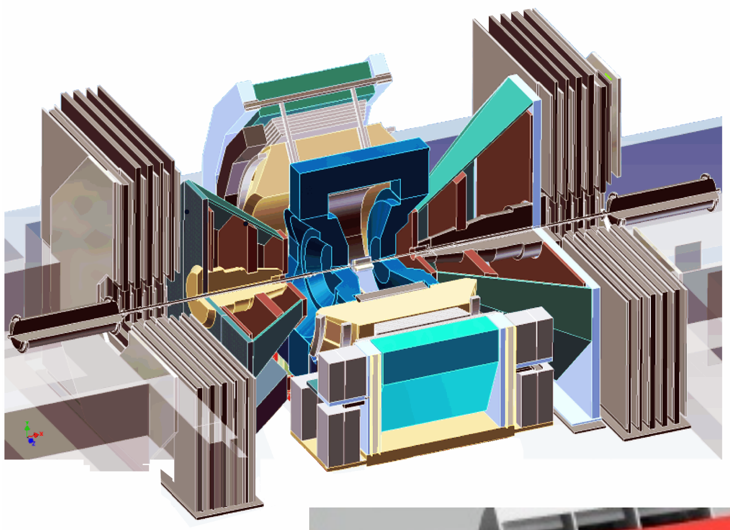
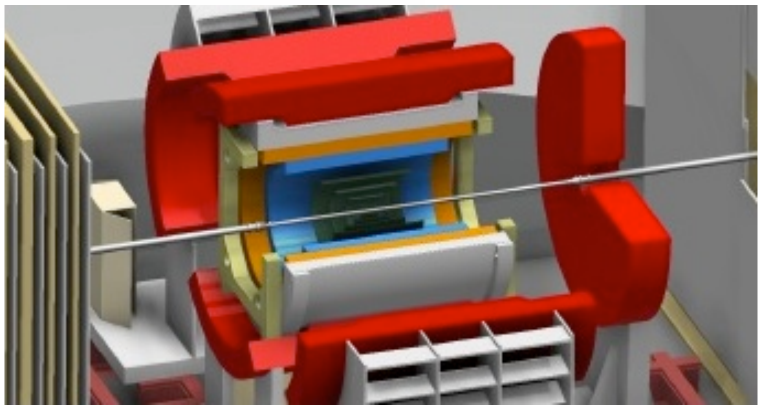
Recent results with photons and jets at RHIC and sPHENIX upgrade including pre-shower detector

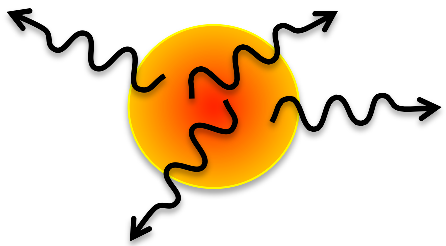
ShinIchi Esumi
Inst. of Physics, Univ. of Tsukuba

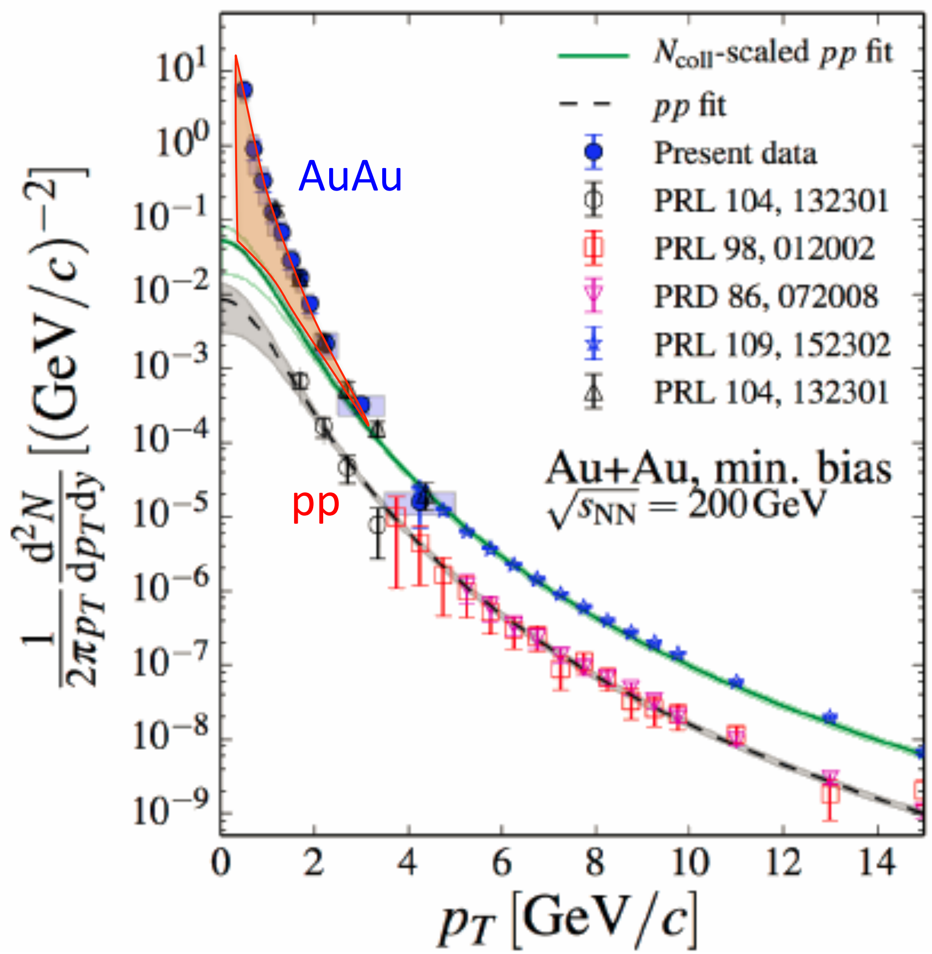




- recent results with γ, jet
- sPHENIX upgrade
- pre-shower detector
- simulations

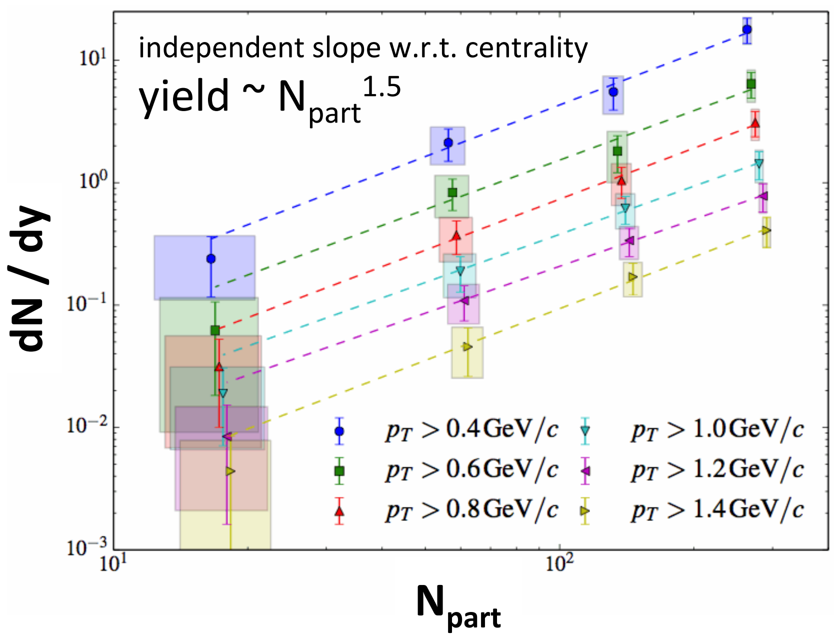
Enhanced thermal photon production at low p_T



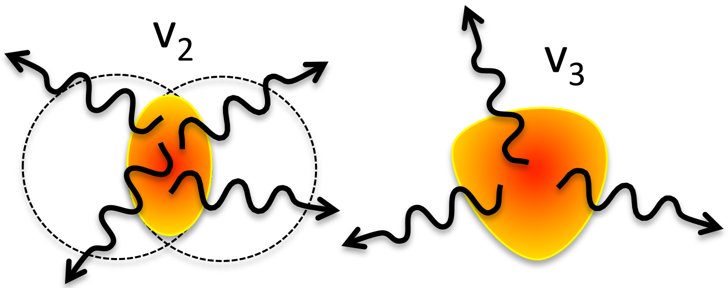


- Virtual and real photon measurements via internal and external conversion methods with electron pair measurements
- Real photon measurements with EMcal
- Initial temperature of 300~600MeV

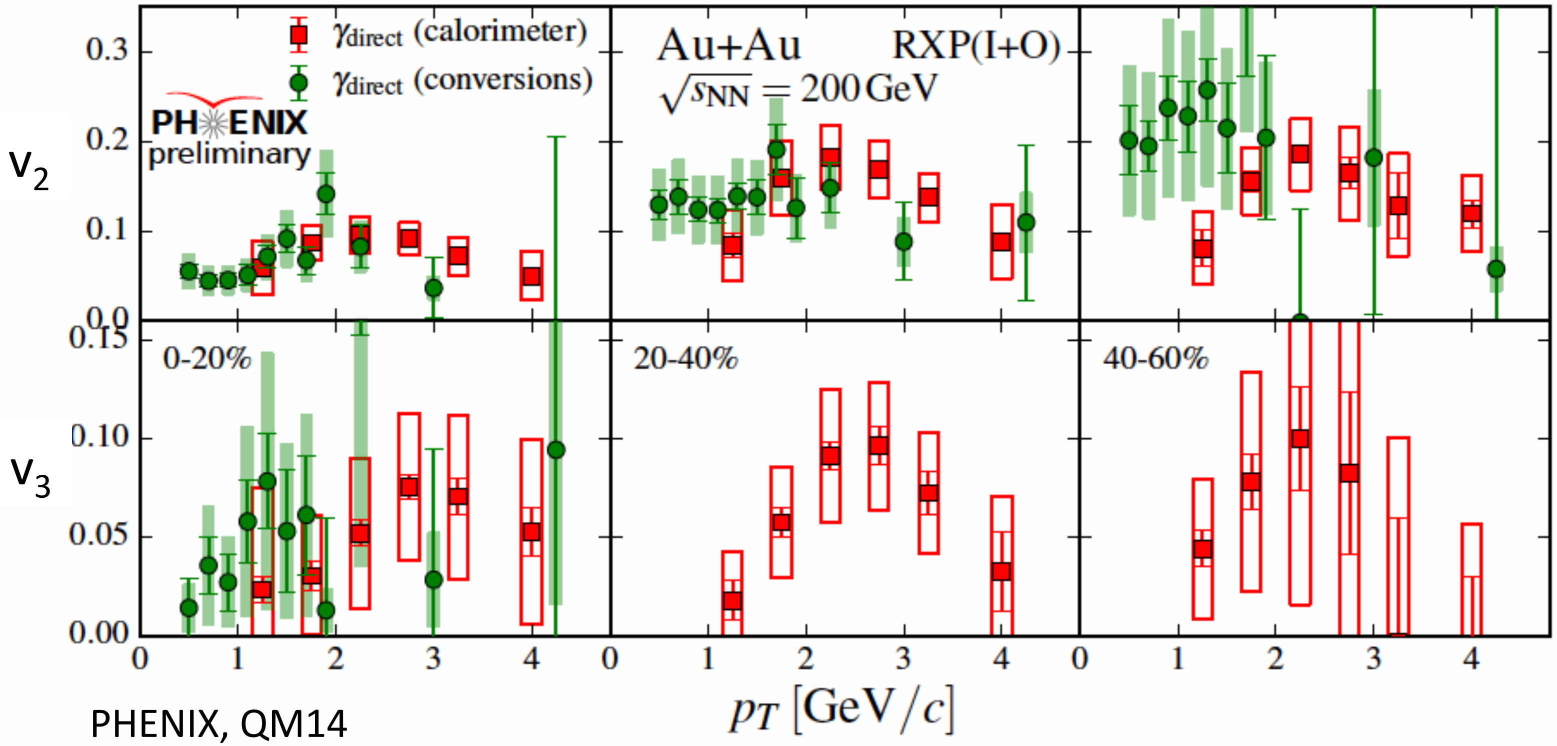
arXiv:1405.3940



Direct (thermal) photon v_2 and v_3



$v_n = < \cos n(\phi^{particle} - \Phi_n^{plane}) >$
(n=2 : elliptic flow), (n=3 : triangular flow)

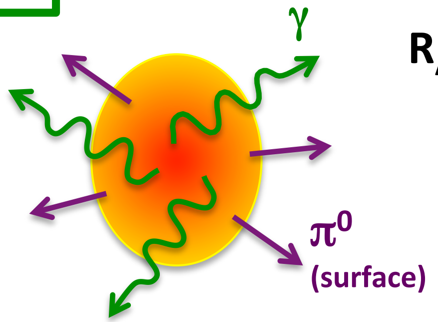


PHENIX, QM14

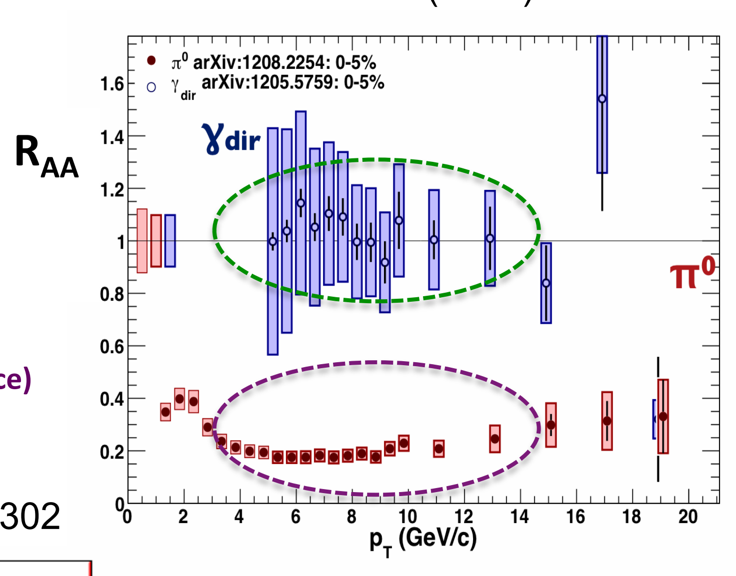
- comparable to hadron for both v_2 and v_3 at 2~3GeV/c
- significant contribution from photons from later stages (inconsistent with early photons from hotter period)
- flatter p_T dependence of v_2 at low p_T

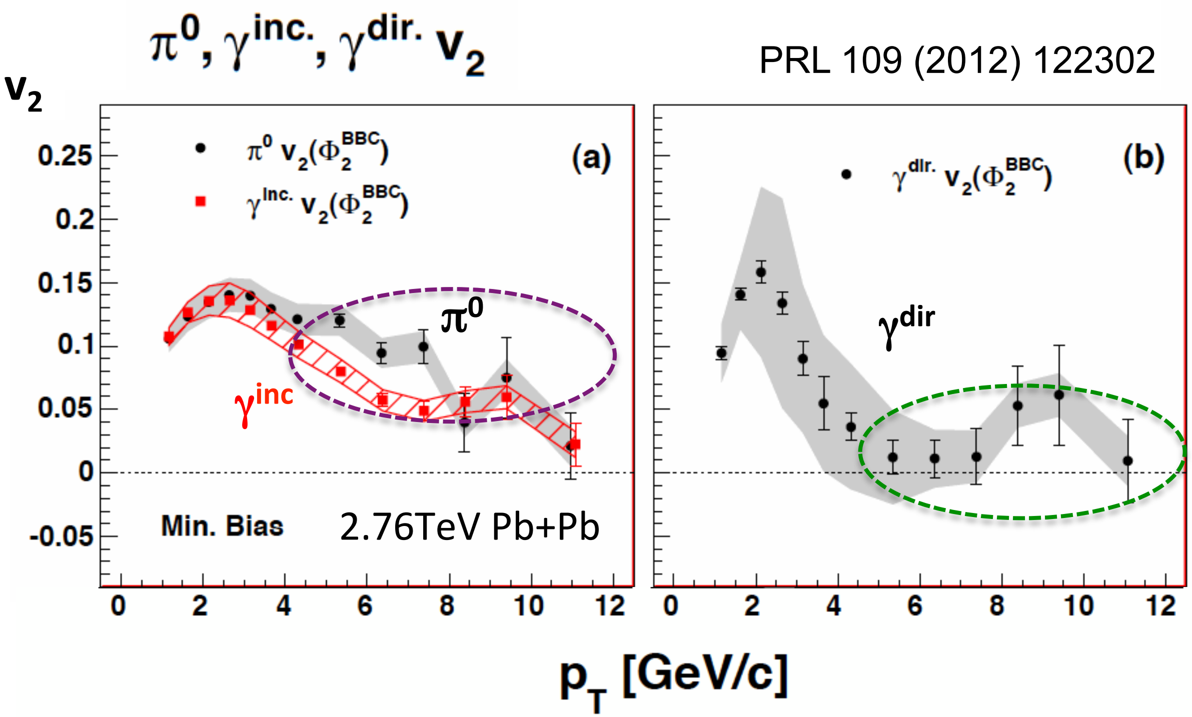
High p_T direct photon as penetrating probe

$p_T > 5$ GeV/c	hadron	γ^{dir}
R_{AA}	< 1	~ 1
v_2	> 0	~ 0



PRL 109 (2012) 152302





$$R_{AA} = \frac{N\,(A+A)}{N_{coll}\;N(p+p)}$$

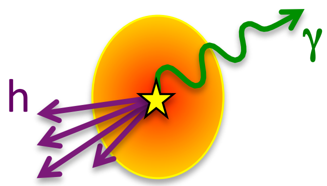
relative yield with respect to a simple independent superposition of pp data

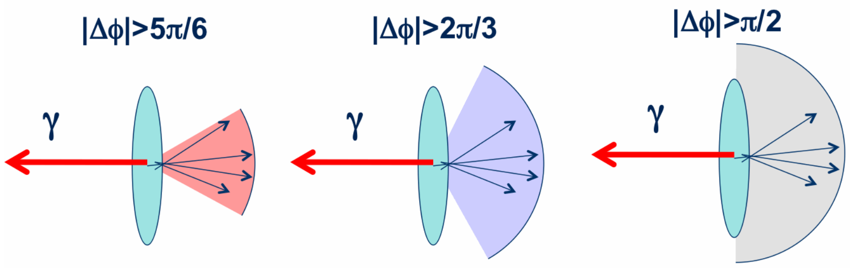
Energy loss at high p_T and re-distribution of the lost-energy at low p_T at RHIC

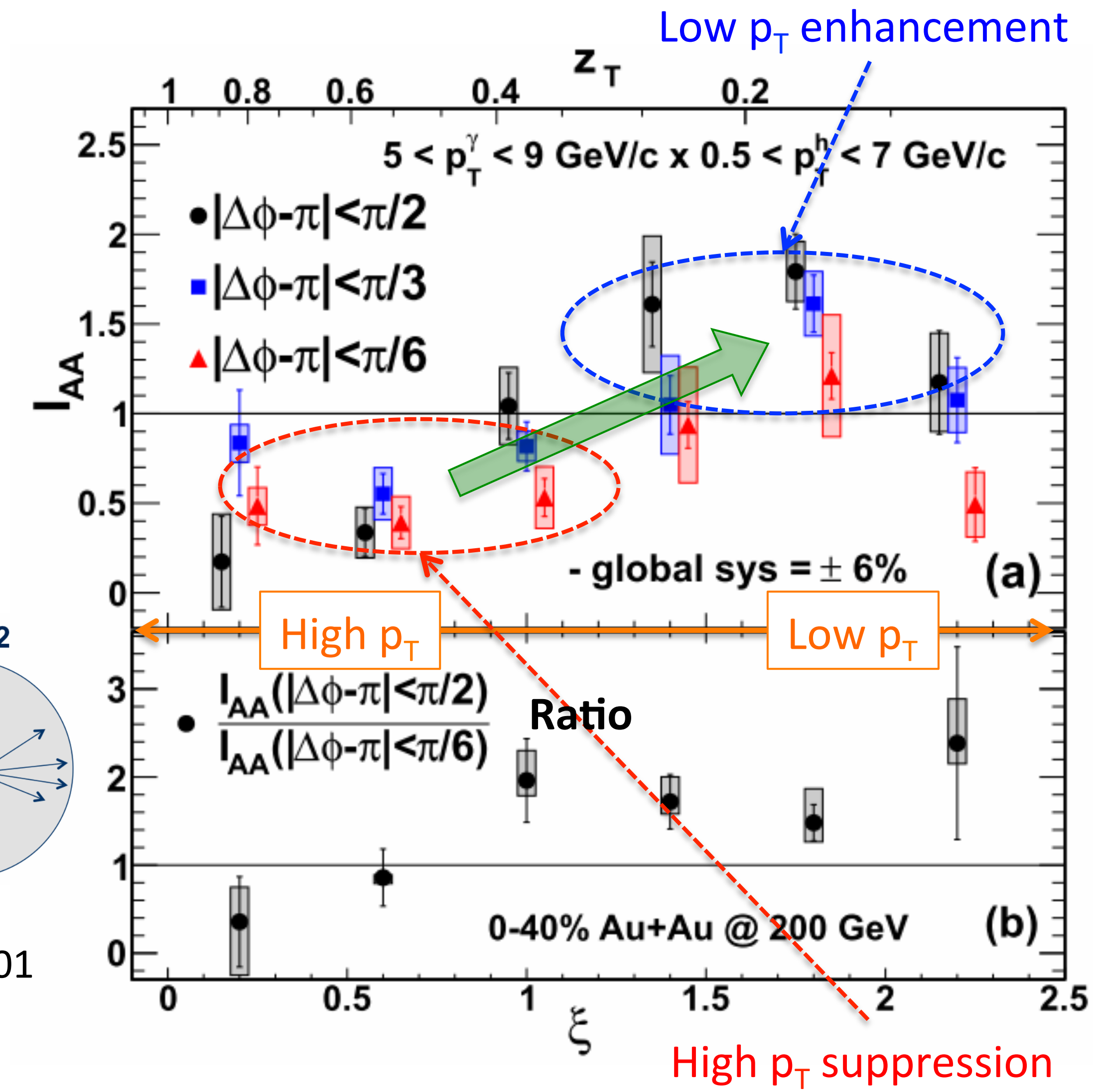
prompt photon - hadron correlation

N_{PTY} = associate hadron yield per trigger γ

$I_{AA} = N_{PTY}(AA) / N_{PTY}(pp)$





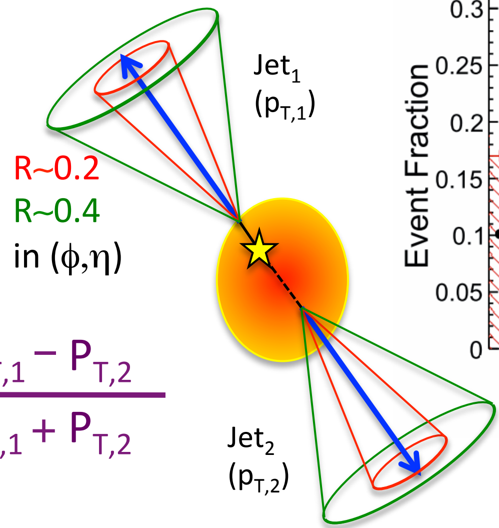


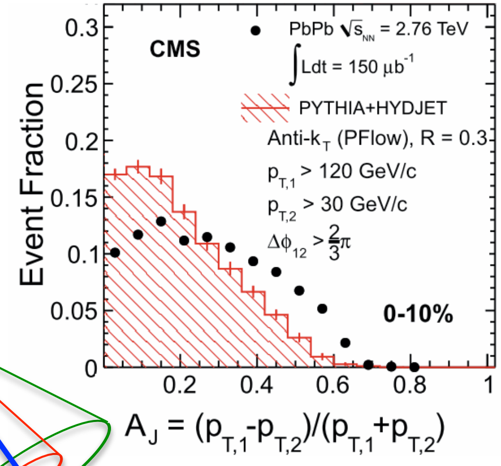
PRL 111 (2013) 032301

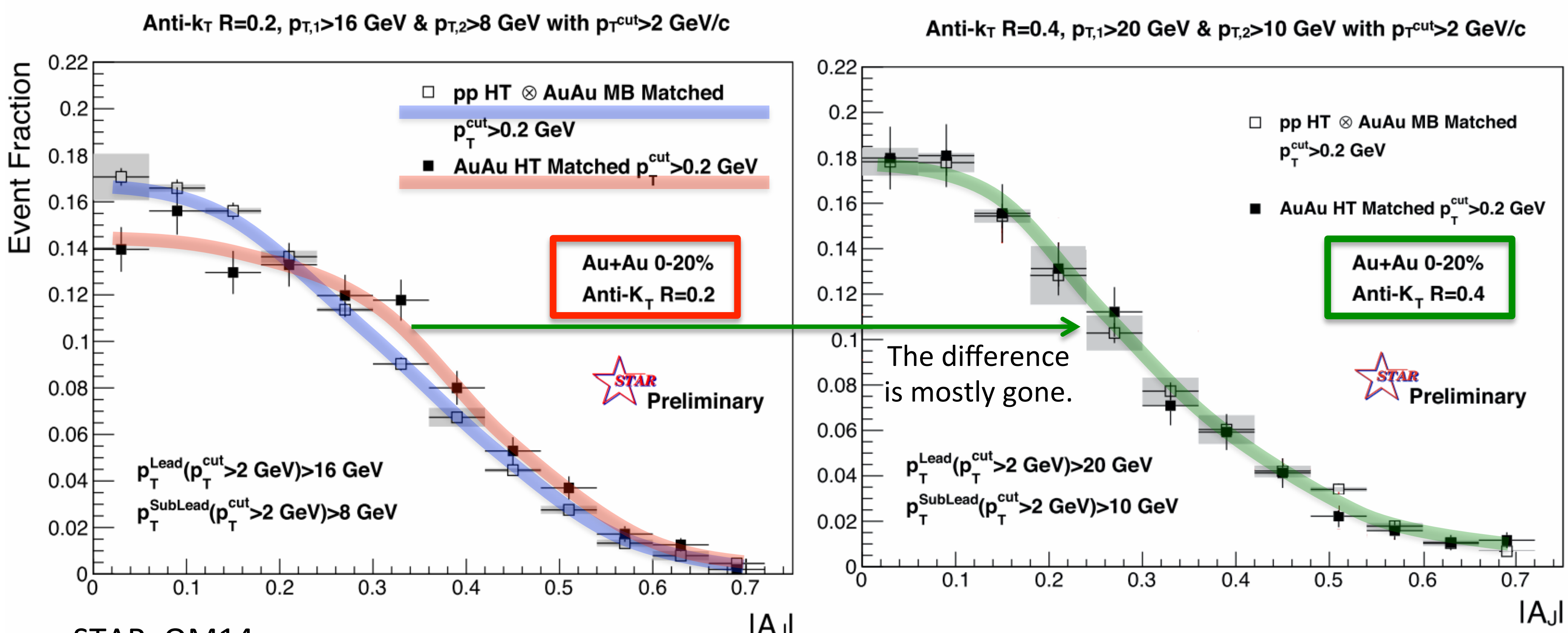
Jet quenching at RHIC vs LHC
(A_J : di-jet energy asymmetry)

- visible effect with smaller jet cone R~0.2 at RHIC
- lower jet energy than LHC, smaller effect than LHC
- mostly recovered jet energy within larger jet cone R~0.4
- Somewhat contradicting with large angle emission of low p_T particles (jet selection bias…)

$$A_J = \frac{P_{T,1} - P_{T,2}}{P_{T,1} + P_{T,2}}$$







STAR, QM14

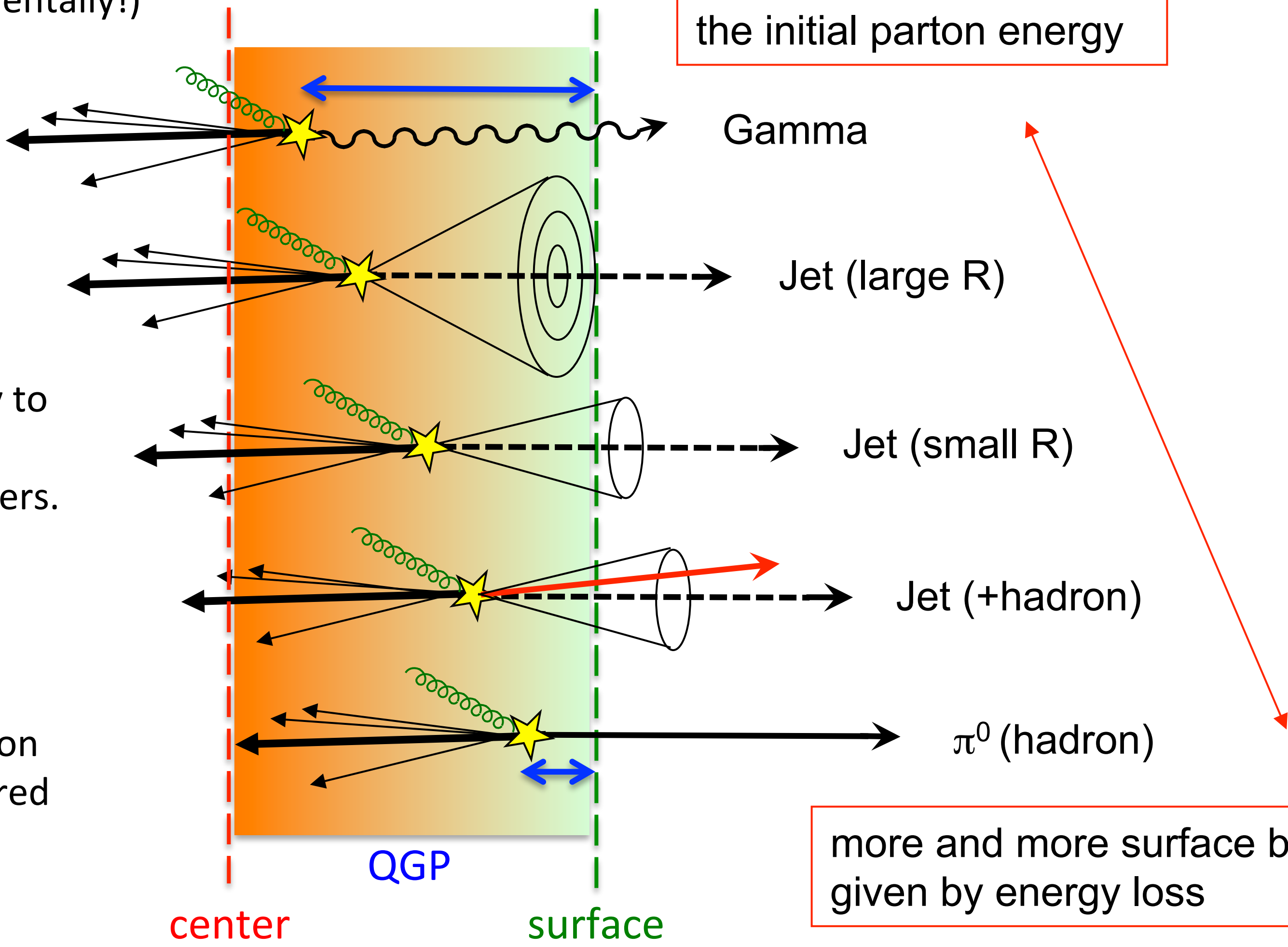
jet-suppression by partonic energy loss and/or modification of fragmentation function

(These two can not clearly be separated experimentally!)

Jet reconstruction is to recover the lost energy to get the original parton depending on parameters.

Jet as a control tool to define path length

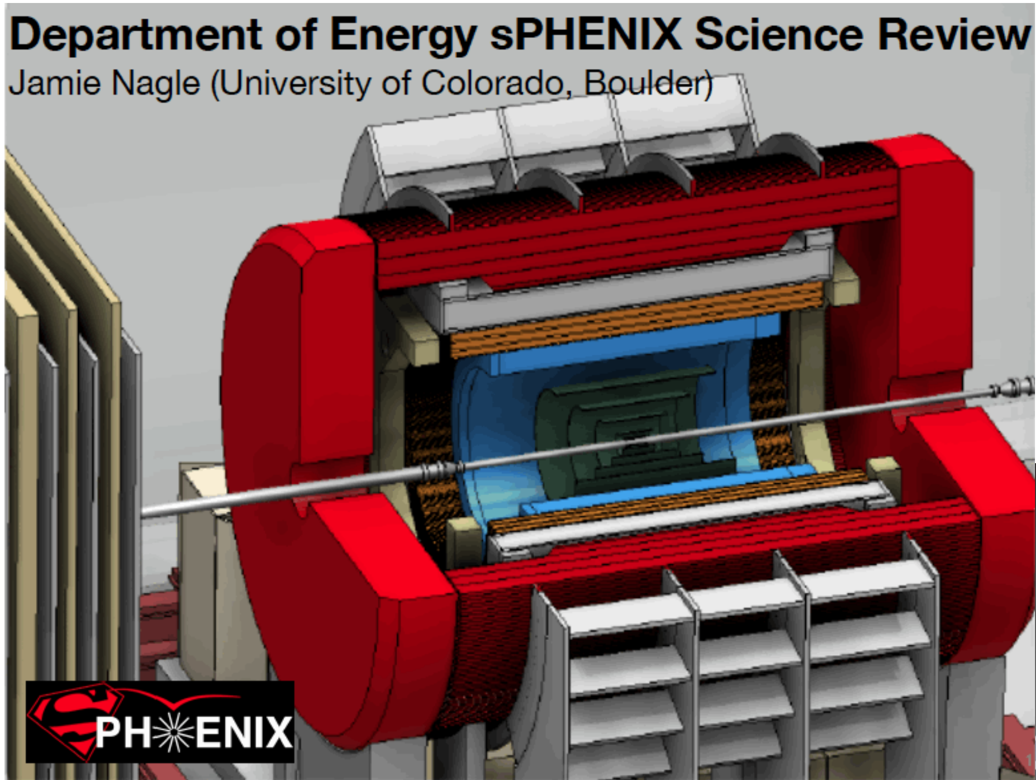
quark/gluon contribution should also be considered



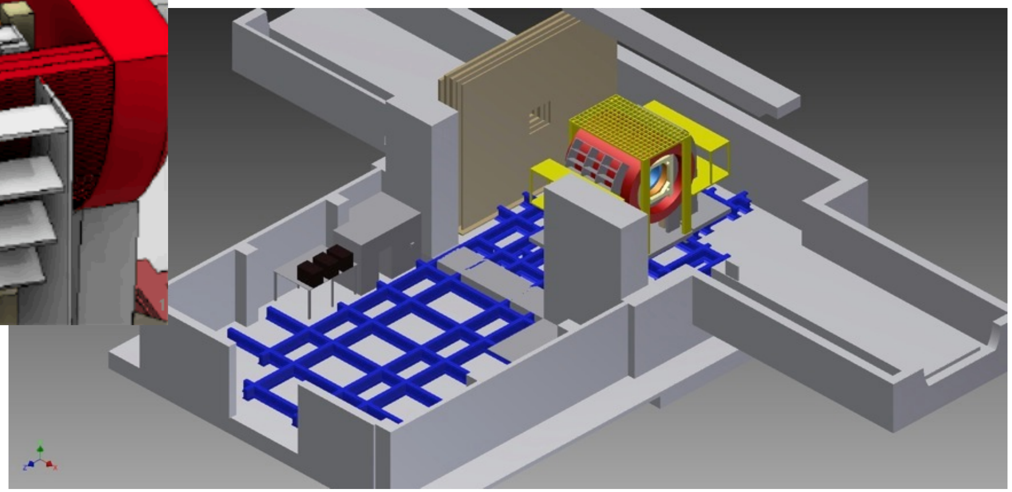
DOE review of sPHENIX science, 1-2/July/2014 at BNL

- Jet measurements
- Upsilon program
- B-jet tagging

Major Instrumentation and Equipment (MIE) proposal to be updated by Nov/2014

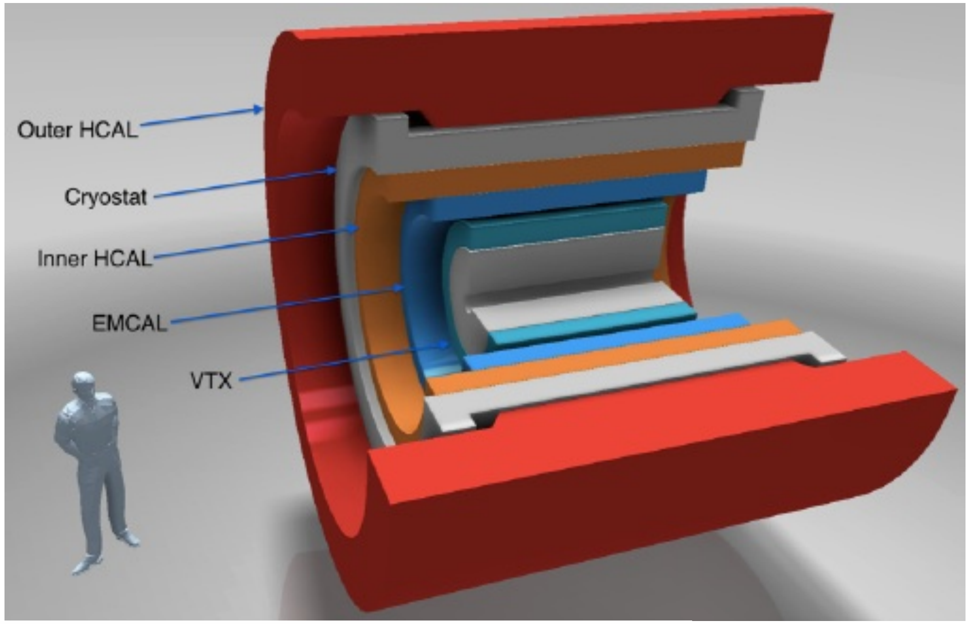


- EM+hadronic calorimetry over $|\eta| < 1.1$
- Re-use existing BaBar 1.5T solenoid
- Silicon tracking
- Pre-shower detector
- DAQ rate ~ 10 kHz



Years	Beam Species and Energies	Science Goals	New Systems Commissioned
2014	15 GeV Au+Au 200 GeV Au+Au	Heavy flavor flow, energy loss, thermalization, etc. Quarkonium studies QCD critical point search	Electron lenses 56 MHz SRF STAR HFT STAR MTD
2015-16	p+p at 200 GeV p+Au, d+Au, ^{3}He+Au at 200 GeV High statistics Au+Au	Extract η/s(T) + constrain initial quantum fluctuations More heavy flavor studies Sphaleron tests Transverse spin physics	PHENIX MPC-EX Coherent e-cooling test end of existing PHENIX detector
2017	No Run		Low energy e-cooling upgrade
2018-19	5-20 GeV Au+Au (BES-2)	Search for QCD critical point and onset of deconfinement	STAR ITPC upgrade Partial commissioning of sPHENIX (in 2019)
2020	No Run		Complete sPHENIX installation STAR forward upgrades
2021-22	Long 200 GeV Au+Au with upgraded detectors p+p, p/d+Au at 200 GeV	Jet, di-jet, γ-jet probes of parton transport and energy loss mechanism Color screening for different quarkonia	sPHENIX
2023-24	No Runs		Transition to eRHIC

Detector concept



Magnetic Solenoid solenoid built for the BaBar experiment at SLAC which became available after the termination of the BaBar program. The cryostat has an inner radius of 140 cm and is 33 cm thick, and can produce a central field of 1.5 T.

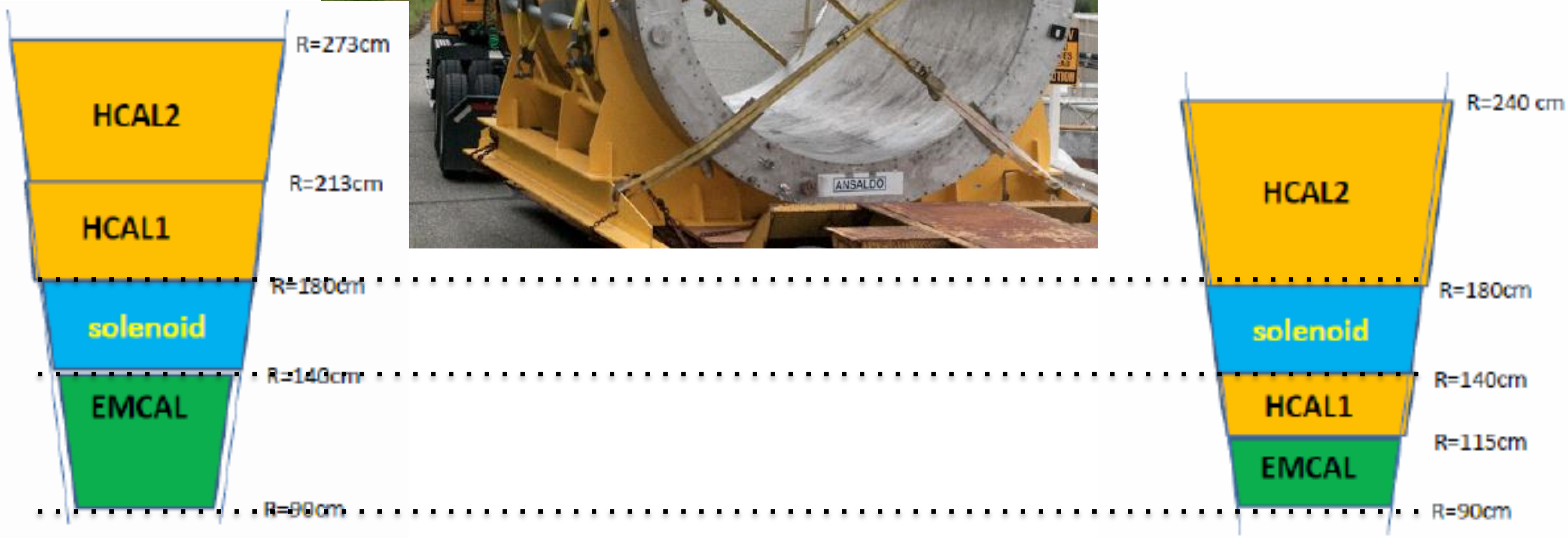
Silicon Tracking six layers of silicon tracking for charged track recontruction and momentum determination.

Electromagnetic Calorimeter tungsten-scintillating fiber sampling calorimeter inside the magnet bore read out with silicon photo-multipliers. The calorimeter has a small Molière radius and short radiation length. allowing for a compact design.

Inner Hadronic Calorimeter sampling calorimeter of non-magnetic metal and scintillator located inside the magnet bore.

Outer Hadronic Calorimeter sampling calorimeter of steel scintillator located outside the cryostat which doubles as the flux return for the solenoid.

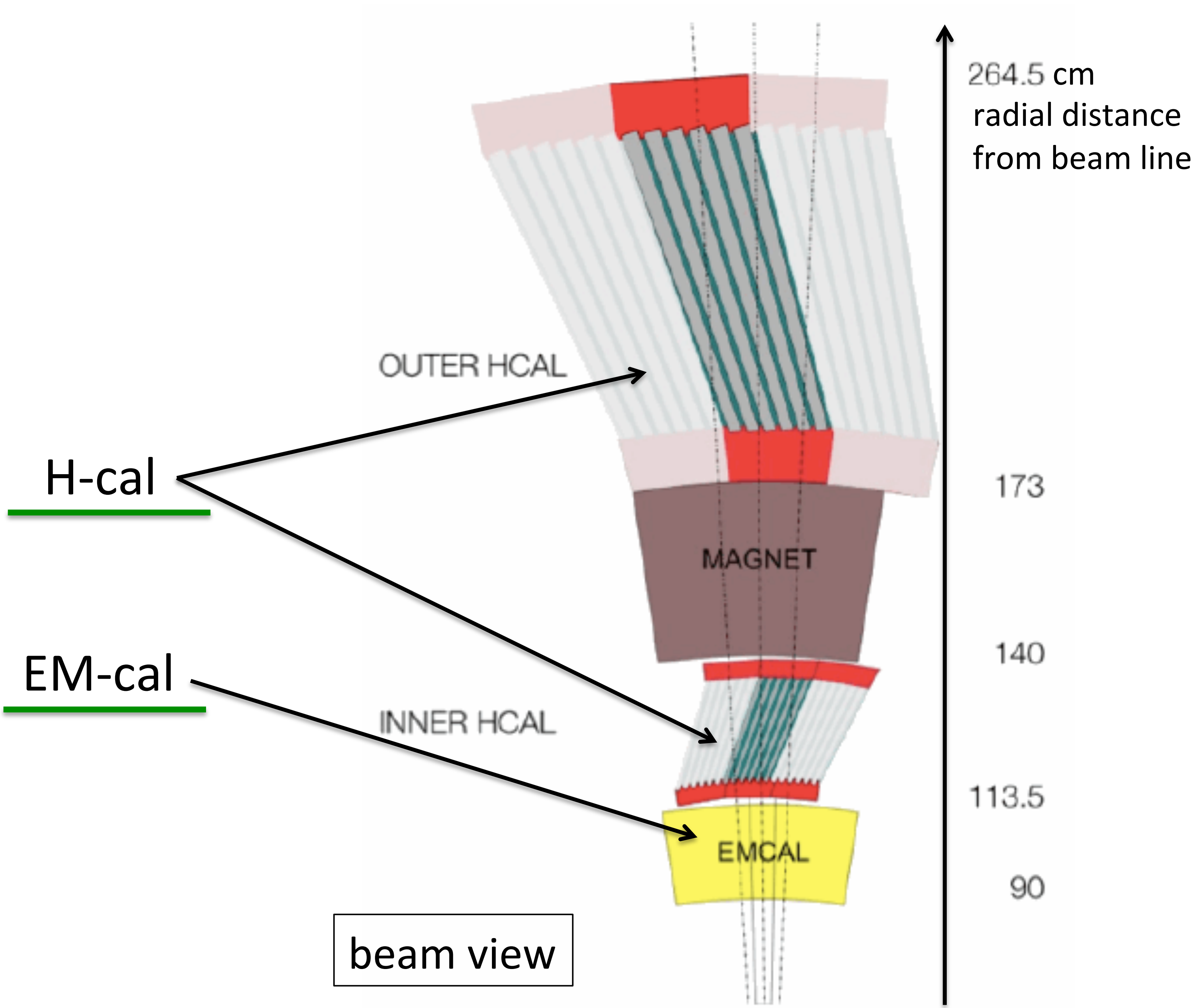
1.5T solenoid from BaBar



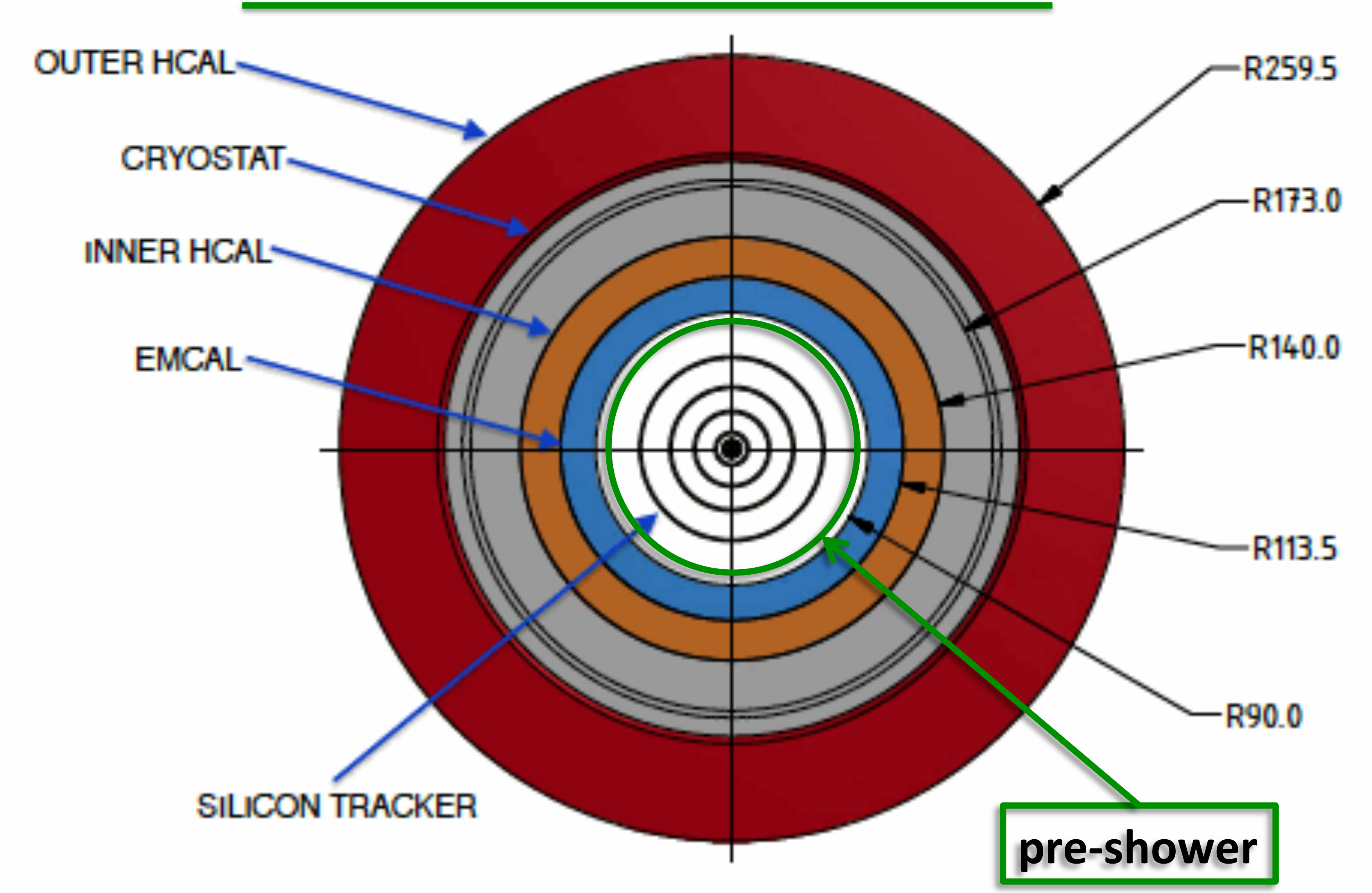
Larger Molière radius
worse for HI collisions
EMCAL can be Pb/Sc

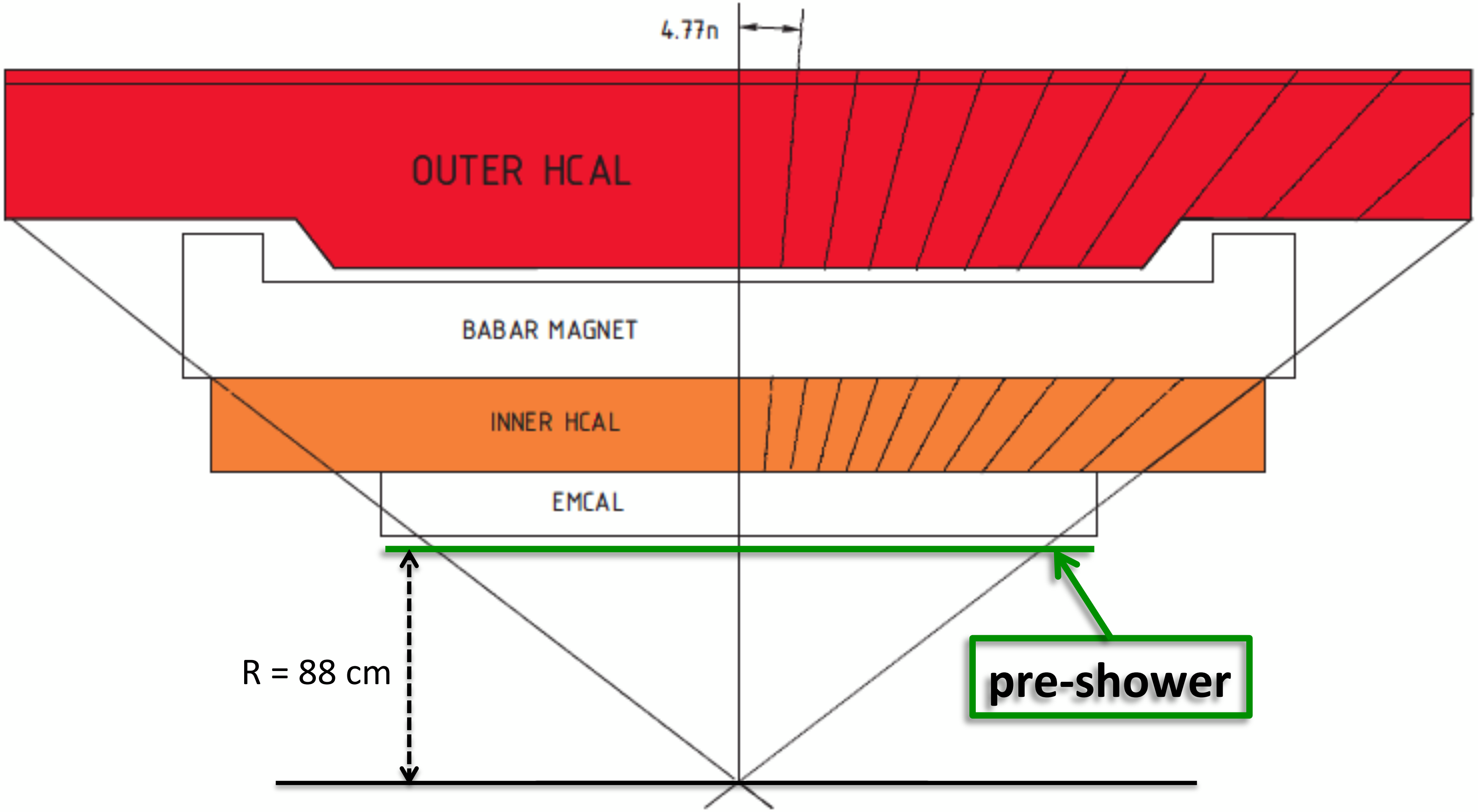
Overall HCAL larger

Smaller Molière radius
better for HI collisions
Thin HCAL section can be
used for e/h separation
Smaller overall HCAL


264.5 cm
radial distance
from beam line
OUTER HCAL
H-cal
173
MAGNET
140
EM-cal
INNER HCAL
113.5
EMCAL
90
beam view

Pre-Shower detector proposal




4.77n
OUTER HCAL
BABAR MAGNET
INNER HCAL
EMCAL
R = 88 cm
pre-shower

Pre-Shower detector design parameters

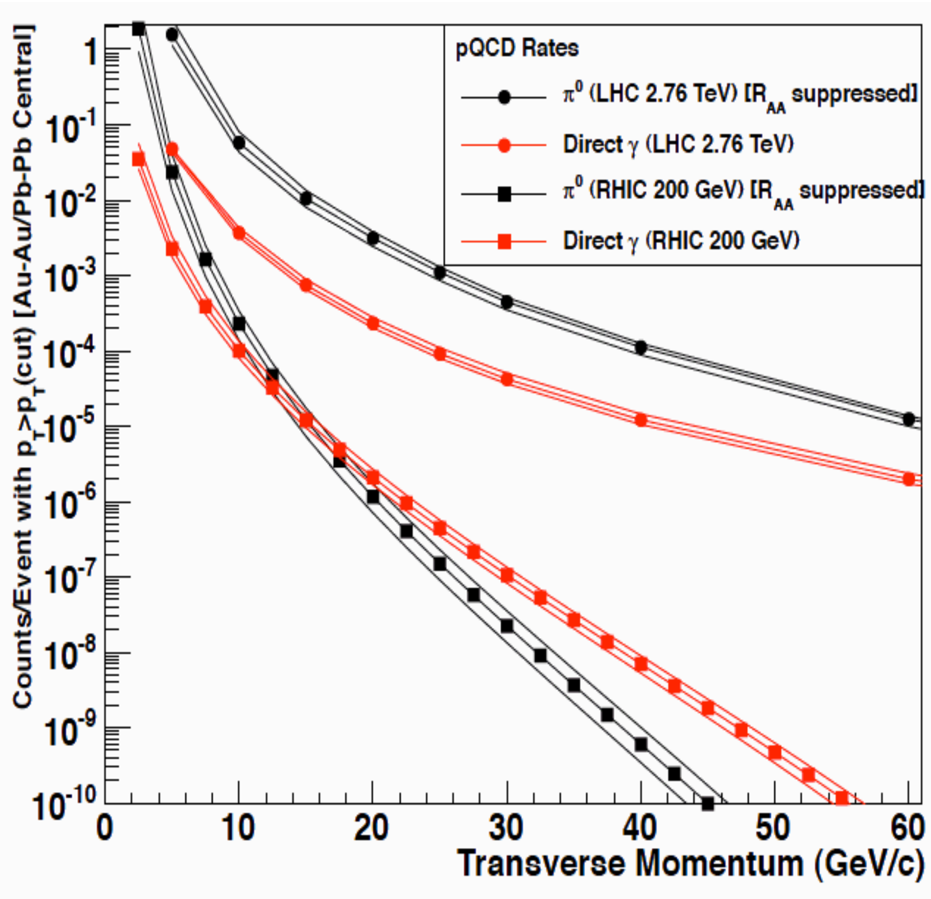
Requirements

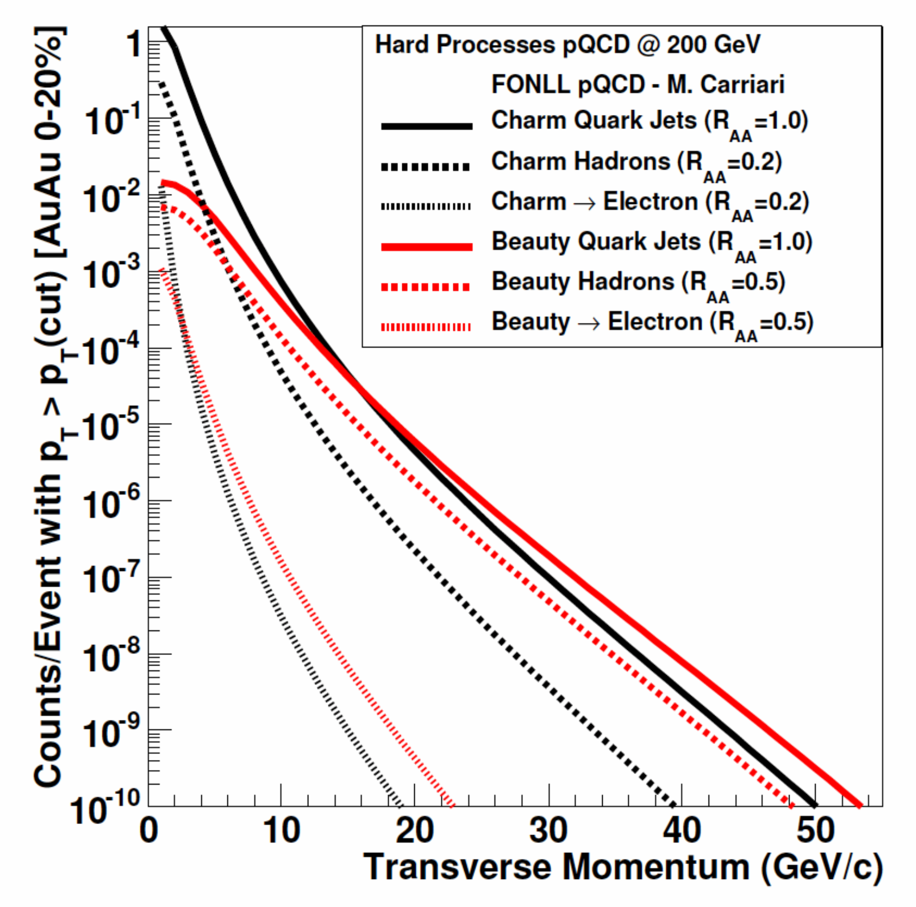
(1) Direct photon identification above ~10GeV/c
(2) π^0 identification up to ~40GeV/c

Detector parameters

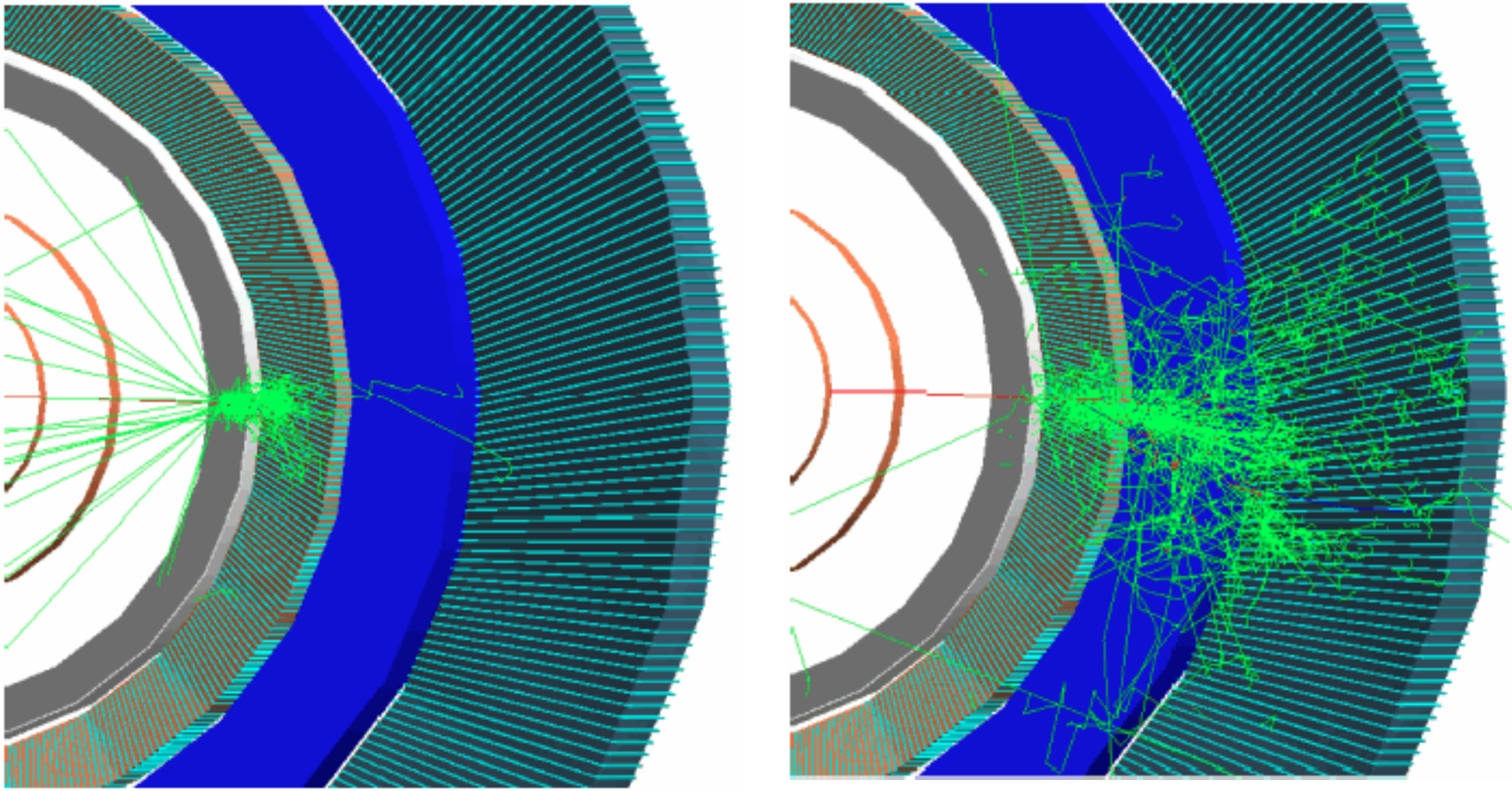
(a) ~25% azimuthal coverage of $|\eta|<1.1$
(~$3m^2$ at R~0.88m)
(b) one layer of Tungsten converter
(~$2X_0$, ~7mm)
(c) one layer of silicon pad-readout
(5x5 ~ $10x10cm^2$ pad , 30 ~ 120k channels)
(d) Occupancy ~ 3% in central 200GeV Au+Au

Photons and heavy quark jets

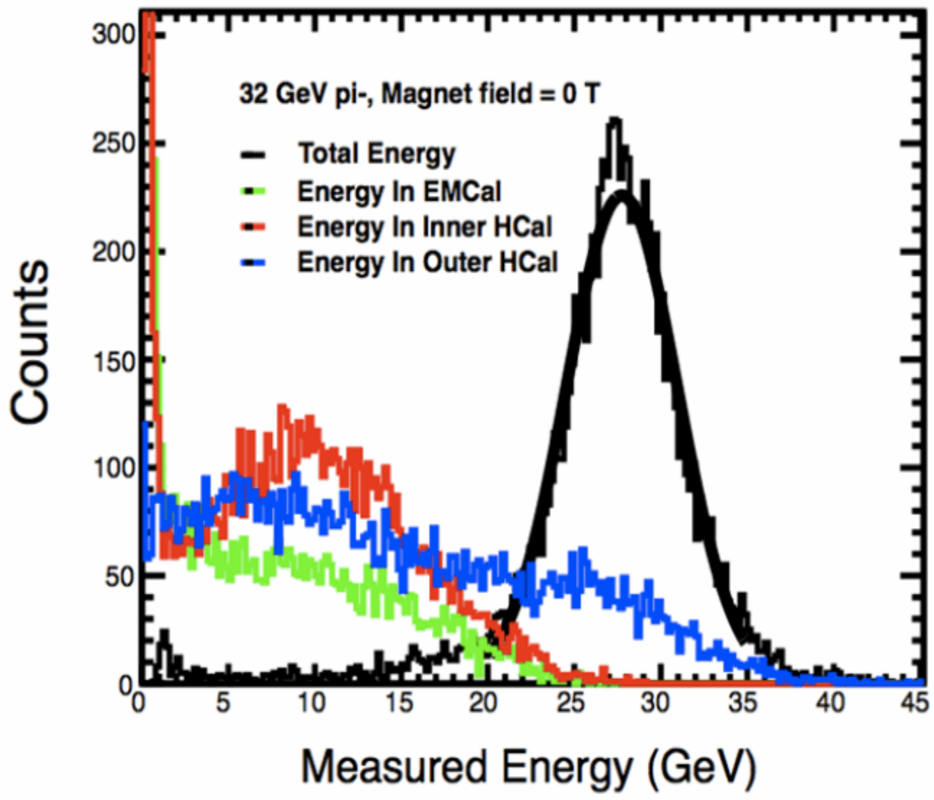




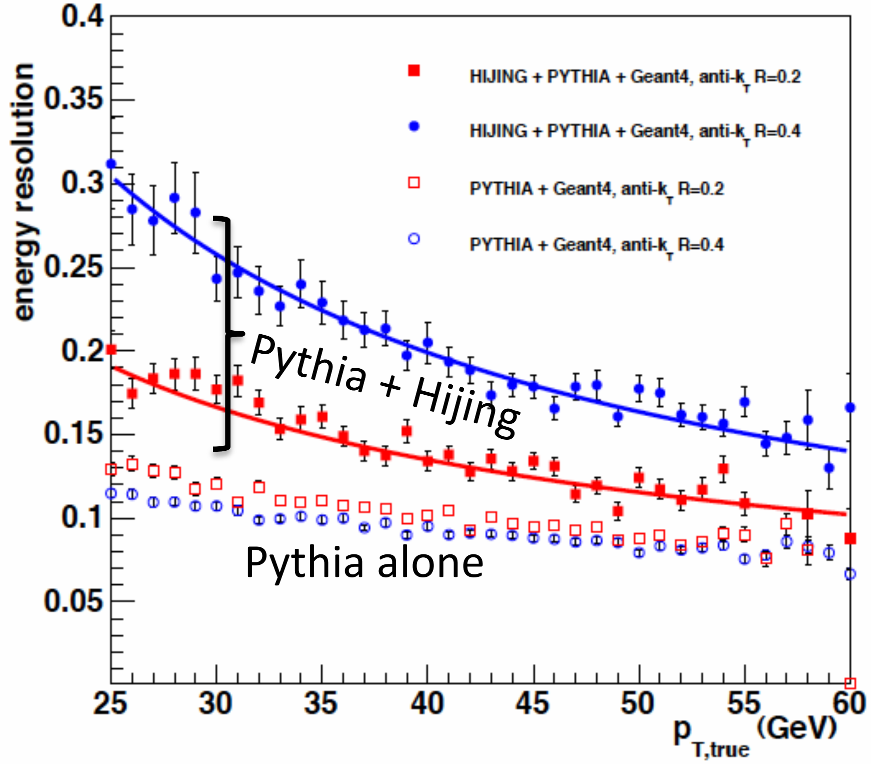
EM and Hadronic shower in Geant



Single particle and jet energy resolution

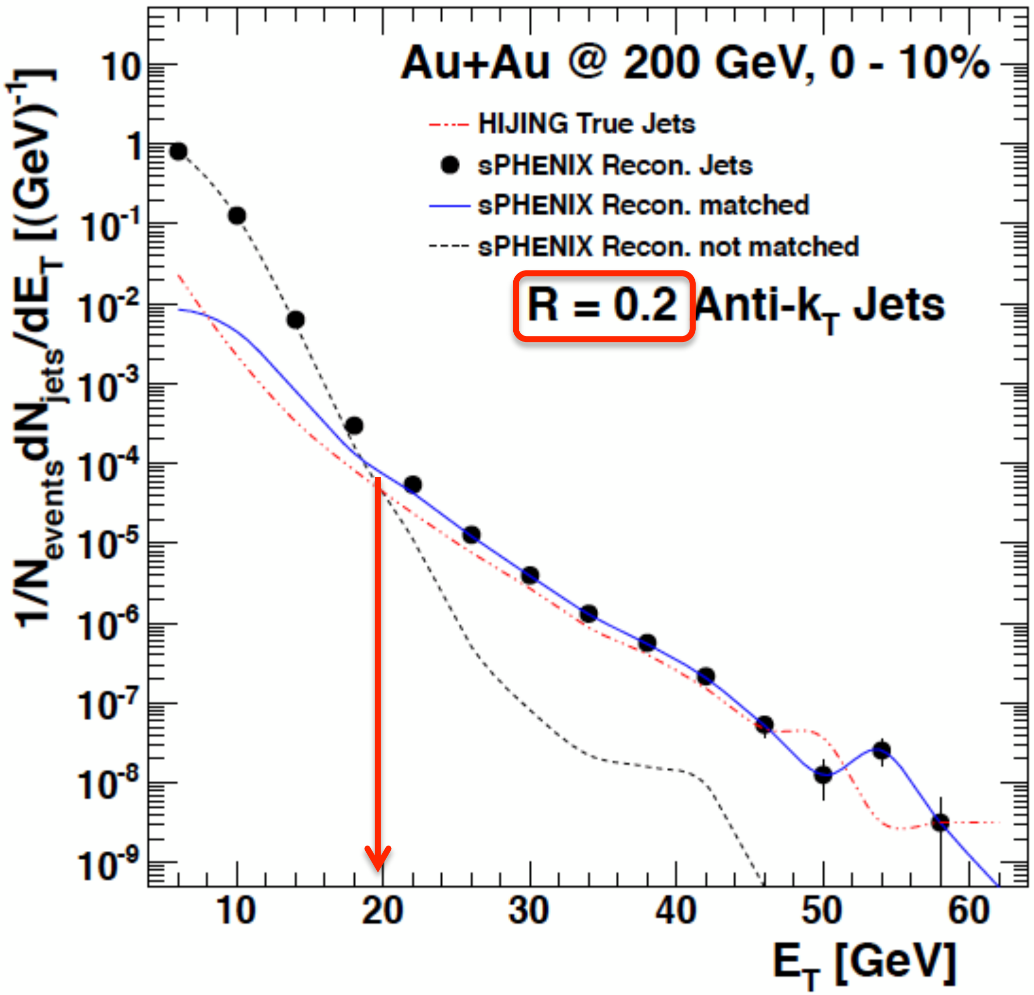


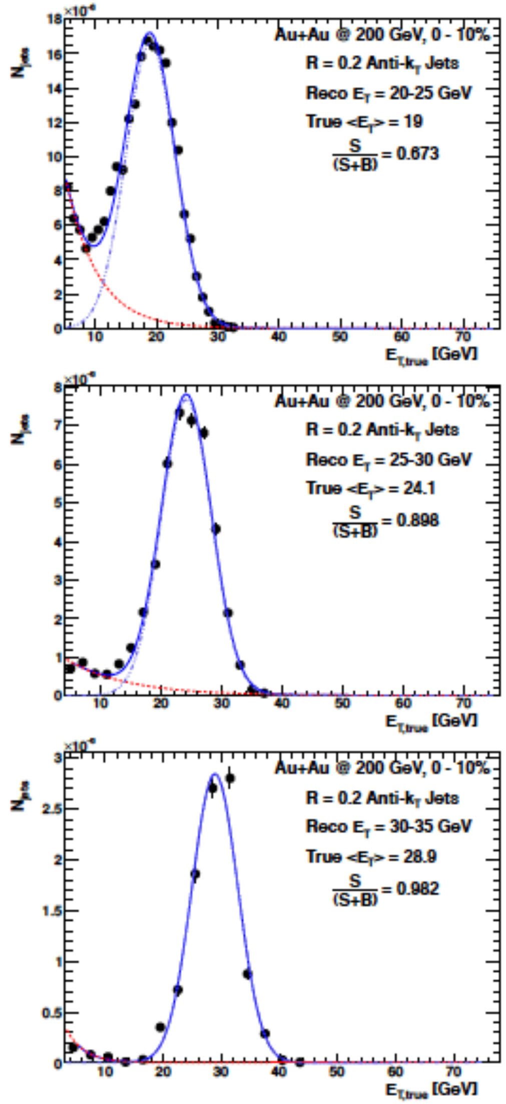
R=0.2 vs R=0.4



simulation

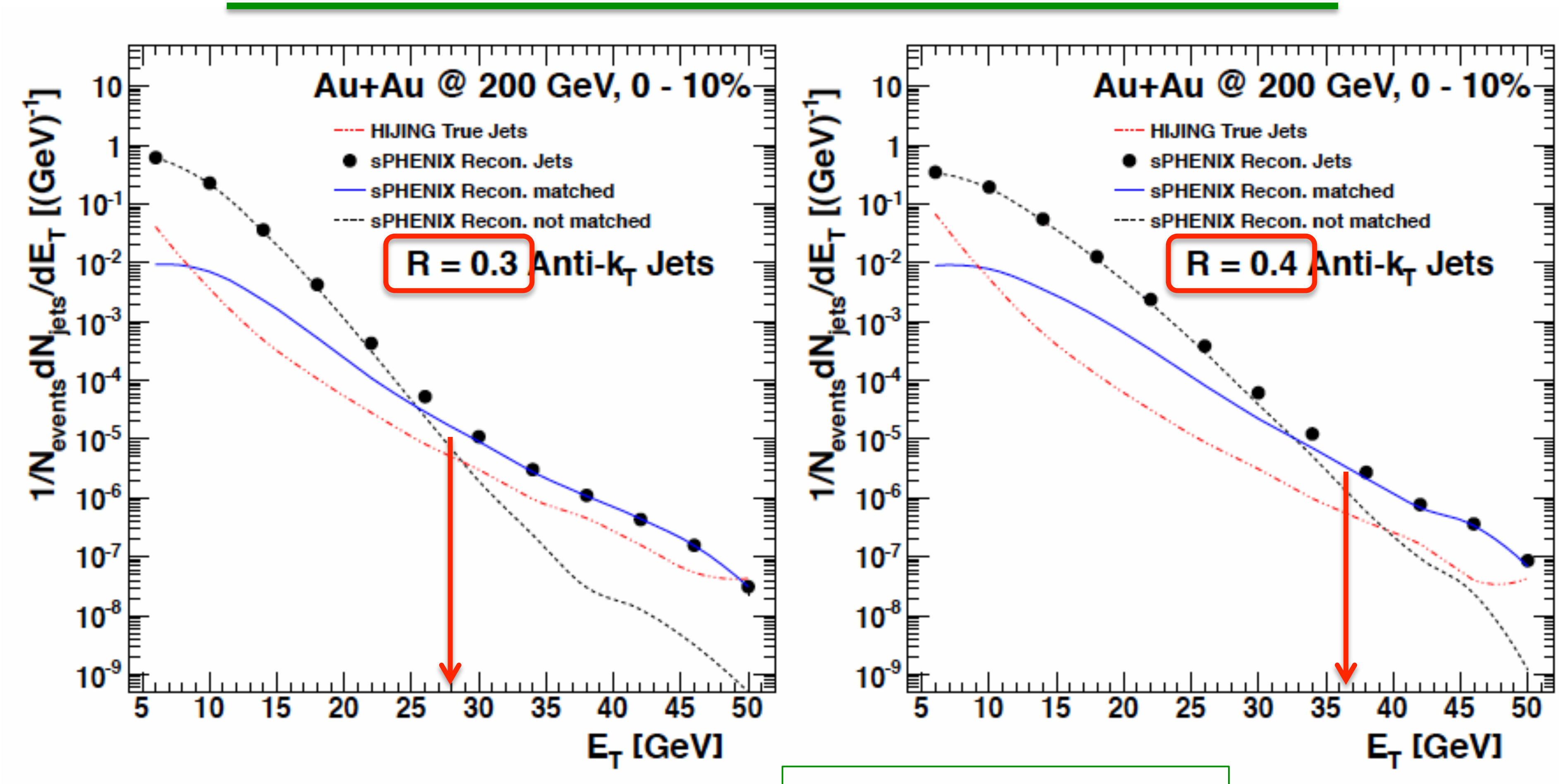
Reconstruction of jet energy distribution





simulation

Competition with underlying H.I. B.G.



R=0.2 : E_T > 20 GeV
R=0.3 : E_T > 28 GeV
R=0.4 : E_T > 36 GeV

A_j distribution --- "LHC vs RHIC"

$$A_J = \frac{P_{T,1} - P_{T,2}}{P_{T,1} + P_{T,2}}$$

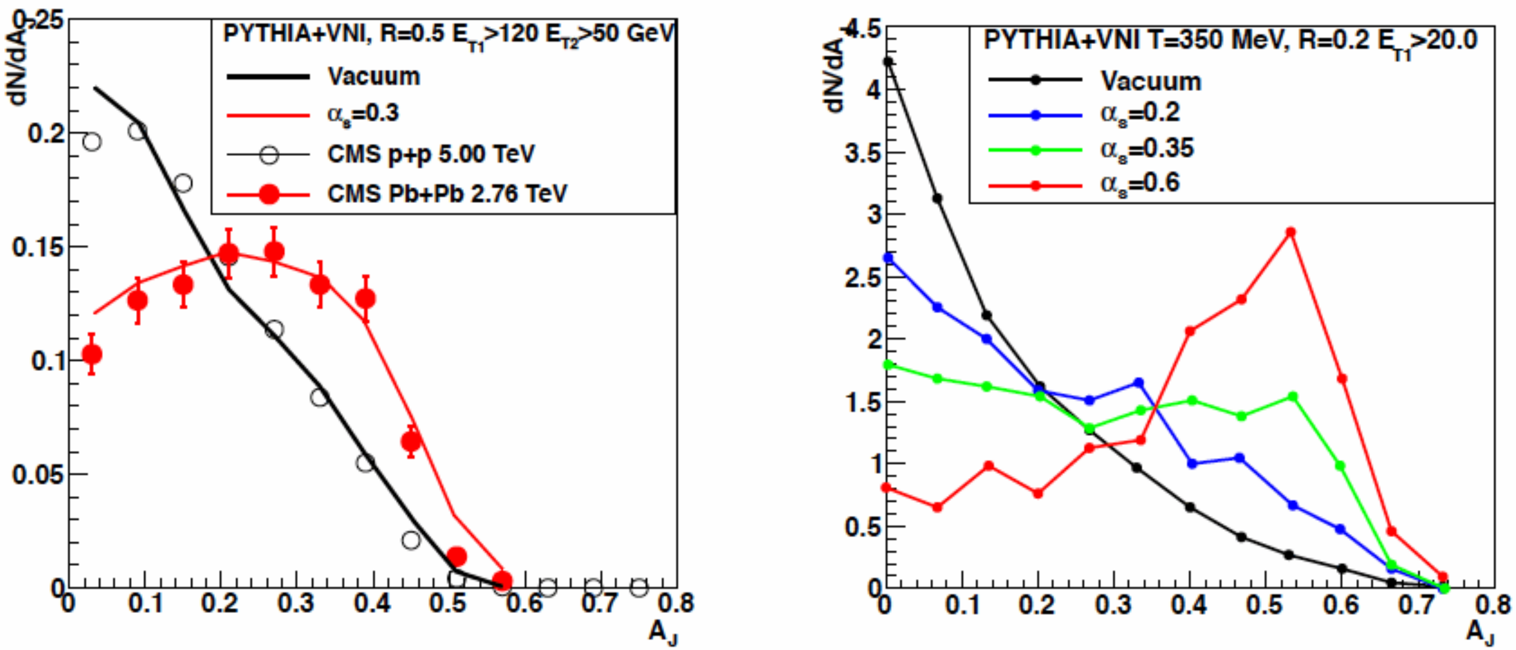
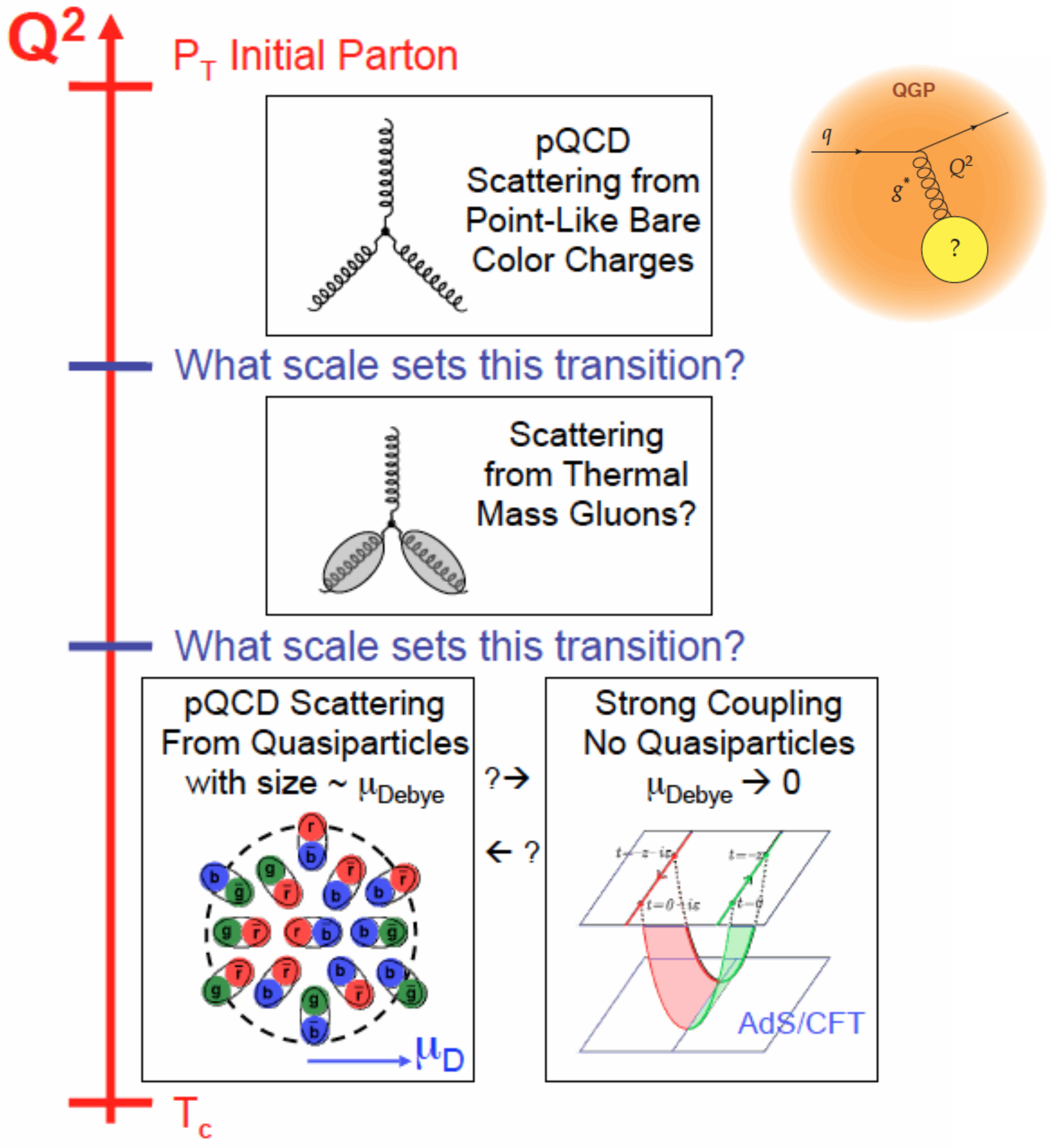
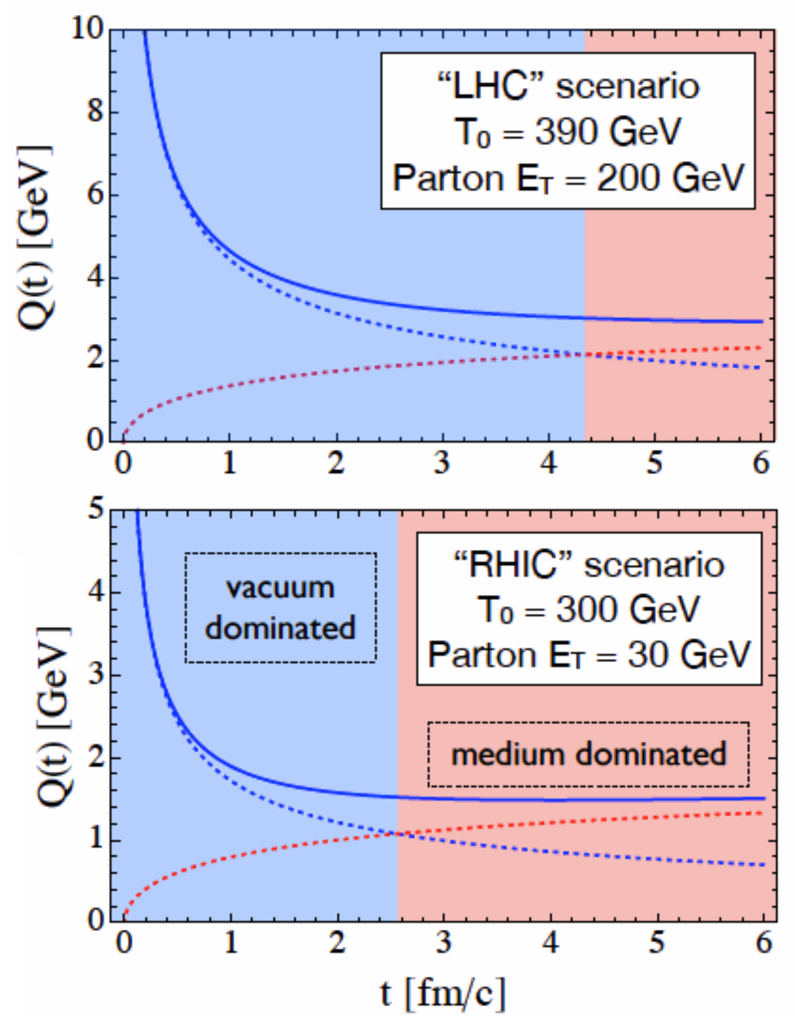


Figure 1.18: (Left) Calculation in VNI parton cascade of dijet A_J with $T = 0.35\,\mathrm{GeV}$ and $\alpha_s = 0.3$ compared to the CMS data [39]. (Right) Calculation for RHIC jet energies, $E_{T,1} > 20\,\mathrm{GeV}$, for a circular geometry of radius 5 fm of A_J for different values of α_s increasing to $\alpha_s = 0.6$ (red line) [86].

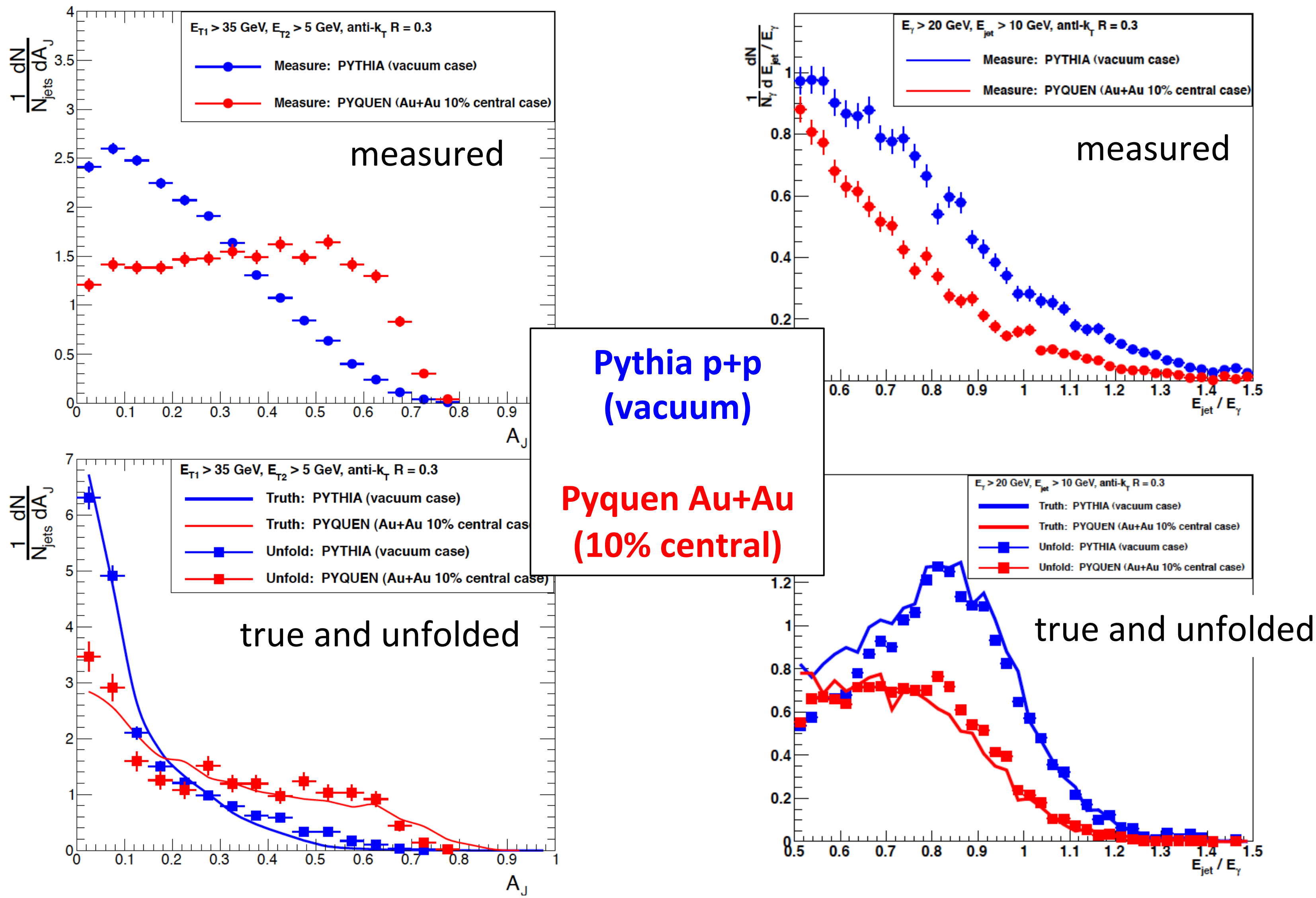
Length and time scale vs energy of probe



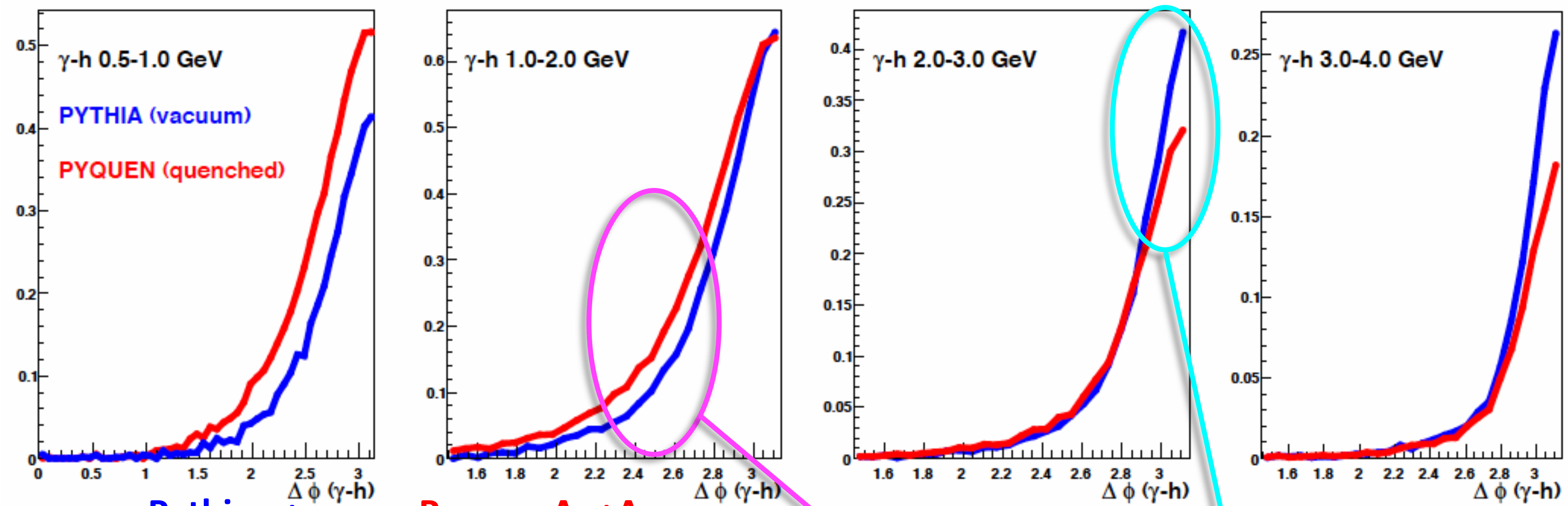


simulation

Di-jet (A_J) γ-jet (E_{Jet}/E_γ)



simulation



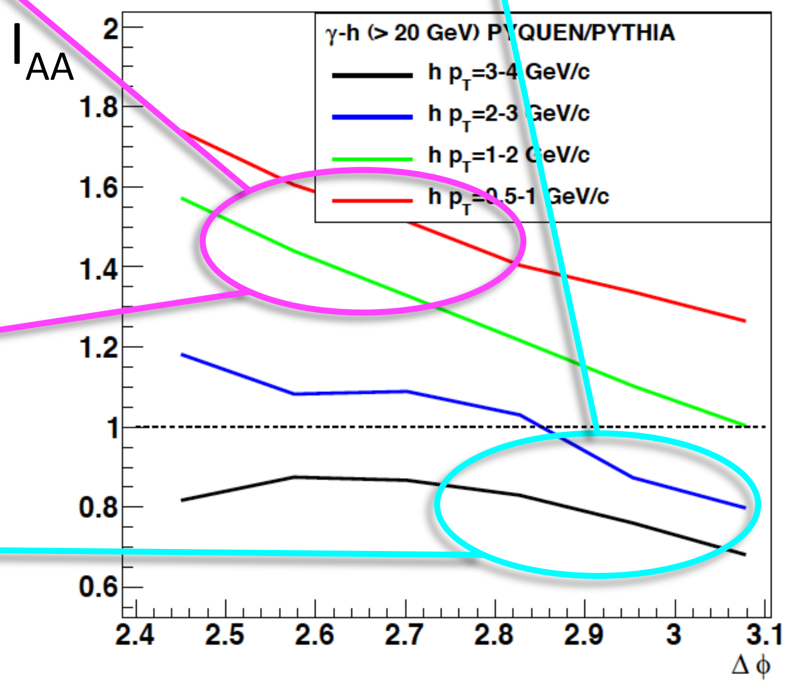
Pythia p+p (vacuum)

Pyquen Au+Au (10% central)

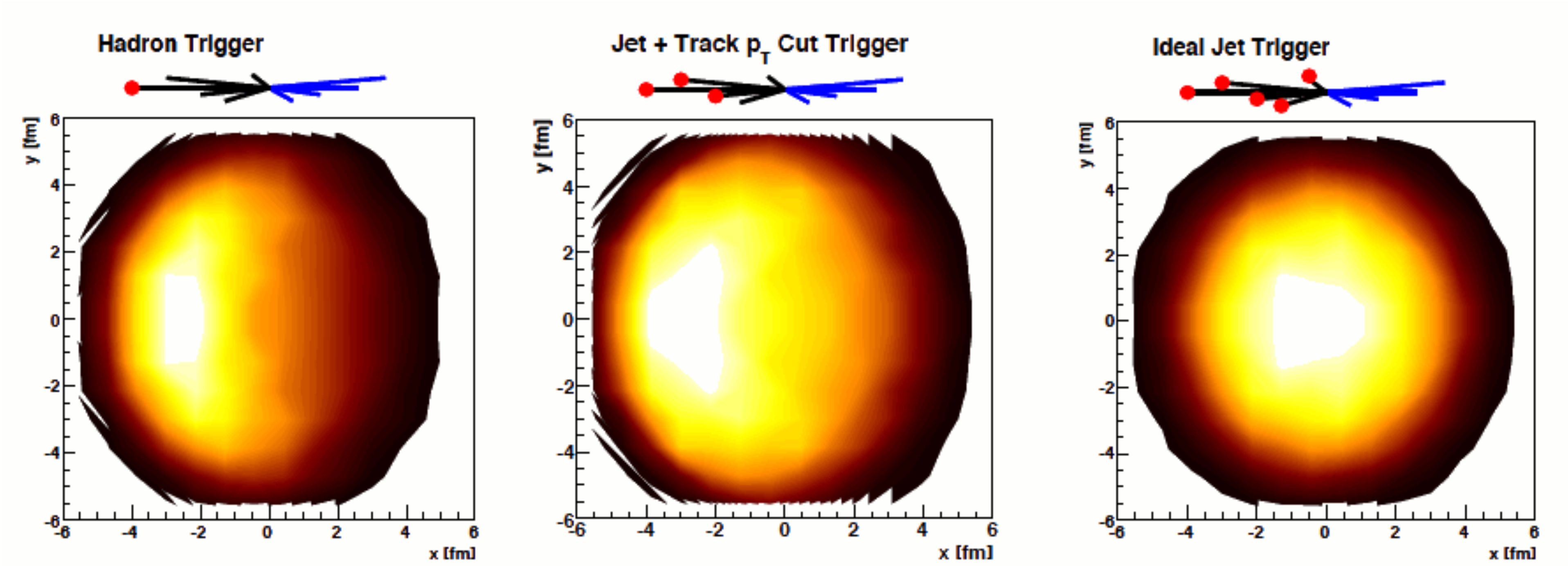
γ-hadron correlation

Lower pT enhanced (re-distribution)

Higher pT suppressed (energy loss)



Surface bias control parameters



hadron – hadron, jet

jet – jet, hadron

Gamma – jet, hadron

smaller cone jet

larger cone jet

maximum biased trigger

hard core jet

soft fragmentation

less biased trigger

Summary

- recent results with γ, jet at RHIC
- sPHENIX upgrade with pre-shower detector
- detector and physics simulations