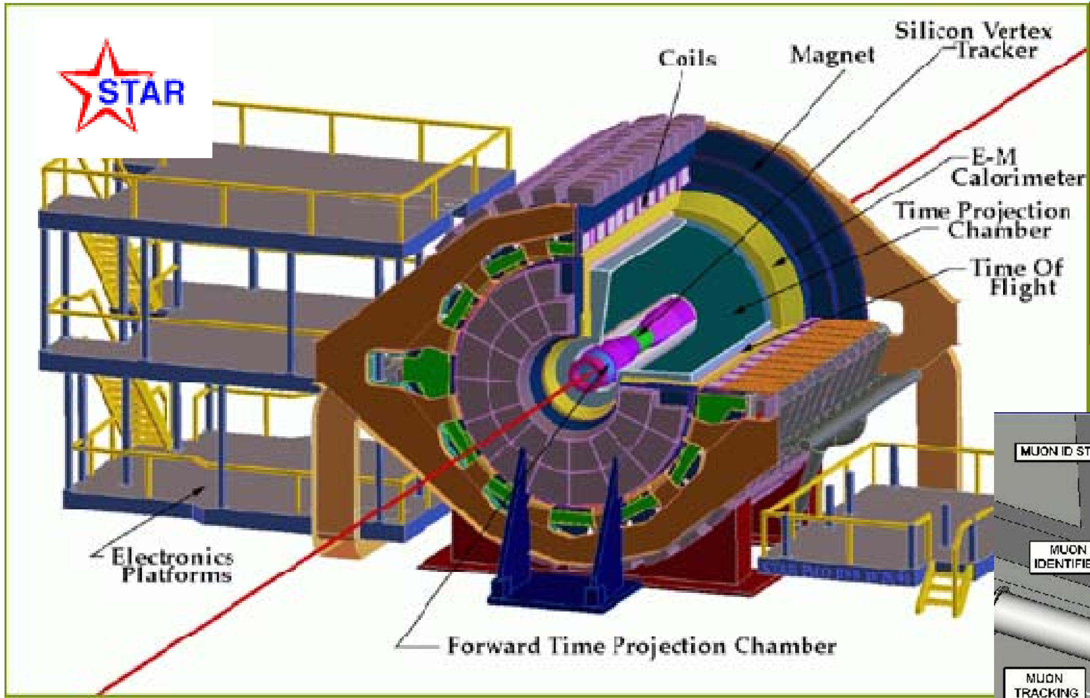


Achieved peak luminosities:	
Au – Au (100 GeV/n)	195×10^{30} cm^{-2} s^{-1}
p↑ – p↑ (255 GeV)	165×10^{30} cm^{-2} s^{-1}
Other large hadron colliders (scaled to 255 GeV):	
Tevatron (p – pbar)	110×10^{30} cm^{-2} s^{-1}
LHC (p – p)	430×10^{30} cm^{-2} s^{-1}

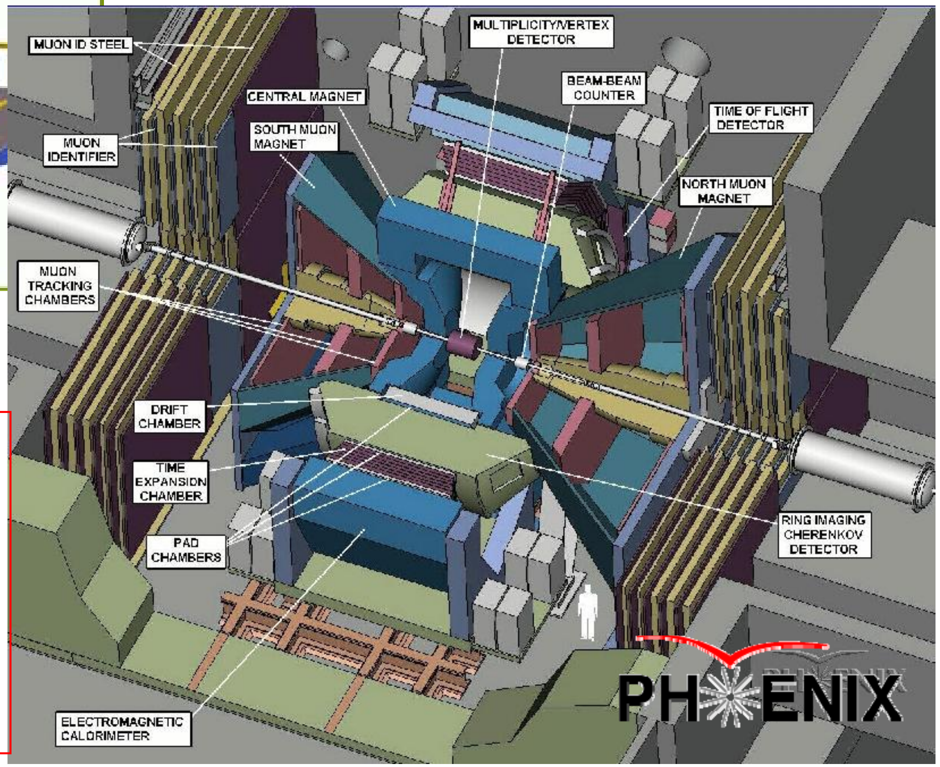
Operated modes (beam energies):	
Au – Au	3.8/4.6/5.8/10/14/32/65/100 GeV/n
U – U	96.4 GeV/n
Cu – Cu	11/31/100 GeV/n
p↑ – p↑	11/31/100/205/250/255 GeV
d – Au*	100 GeV/n
Cu – Au*	100 GeV/n
Planned or possible future modes:	
Au – Au	2.5 GeV/n
p↑ – Au*	100 GeV/n
p↑ – ^{3}He↑*	166 GeV/n

(*asymmetric rigidity)

RHIC実験



- STAR detector
  - 2π coverage for jet measurement
  - barrel TPC and EMC
  - endcap EMC



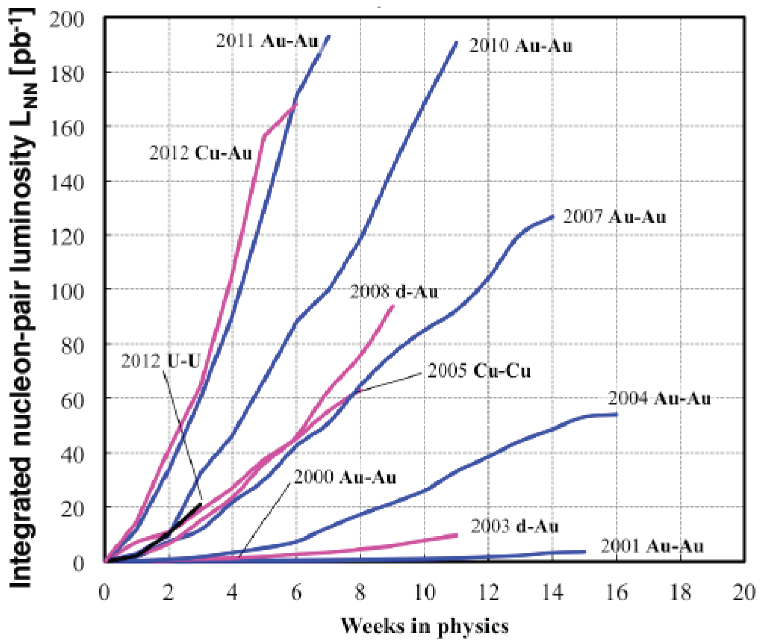
- PHENIX detector
  - limited acceptance
  - high resolution central EMCal
  - high-rate trigger and DAQ
  - forward muon detectors

RHICの稼動実績

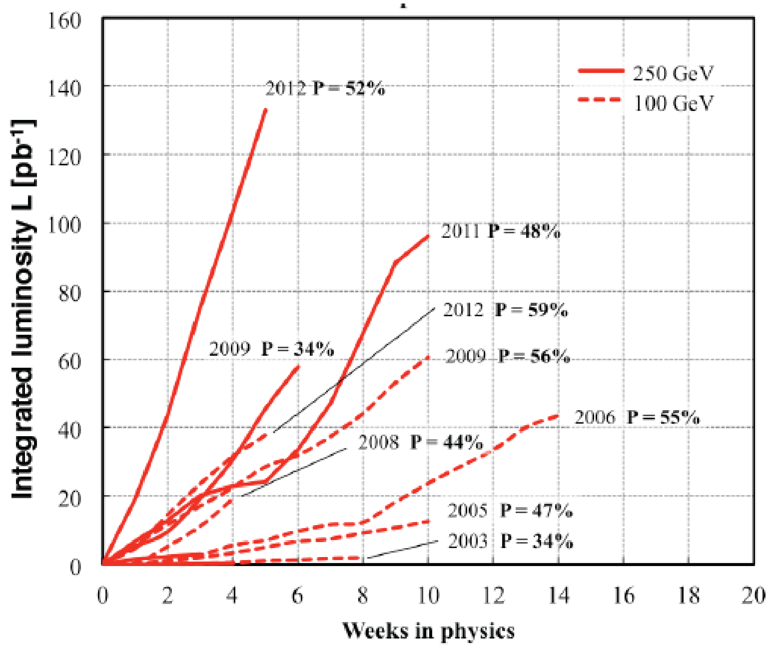
3

RHIC Integrated Luminosity and Polarization (RHIC II performance!)

Heavy ion runs



Polarized proton runs



- Further upgrades:
  - 56 MHz SRF system to reduce vertex length
  - Electron lenses to ~ double pp luminosity
  - Polarization goal: 70 %

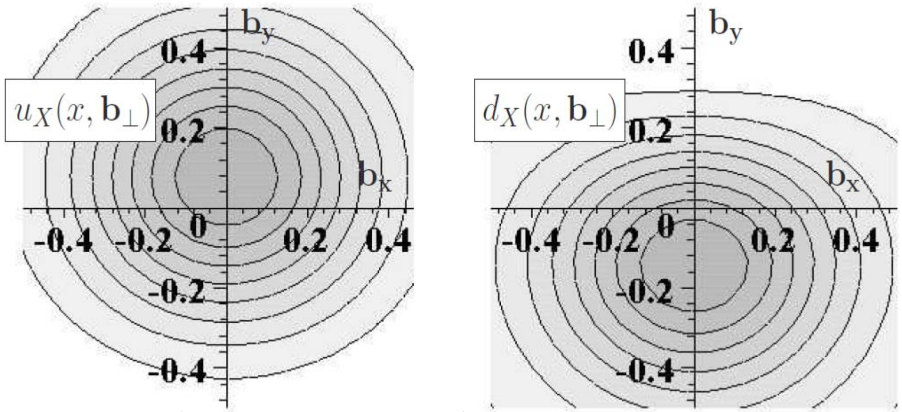
Nucleon-pair luminosity: luminosity calculated with nucleons of nuclei treated independently; allows comparison of luminosities of different species; appropriate quantity for comparison runs.

RHIC偏極陽子衝突実験

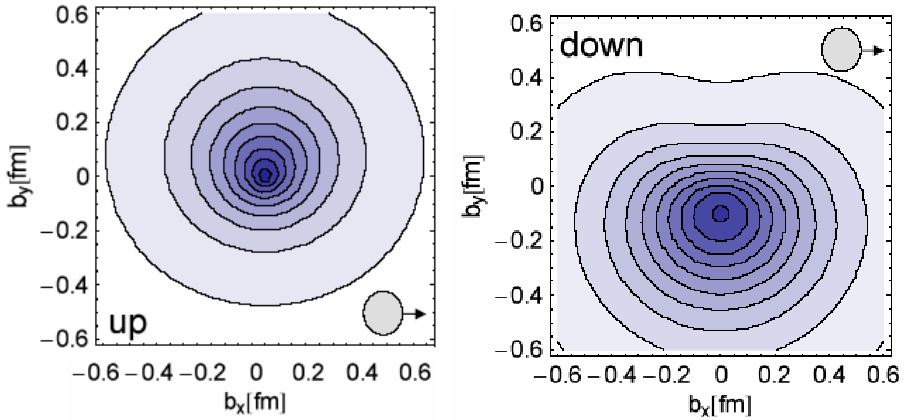
- マイルストーン
  - 縦偏極
    - グルーオンの偏極
    - W-boson非対称度
  - 横偏極
    - DIS実験との比較

Year	#	Milestone
2013	HP8	Measure flavor-identified q and $\overline{q}$ contributions to the spin of the proton via the longitudinal-spin asymmetry of W production.
2013	HP12 (update of HP1, met in 2008)	Utilize polarized proton collisions at center of mass energies of 200 and 500 GeV, in combination with global QCD analyses, to determine if gluons have appreciable polarization over any range of momentum fraction between 1 and 30% of the momentum of a polarized proton.
2015	HP13 (new)	Test unique QCD predictions for relations between single-transverse spin phenomena in p-p scattering and those observed in deep-inelastic lepton scattering.

- 将来計画
    - 横運動量(k_T)依存性
    - 空間分布(トモグラフィー)



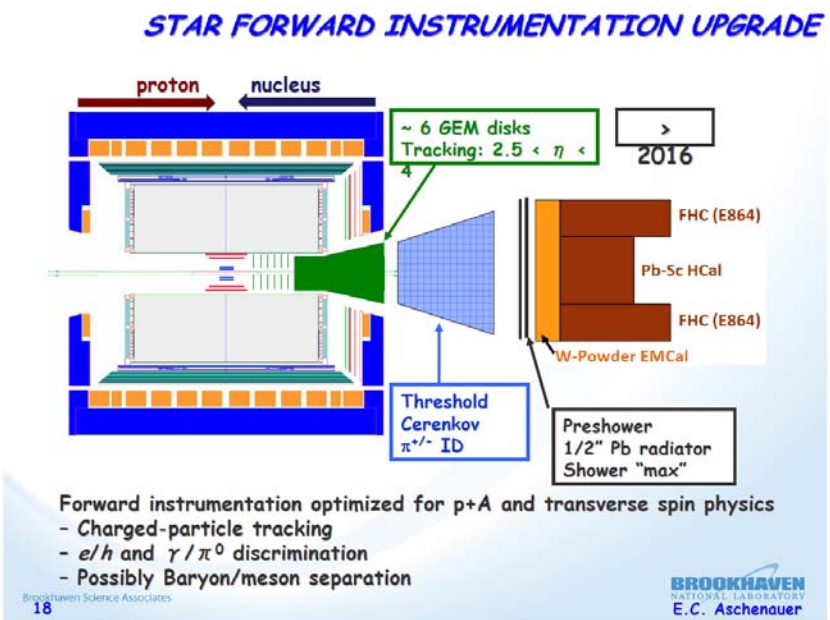
一般化された分布関数を用いた
現象論的模型

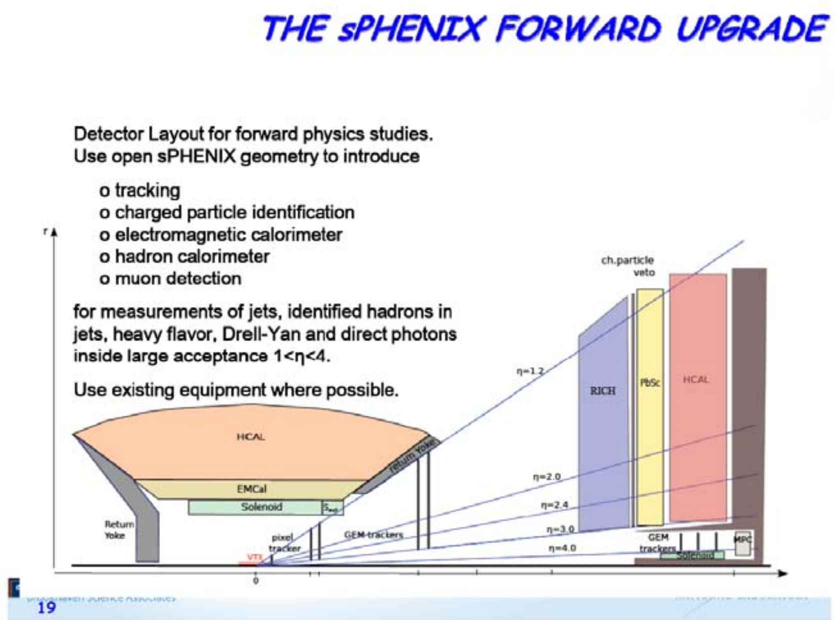


Lattice QCD 計算

RHIC偏極陽子衝突実験

- 将来計画
  - 核子構造の多次元での記述
    - 横運動量(k_T)依存性
      - Transverse-momentum dependent (TMD) 分布関数
        - » Drell-Yan反応の測定
    - 空間分布(トモグラフィー)
      - Generalized parton distribution (GPD)
        - » Deeply-Virtual Compton Scatteringの測定@eRHIC
        - » 偏極pA/dA?

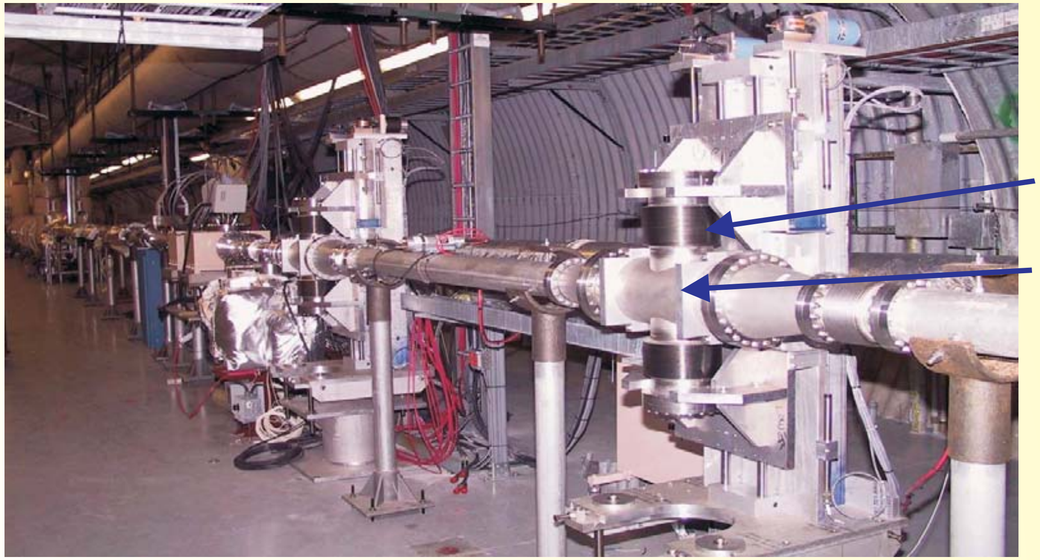


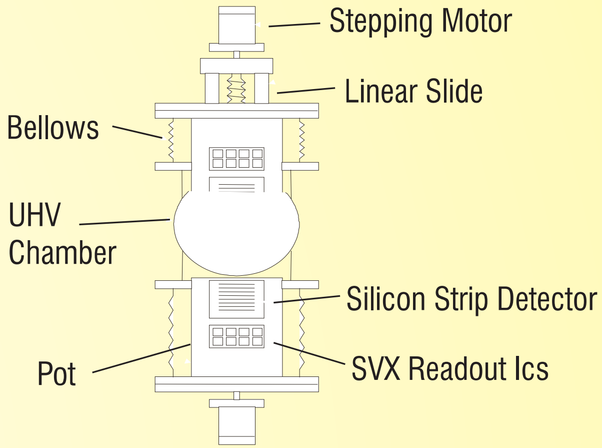


RHIC での前方粒子生成

- Roman-Pot（最前方陽子）

Roman Pot Stations





Roman Pot Detector System

The Detector System consists of cylindrical vessels called Roman Pots that house the detectors and can be inserted into the vacuum for data taking and retracted during beam fills. The vertical position of the pots is measured to a precision of 25 um. During experimental running the pots were moved to within 15 mm $\approx 15\sigma$ of the beam.

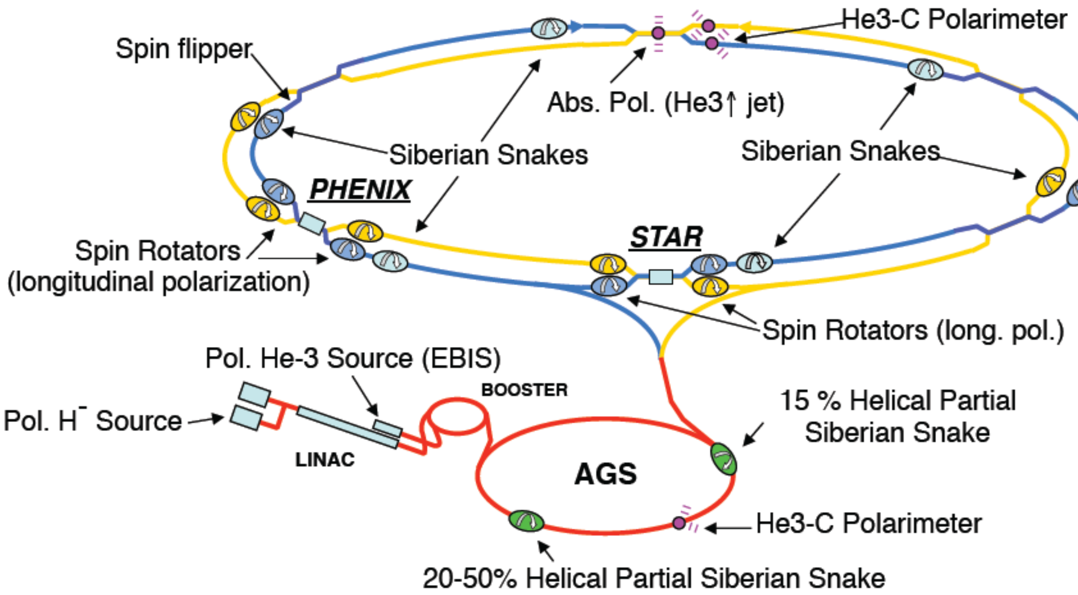
RHIC での前方粒子生成

- 偏極Helium-3

13

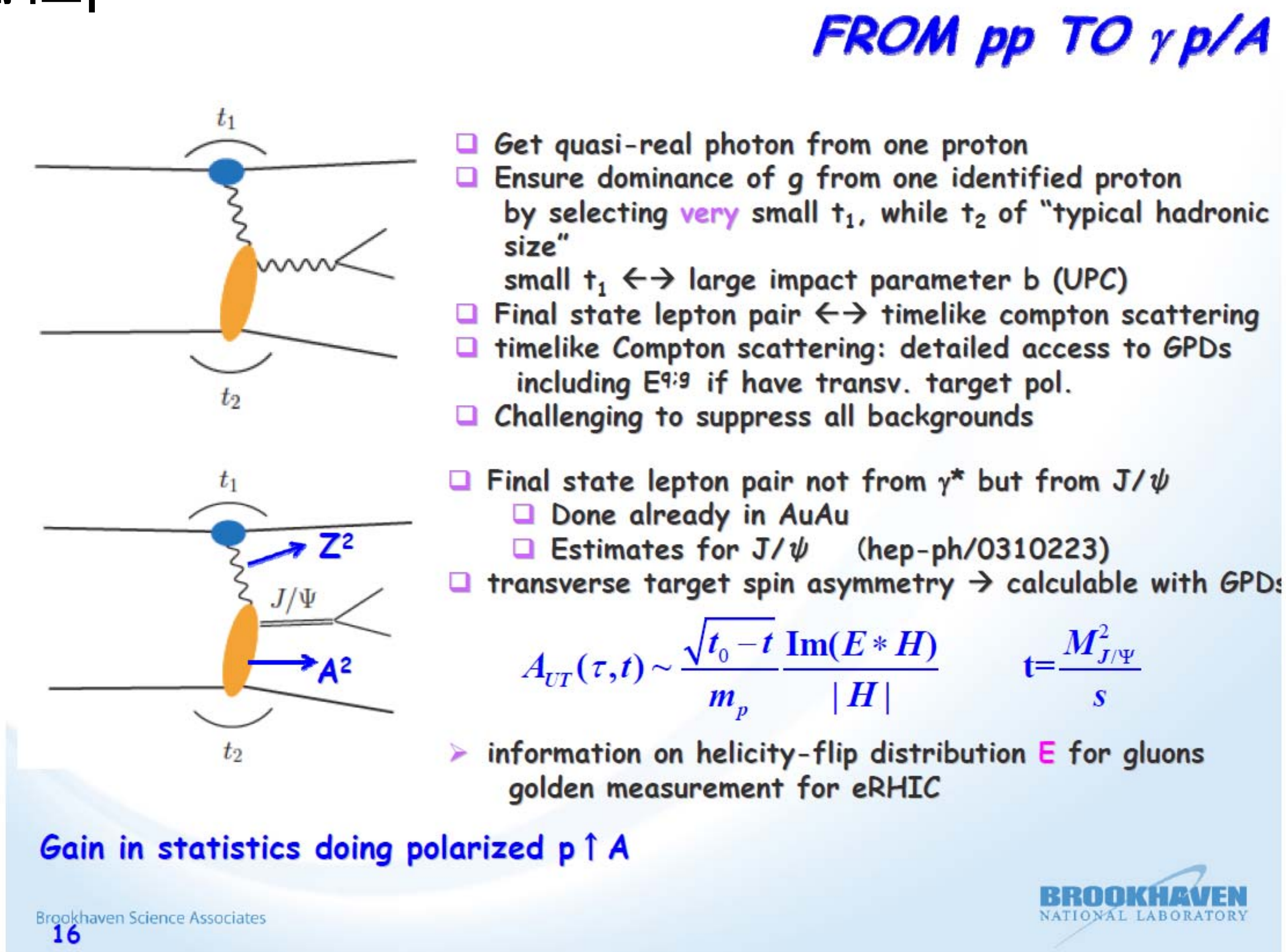
Polarized ^{3}He in RHIC

- Polarized ^{3}He possible from new EBIS (J. Maxwell, Tue., 3:30 pm)
- Max. energy in RHIC: 170 GeV/n
- Depolarizing res. are stronger, however no depolarization expected with six snakes in RHIC
- Accelerated unpolarized ^{3}He from EBIS in AGS
- Relative pol.: ^{3}He-C CNI polarimeter; successfully tested with unpolarized ^{3}He
- Absolute pol.: ^{3}He-^{3}He CNI polarimeter using polarized ^{3}He jet?



RHICでの前方粒子生成

- 偏極pA/dA



Run13（及びRun14）

For example, 20 weeks of RHIC refrigerator operation in FY 2012 could be scheduled in the following way:

Cool-down from 50 K to 4 K	1 week
Set-up mode 1 (pp2pp)	1 ½ week (no dedicated time for experiments)
Data taking mode 1	½ week
Set-up mode 2 (p↑-p↑ at 255 GeV)	½ week (no dedicated time for experiments)
Ramp-up mode 2	1 weeks (8 h/night for experiments)
Data taking mode 2 with further ramp-up	12 weeks
Set-up mode 3 (Au-Au at 7.5 GeV/nucleon)	½ week (no dedicated time for experiments)
Data taking mode 3 with further ramp-up	2 ½ weeks
Warm-up	½ week

PHENIX beam use proposal

Species	$\sqrt{s_{NN}}$ (GeV)	weeks	|z|<30cm	|z|<10cm	delivered	Polariz.
Run13:						
p+p	500	10-15	250 pb^{-1}	97 pb^{-1}	~750 pb^{-1}	55%
p+p	200	4	16 pb^{-1}	> 5.5 pb^{-1}	48 pb^{-1}	60%
or p+p	*39*	*1*	*0.2-0.3 pb^{-1}*		*0.9 pb^{-1}*	
Run-14:						
Au+Au	200	6-8	1.7 nb^{-1}	1 nb^{-1}	5 nb^{-1}	
d+Au	200	Rest of run				

43

PHENIX

STAR BUR for Runs 13 and 14

Run	*	Beam Energy	Time	System	Goals
13	3	$\sqrt{s}$ = 510 GeV	4 days	$p_\uparrow p_\uparrow$	σ_{TOT}, A_N, A_{NN}, A_{SS}, Exclusive Central Production
	1		10 weeks	$p_\rightarrow p_\rightarrow$	i) $W^\pm$ A_L: P^2*L= 50 pb^{-1} ii) di-jets A_{LL}: P^4*L= 15 pb^{-1}
	2	$\sqrt{s_{NN}}$ = 200 GeV	4 weeks	Au + Au	i) MTD e-μ correlation, 2 nb^{-1} (280M central events) ii) HFT engineering run
14	1	$\sqrt{s_{NN}}$ = 200 GeV	10 weeks	Au + Au	i) HFT & MTD heavy flavor, 10 nb^{-1}(500M M.B.) ii) Fixed-target data taking
	2	$\sqrt{s}$ = 200 GeV	5 weeks	$p_\rightarrow p_\rightarrow$	i) Heavy ion reference data L= 40 pb^{-1} (500M M.B.) ii) Δg, L= 40 pb^{-1}

Run 13: 20 cryo-week. 510pp: 55% polarization

Run 14: 20 cryo-week. 200pp: 65% polarization

* Physics priorities

Nu Xu BNL PAC, June 7 - 8, 2012 43/43

RHIC加速器の状況

- 今後の予定
  - 新偏極イオン源
  - 電子レンズ
  - 偏極Helium-3
  - 偏極pA/dA
  - Coherent electron cooling (CeC)
  - eRHIC

Table 3. *Approximate timeline for next-decade RHIC science program. The science goals are illustrative; many others will also be pursued with same colliding beam species and energies. Species, goals and subsystems in blue are aimed primarily at the cold nuclear matter program.*

Years[a)]	Beam Species and Energies	Science Goals	New Systems Commissioned	Comments
2013	500 GeV $\vec{p}+\vec{p}$; 15 GeV Au+Au	Sea antiquark and gluon polarization; QCD critical point search	Electron lenses; upgraded pol'd source; STAR Heavy Flavor Tracker (HFT) prototype	15 GeV Au+Au completes phase 1 of beam energy scan
2014	200 GeV Au+Au and baseline data via 200 GeV p+p (needed for new det. subsystems)	Heavy flavor flow, energy loss, thermalization, etc.; quarkonium studies	56 MHz SRF; full HFT; STAR Muon Telescope Detector; PHENIX Muon Piston Calorimeter Extension (MPC-EX)	Separation of c and b-quarks now possible for both STAR & PHENIX; high-energy luminosity upgrade completed
2015-2017	High statistics Au+Au at 200 and ~40 GeV; U+U/Cu+Au at 1-2 energies; 200 GeV p+A; 500 GeV $\vec{p}+\vec{p}$	Precision extraction of $\eta/s(T)$ and constraints on initial quantum fluctuations; gluon densities and saturation (p+A); continued heavy flavor studies; sphaleron tests @ $\mu_B\neq0$; complete p+p W production program	Coherent Electron Cooling (CeC) test; Low-energy electron cooling; STAR inner TPC pad row upgrade	CeC test for eRHIC R&D; low-E electron cooling and STAR TPC upgrade ready by end of this period; p+A exploits MPC-EX
2018-2021	5-20 GeV Au+Au (beam energy scan phase 2); long 200 GeV + 1-2 lower energies Au+Au with upgraded dets.; 500 GeV $\vec{p}+\vec{p}$; 200 GeV $\vec{p}+A$; baseline data @ 200 GeV and lower energies	Order of magnitude increase in sensitivity to signals of QCD critical point and onset of deconfinement; jet, di-jet, γ-jet quenching probes of energy loss mechanism; color screening for different quarkonium states; transverse spin asymmetries for Drell-Yan and gluon saturation	sPHENIX; forward physics upgrades	Other collider upgrade options under consideration for this time period include: polarized ^{3}He beams; additional Siberian Snakes; higher frequency stochastic cooling

a) After roughly 2021, we envision the eRHIC construction era beginning.

RHIC加速器の状況

- Tribbleパネル