New experimental conditions in the near future at RHIC and LHC

David Morrison
Brookhaven National Laboratory

Initial Stages 2016


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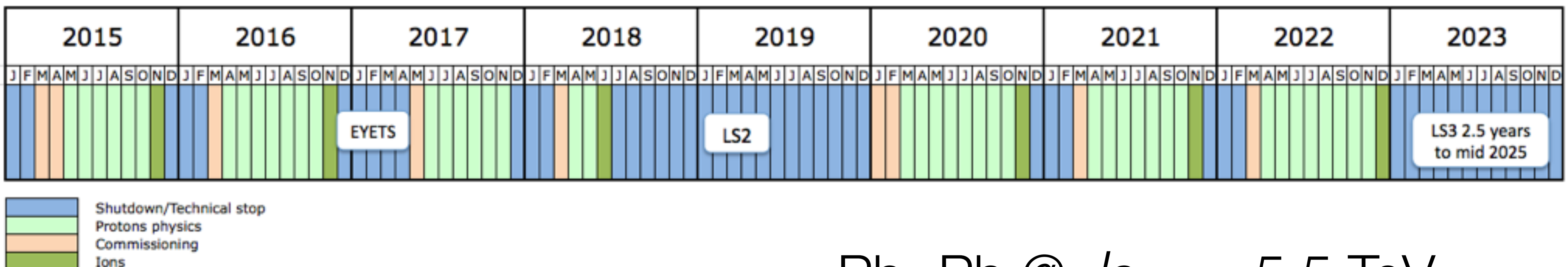
Defining “near future”

LHC schedule through Run 3



Pb+Pb @ $\sqrt{s_{NN}}$ = 5.5 TeV
peak collision rate ≈ 50 kHz

←past   now   far future→

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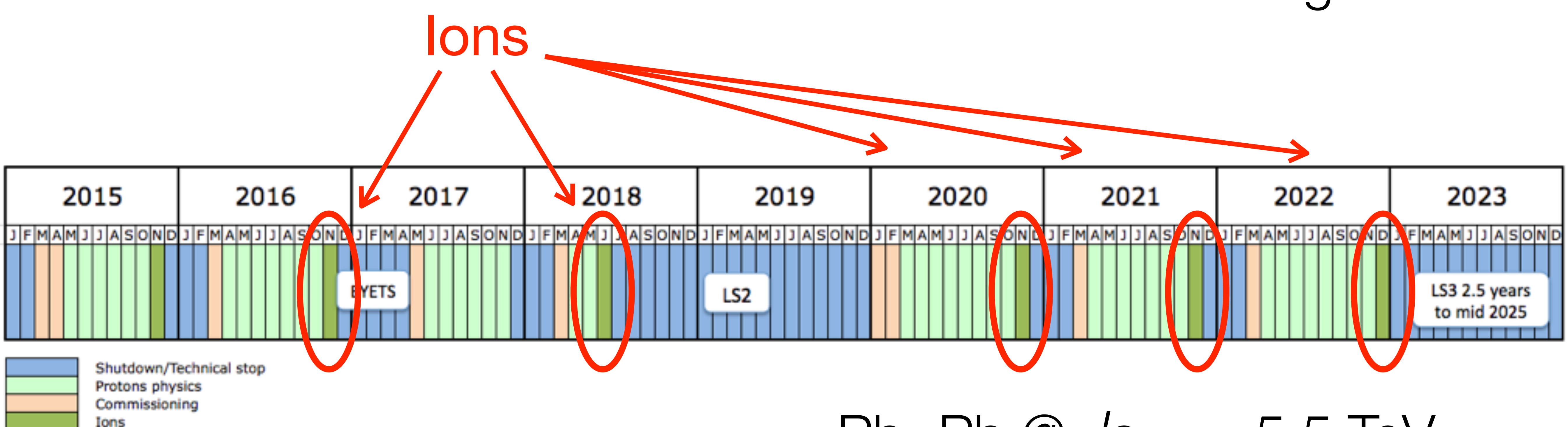

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BNL's plan for the same time period

Years	Beam Species and	Science Goals	New Systems
2014	Au+Au at 15 GeV Au+Au at 200 GeV ^{3}He+Au at 200 GeV	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, p↑+Al at 200 GeV High statistics Au+Au Au+Au at 62 GeV ?	Extract $\eta/s(T)$ + constrain initial quantum fluctuations Complete heavy flavor studies Sphaleron tests Parton saturation tests	PHENIX MPC-EX STAR FMS preshower Roman Pots Coherent e-cooling test
2017	p↑+p↑ at 510 GeV	Transverse spin physics Sign change in Sivers function	
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≥ 2023 ?	No Runs		Transition to eRHIC

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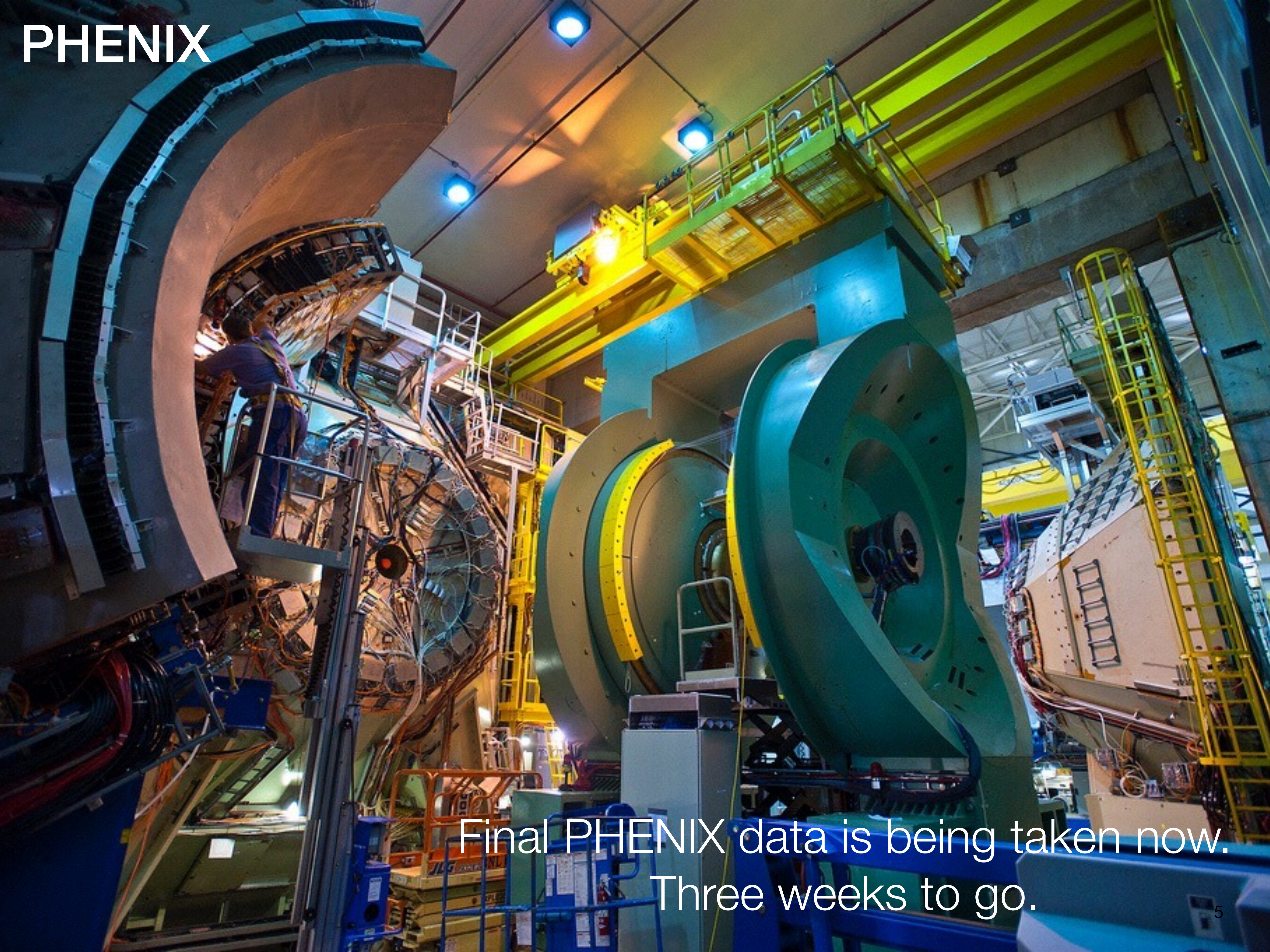
What are “new experimental conditions”?

- Changes to beam conditions
  - novel collision systems
  - new collision energies
  - higher luminosity

Focus here on how experiments are preparing to use these beam conditions

- Changes to experimental equipment
  - higher DAQ rates
  - improved triggering capabilities
  - adding, improving, or replacing subdetectors or even whole experiments
- Every single one of these things is happening over the next years

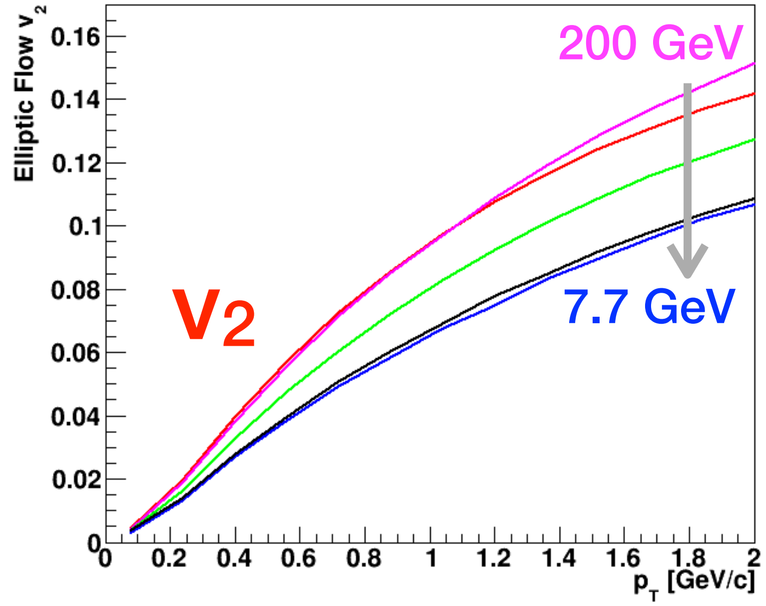
PHENIX

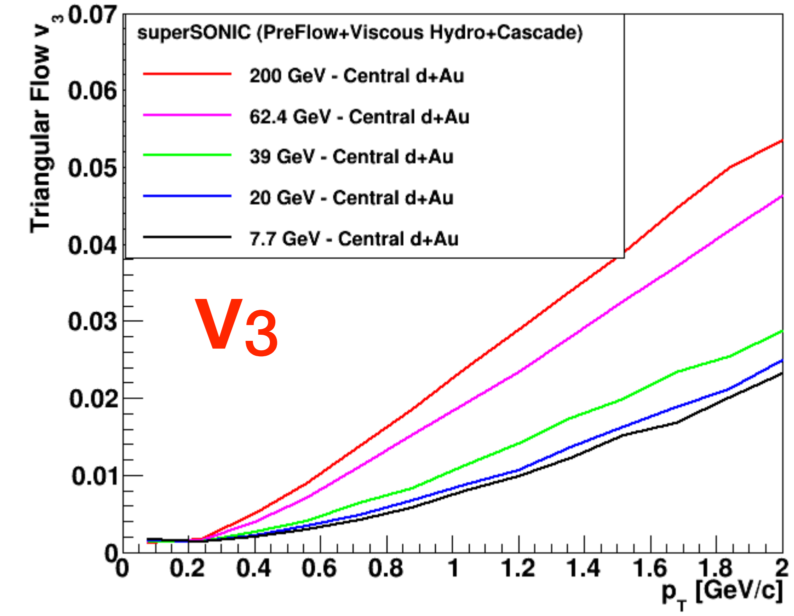


Final PHENIX data is being taken now.
Three weeks to go.

superSONIC calculations of d+Au
Eur. Phys. J., C75(1):15 (2015)

discussion of pre-flow at IS2014
J. Orjuela-Koop's talk IS2016

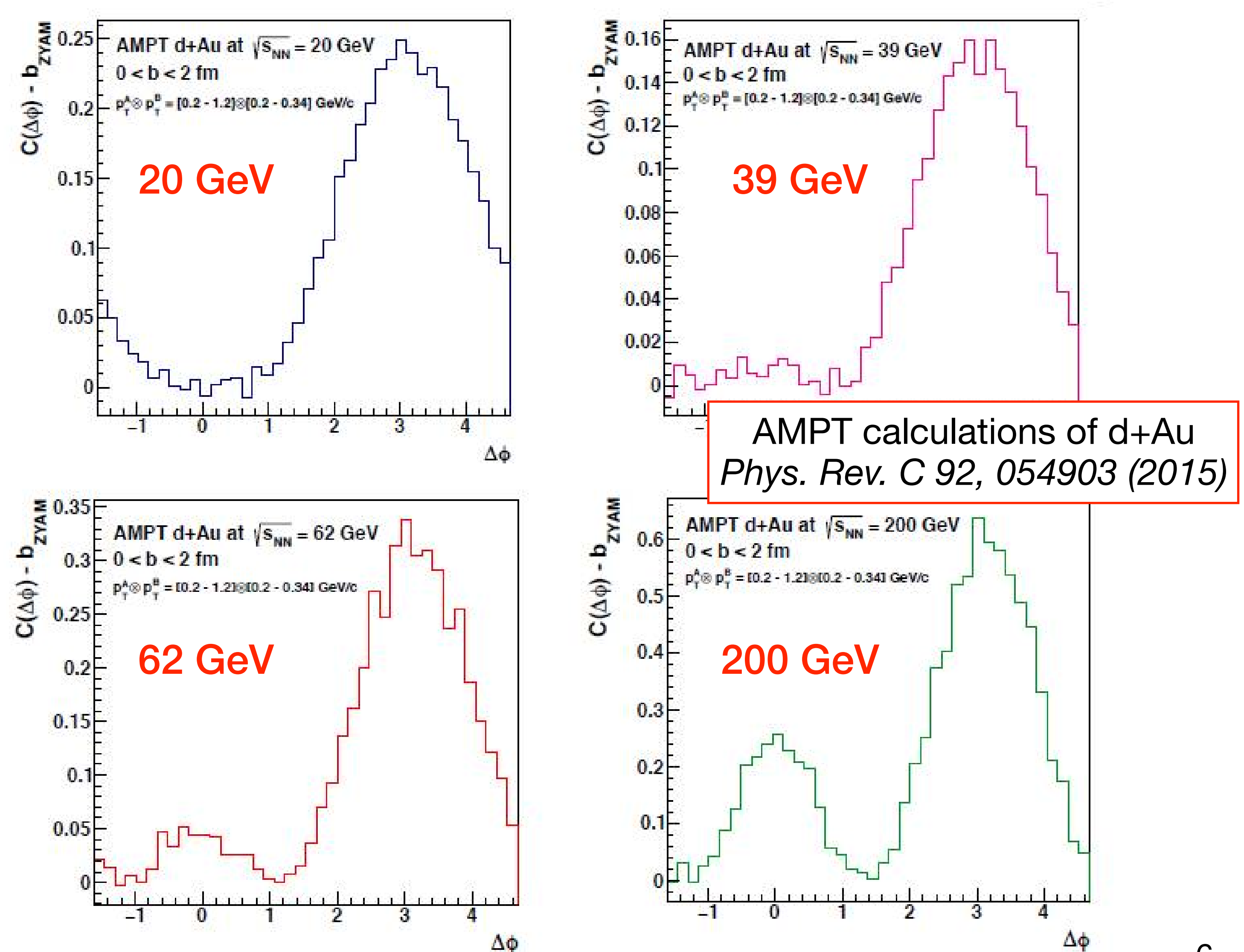




d+Au beam energy scan: recorded 1.1B events at 200 GeV, successful 62.4 GeV just completed, switching to 20 GeV today!

d+Au @ 200 GeV – 20x 2008 data
improved event plane via endcap
silicon detectors

role of pre-equilibrium flow,
time spent in low viscosity sQGP
phase – v_3 provides additional
sensitivity



AMPT calculations of d+Au
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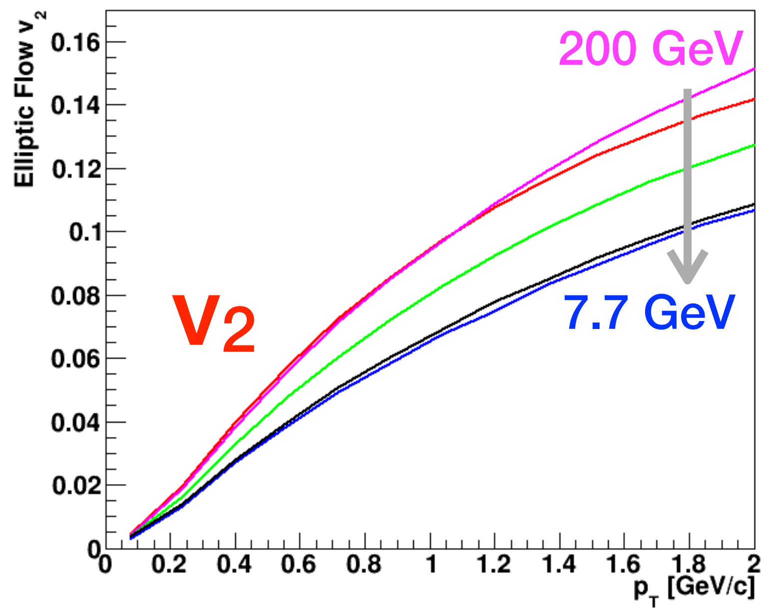

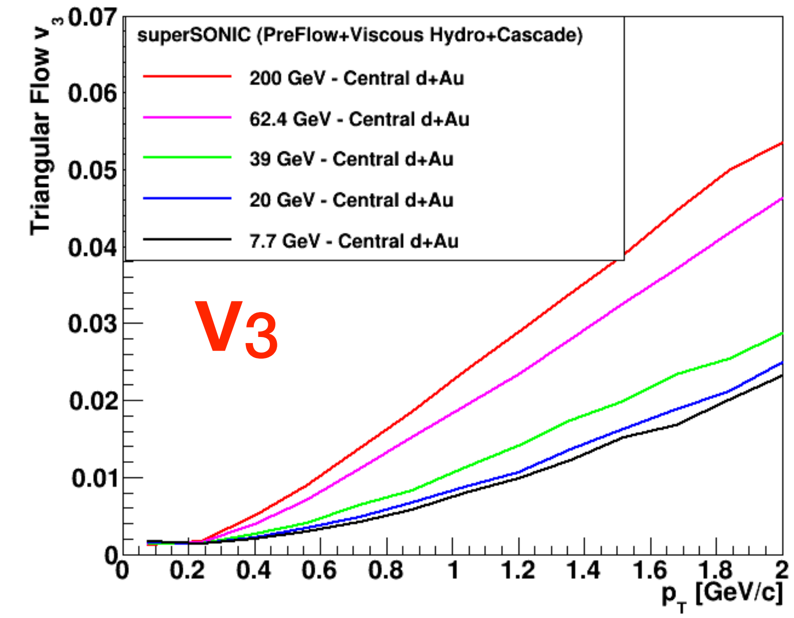

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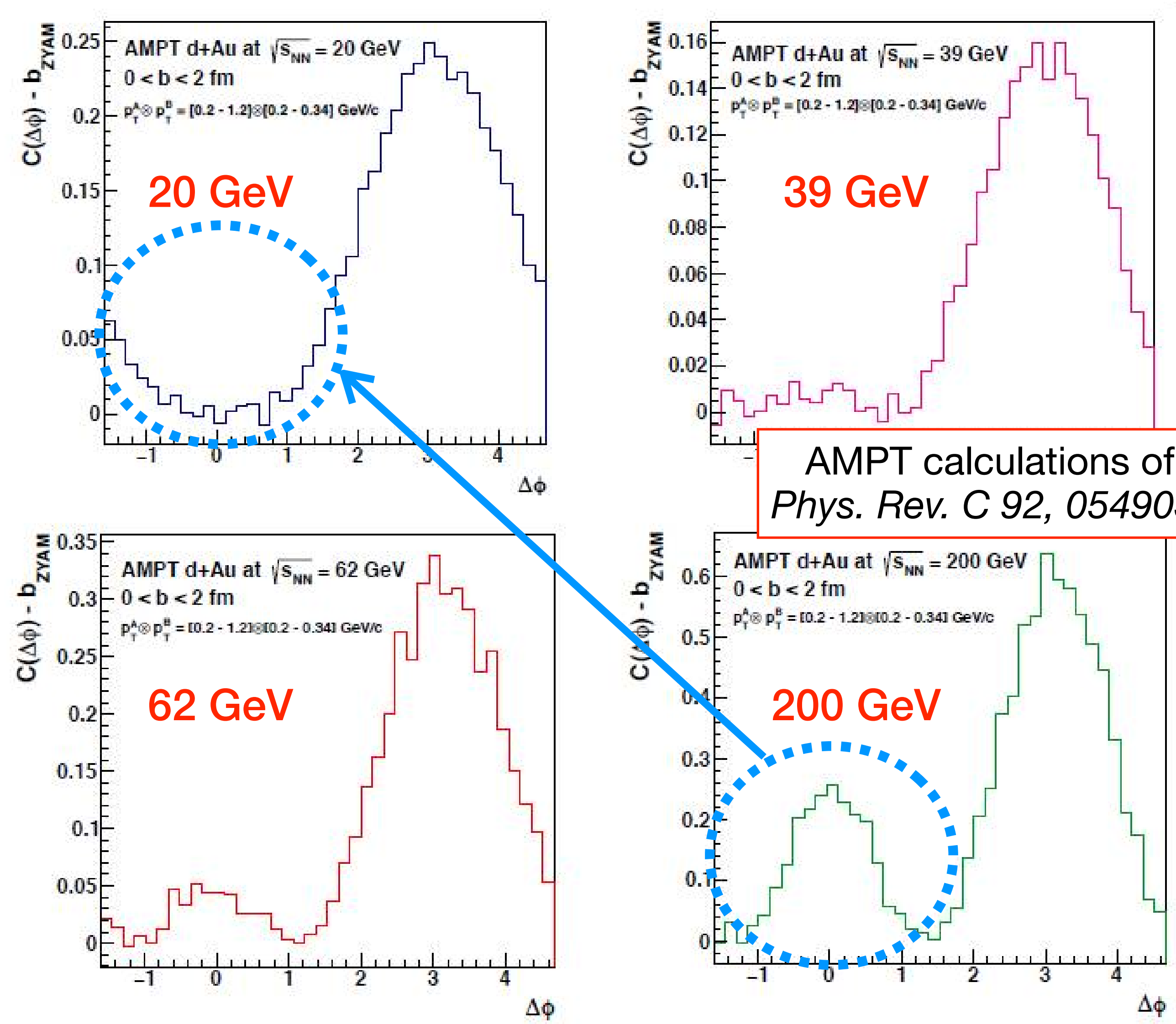

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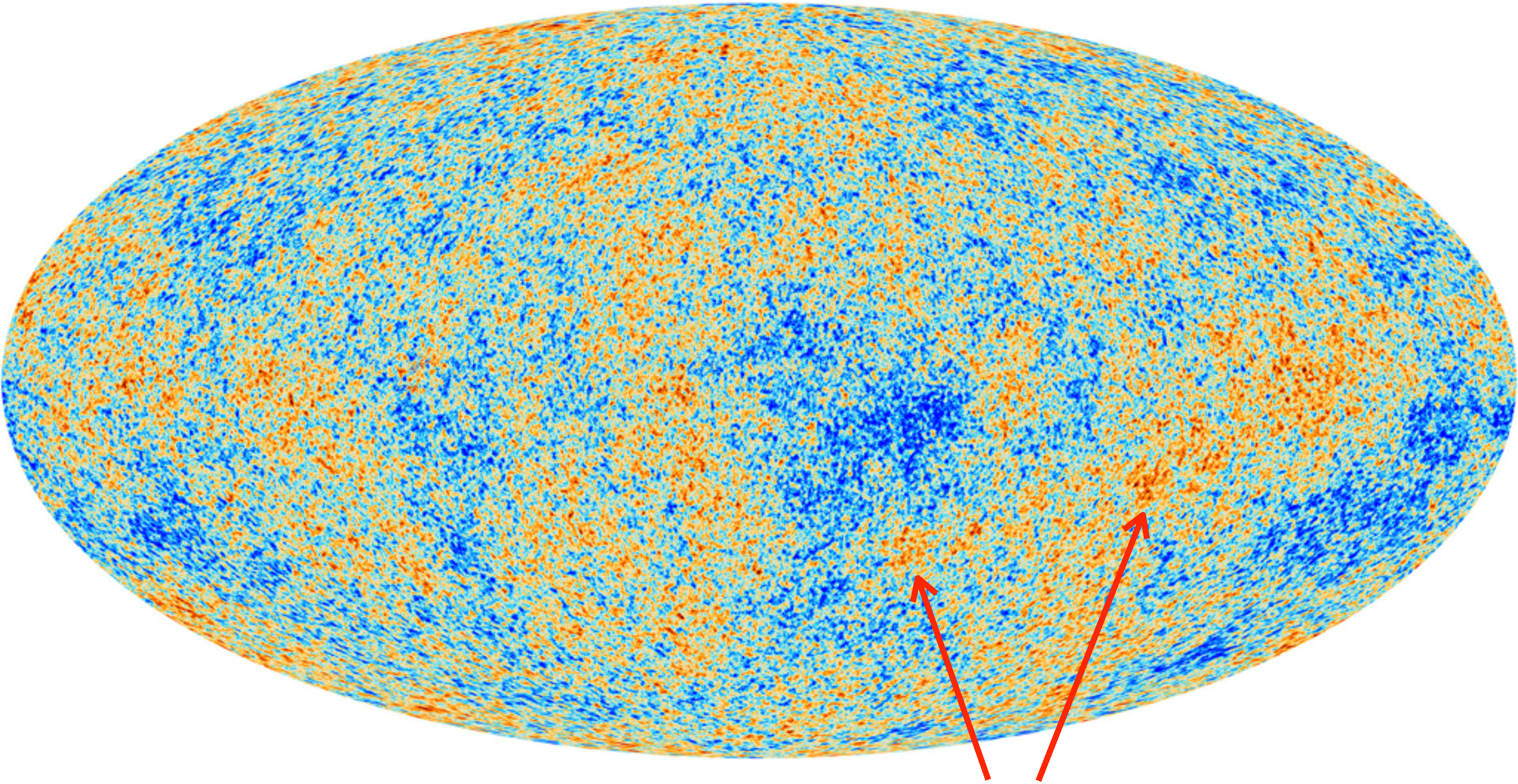
RHIC Run-18

Future RHIC Run Plans: The plan for RHIC runs before the BES-II has recently been refined to include independent runs in 2017 and 2018. The change is driven by the desire to permit a sufficiently long run with transversely polarized p+p collisions at 510 GeV in Run-17 (up to 19 cryo-weeks depending on budgetary constraints) to "test unique QCD predictions for relations between single-transverse spin phenomena in p-p scattering and those observed in deep-inelastic scattering" (NP Milestone HP13), and the **plan to collide isobars (^{96}Zr+^{96}Zr and ^{96}Ru+^{96}Ru) at 200 GeV in Run-18 (13 cryo-weeks) as a critical test of the contribution from the possible Chiral Magnetic Effect to the various observed charge separation effects.**

BNL ALD Berndt Mueller – two weeks ago

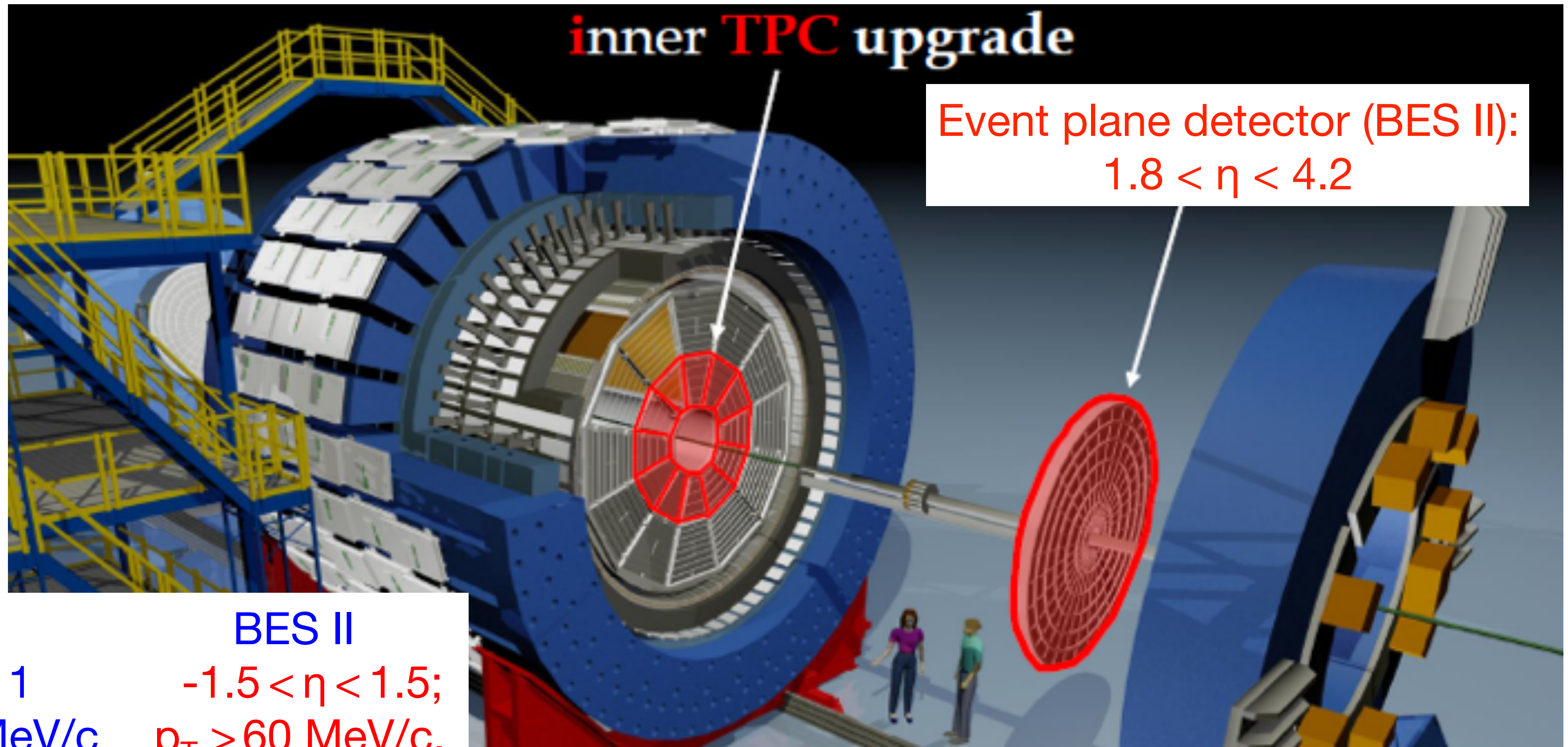
If observed effects are due to CME, should scale with Z^2



widely separated correlations now needed to be established at very early times

Planck CMB

STAR upgrades for η coverage, EP determination

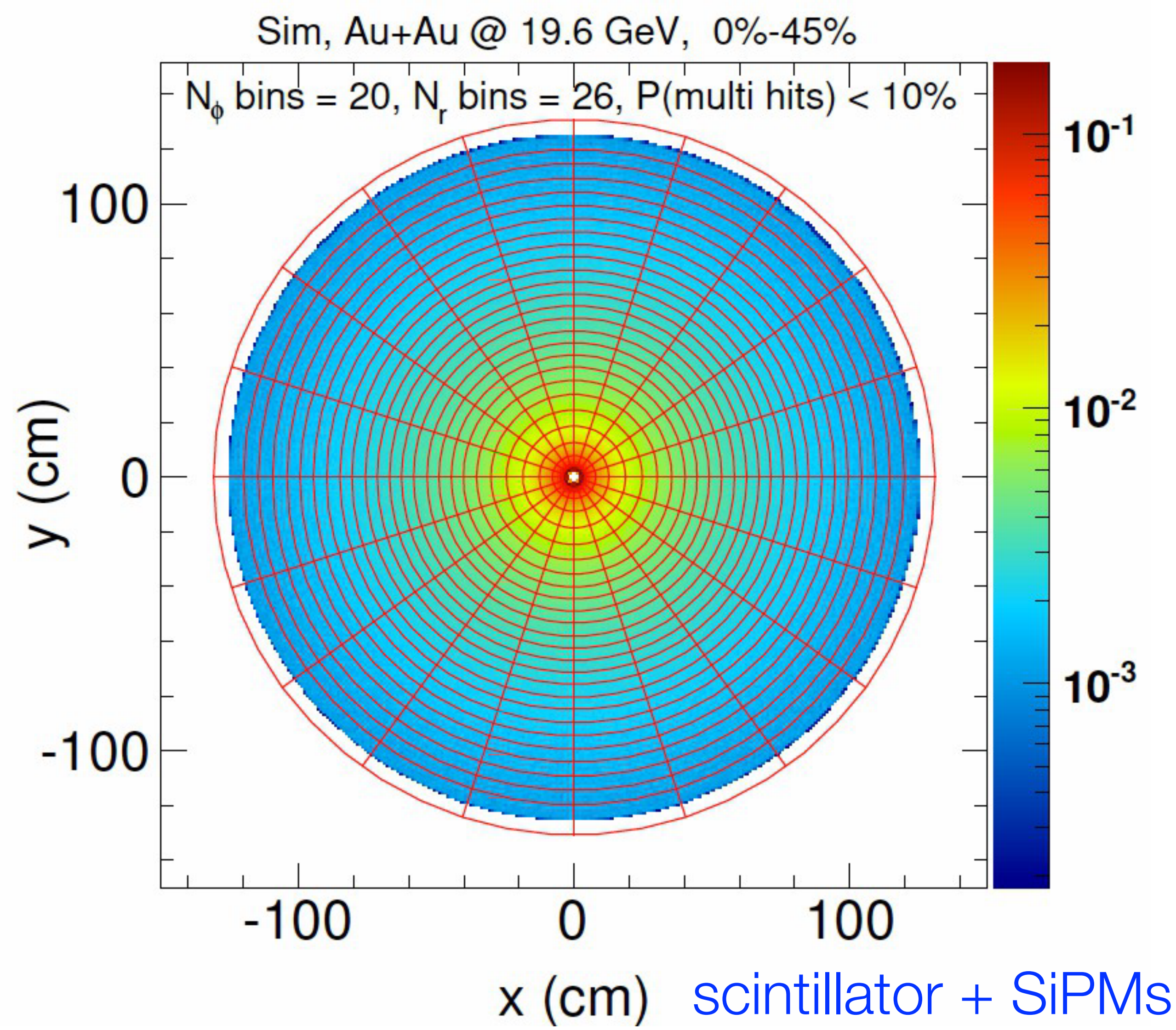


Now	BES II
$-1 < \eta < 1$	$-1.5 < \eta < 1.5$;
$p_T > 125$ MeV/c	$p_T > 60$ MeV/c.

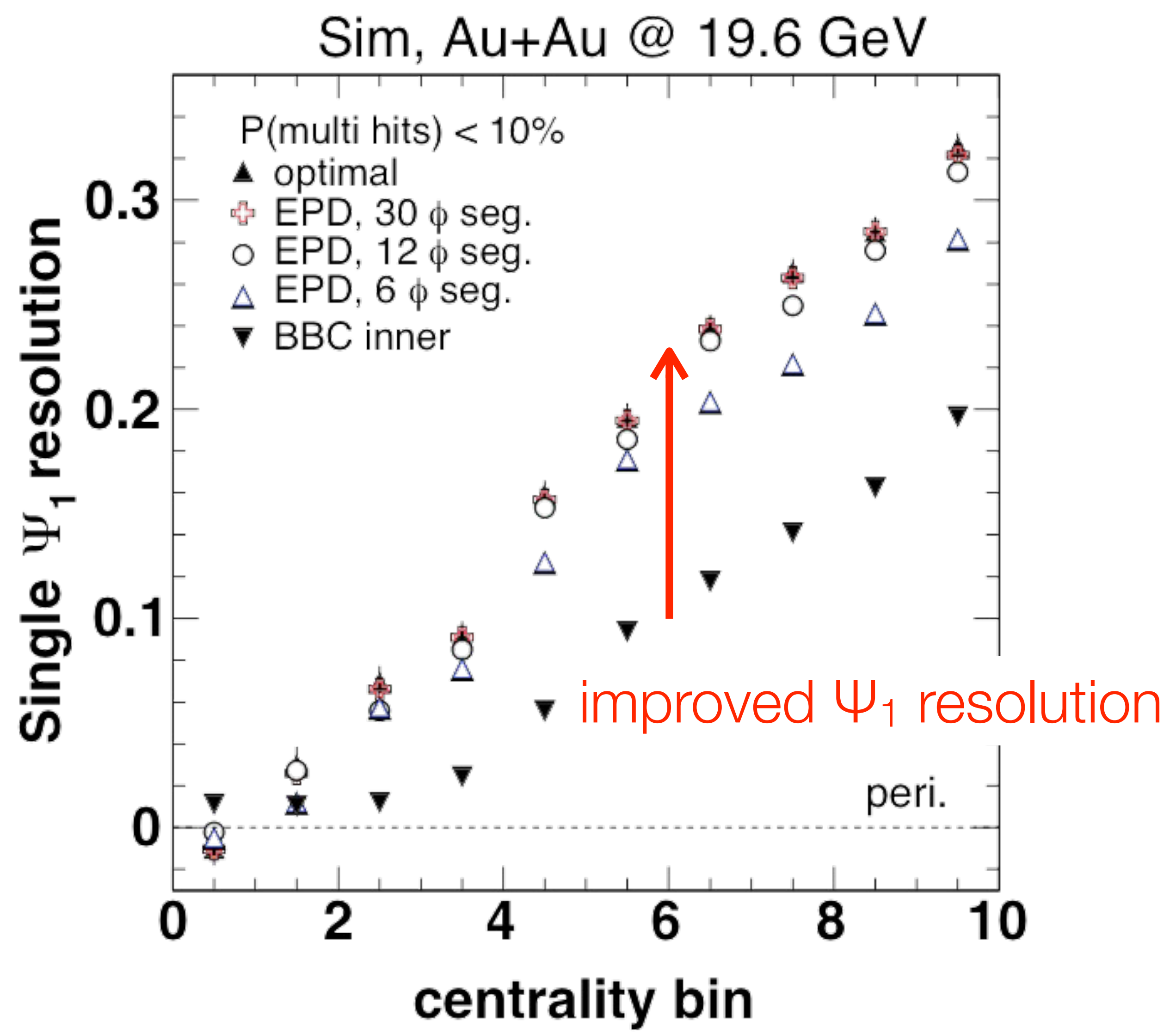
- What is the structure of the initial state and how does it evolve with rapidity?
- Over what rapidity range does coherence in the initial state persist?
- What mechanism or mechanisms transport baryons toward mid-rapidity?
- How large are hydrodynamic fluctuations and how far do they spread in rapidity space?

Opportunities for Exploring Longitudinal Dynamics in Heavy Ion Collisions at RHIC
RBRC workshop at BNL, January 2016

Event plane detector for STAR in the BES II



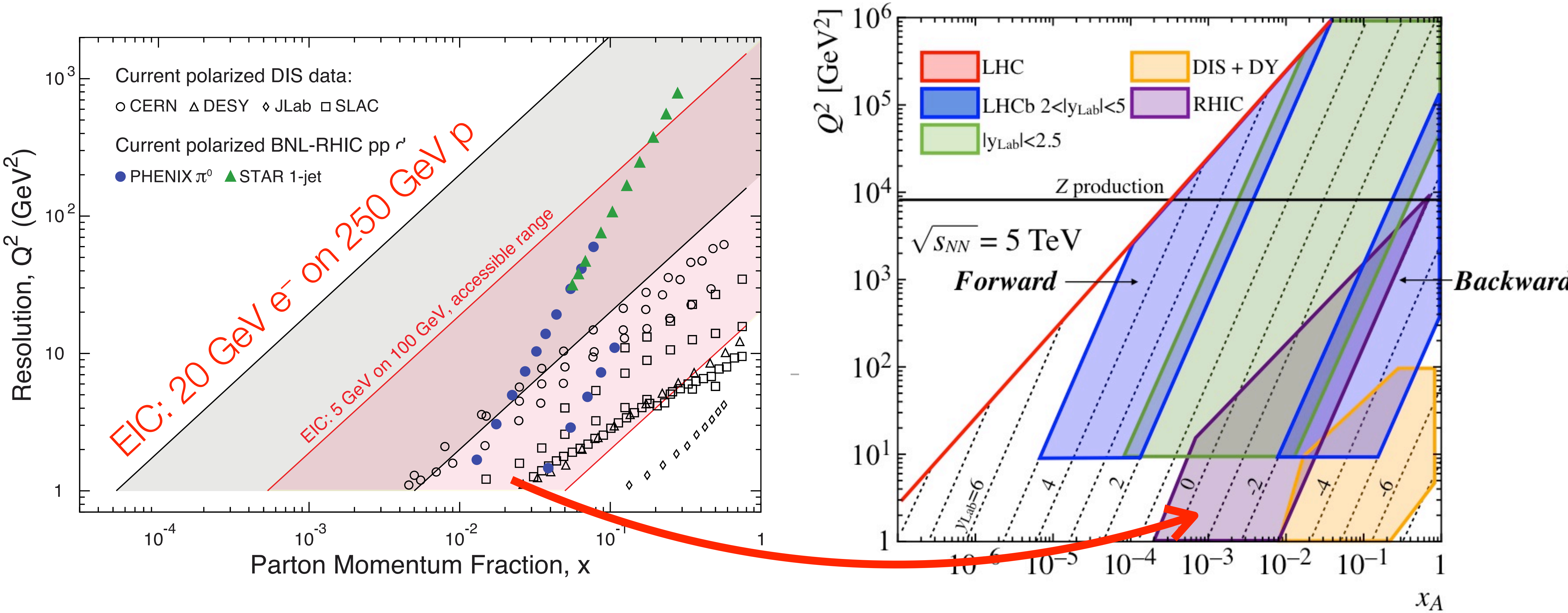
scintillator + SiPMs



central ⟷ peripheral

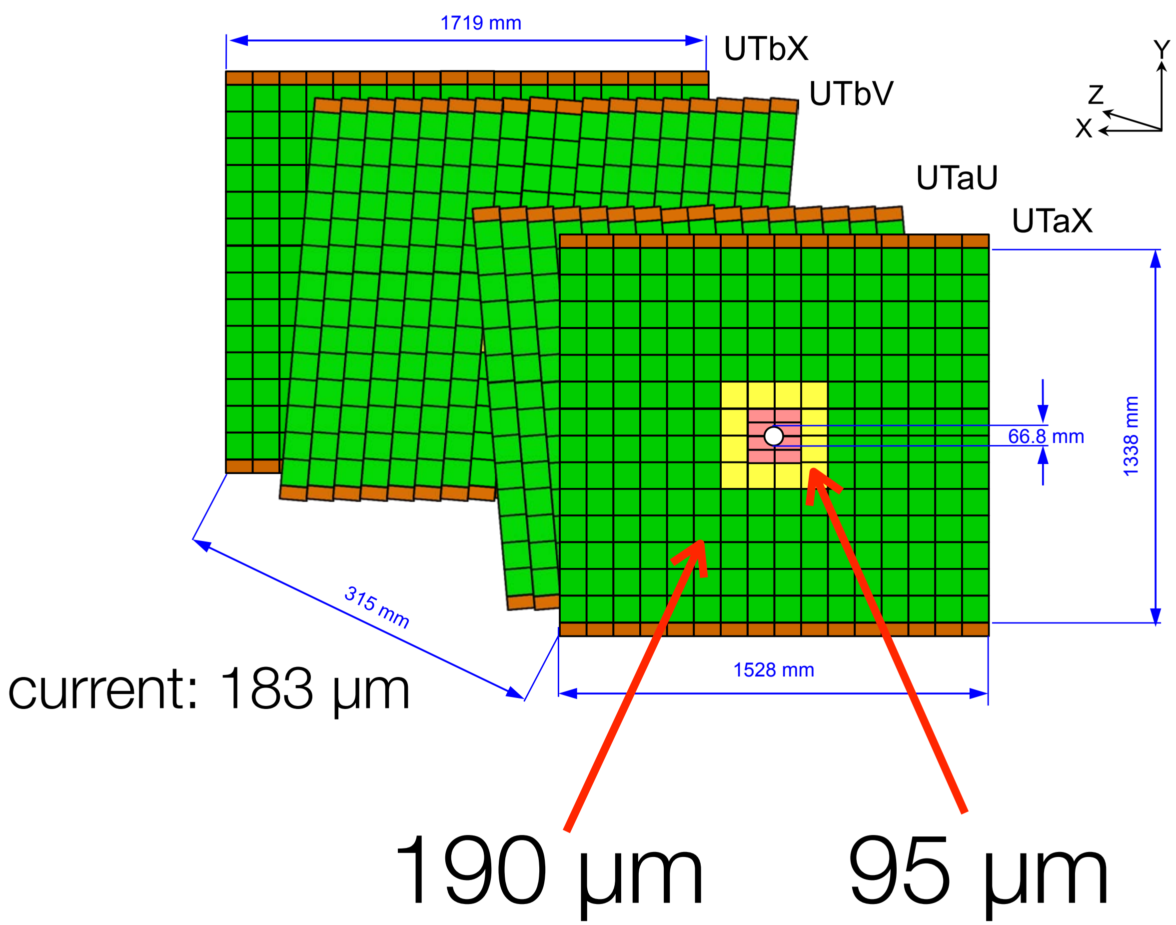
F. Videbaek WWND'15

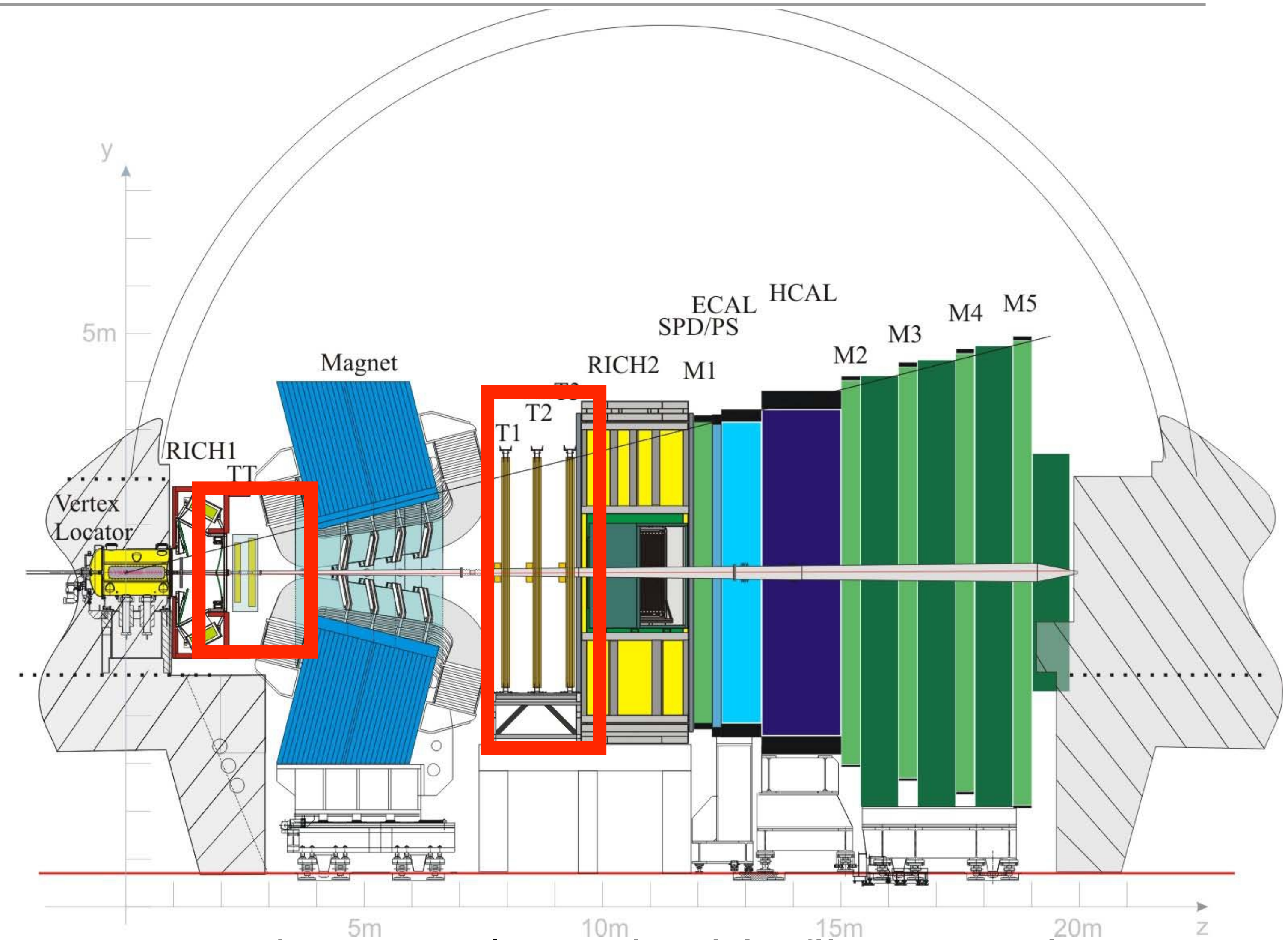
LHCb



design driven by LHCb primary physics goals: very welcome "side benefit" excellent forward & backward capability in p+Pb

LHCb: moderating occupancy effects with granularity





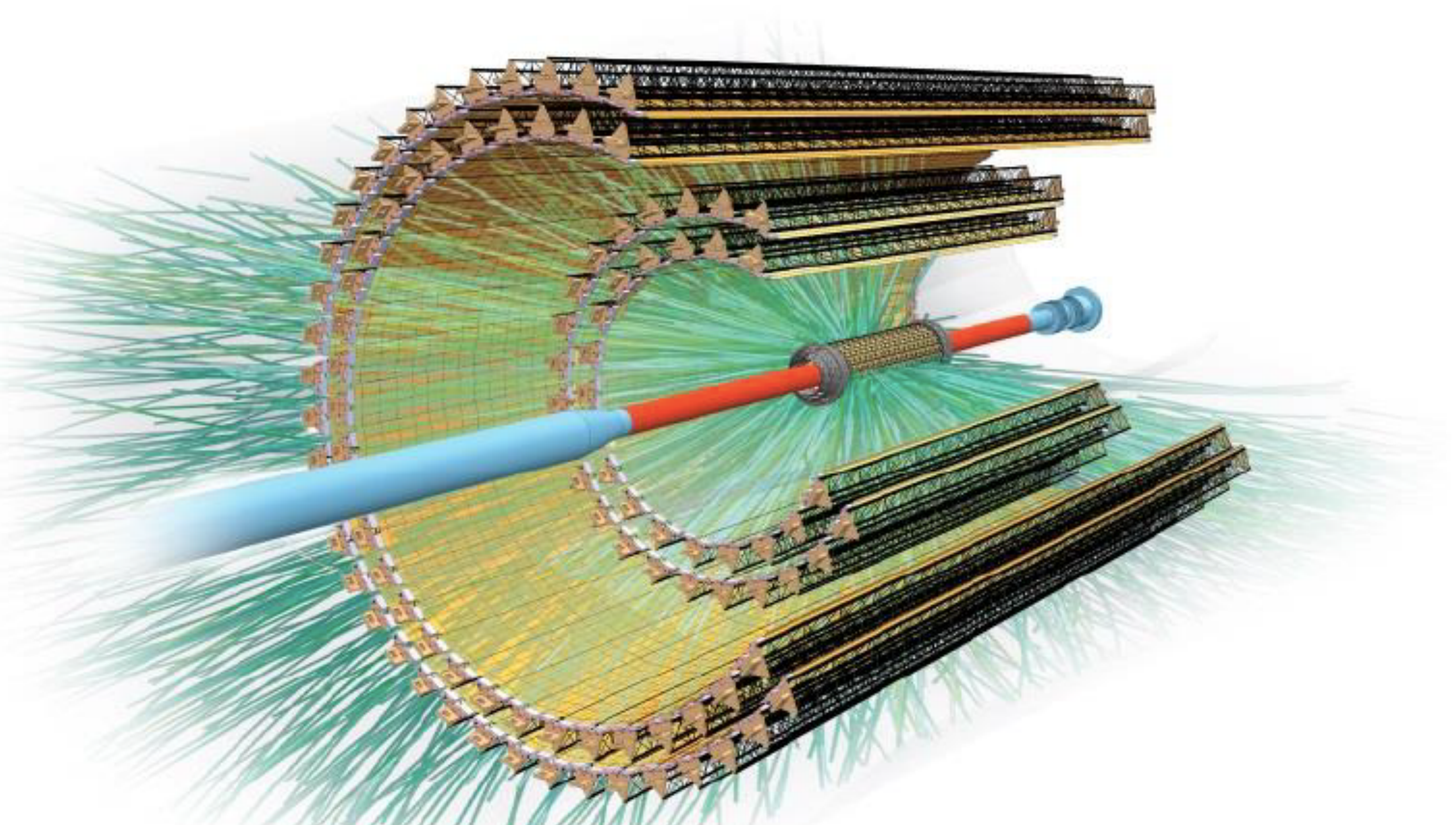
straw tubes replaced with fiber tracker

- LHCb took part in the PbPb running as well
  - Analysis of Pb-Pb data commencing
  - Expected centrality reach at around 50%

– Johan Blouw IS2016

Pb+p configuration puts high multiplicity into acceptance

ALICE upgrades: strategy for exploiting luminosity



MAPS-based inner tracker
(ITS and MFT)

very low mass, very fast, very precise

ITS: read out Pb+Pb > 100 kHz

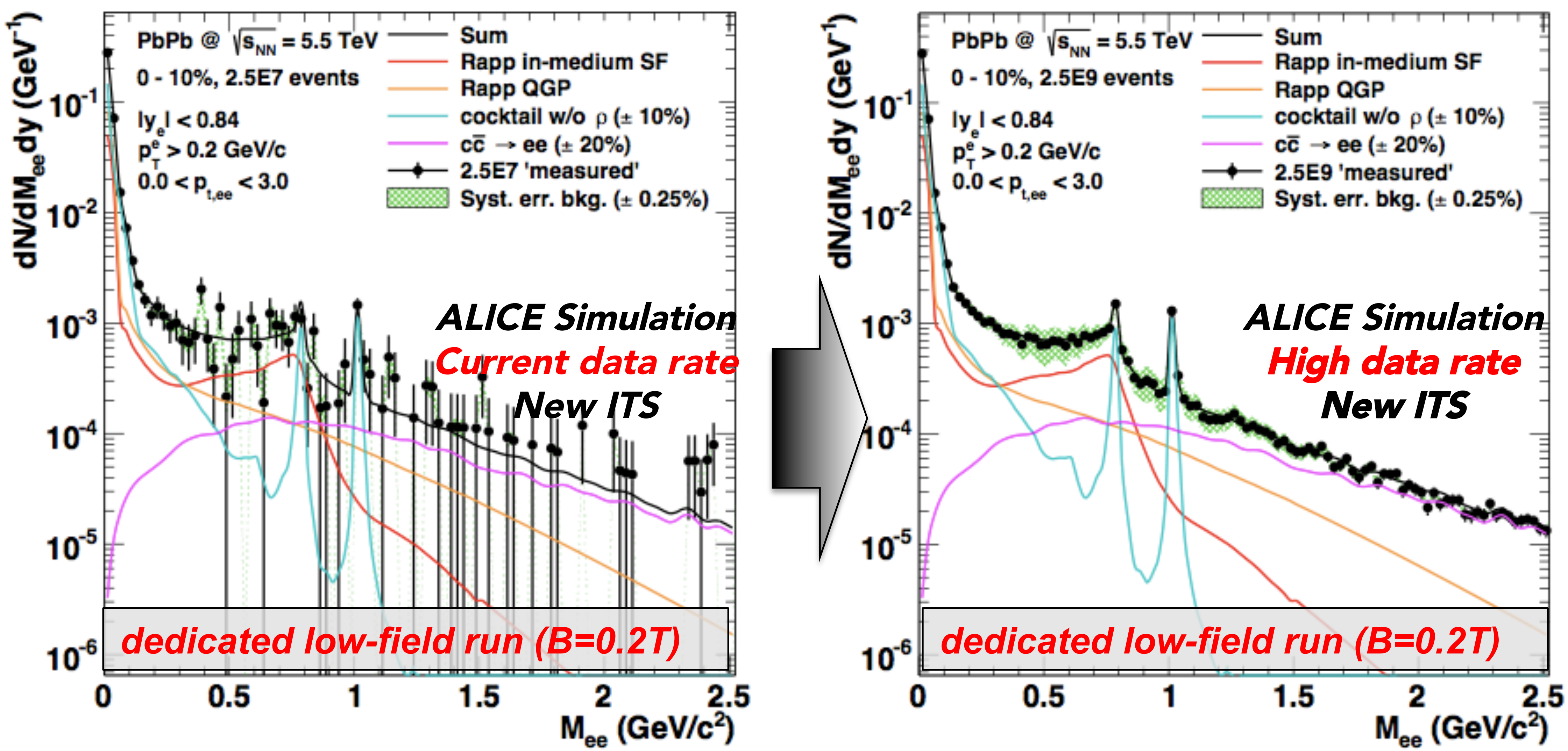
40 μm [z,rϕ] at low p_T = 500 MeV/c

TPC: read out Pb+Pb ~ 50 kHz

capability to employ heavy flavors down to low p_T in manner analogous to light flavors: v_n, R_{AA}

Example: Low mass di-electrons

- Increase statistics
- Suppress combinatorial background (π^0 Dalitz decays, photon conversion)
- Reduce systematic uncertainty from semi-leptonic charm decays
  - Improved secondary vertex resolution



D.Silvermyr, RHIC & AGS Users Mtg (2014)

CMS and ATLAS: employing complex triggers

approach to selecting desired events builds on trigger infrastructure developed for p+p being employed very successfully in Pb+Pb and p+Pb

- Uses $L_{\text{int}} = 515\ \mu\text{b}^{-1}$ of data with a special UPC muon trigger
  - Loose muon L1 trigger
  - Limit of total $E_{\text{T}} < 50$ GeV at L1
  - Maximum of 1 hit in both MBTS inner rings
  - At least one track with 400 MeV measured by high-level trigger tracking algorithm

ATLAS UPC
P. Steinberg IS2016

CMS D^0
G M Innocenti IS2016

"At L1, the triggers relied on minimum bias and jet seeds. At HLT, the D meson trigger ran global track reconstruction, including the reconstruction of displaced tracks of secondary origin. Events were saved if the mass of the D-meson candidates were compatible with the expected mass."

– Kaya Tatar and Krisztián Krajczár (MIT)

poster at LHCC meeting March 2016

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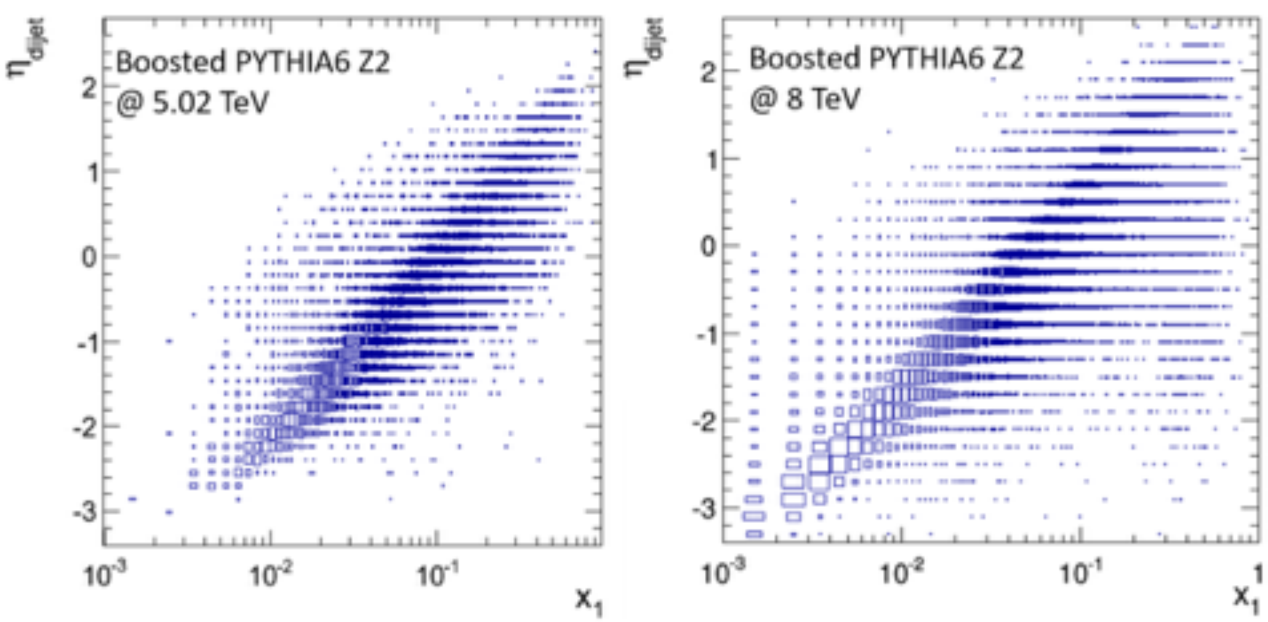
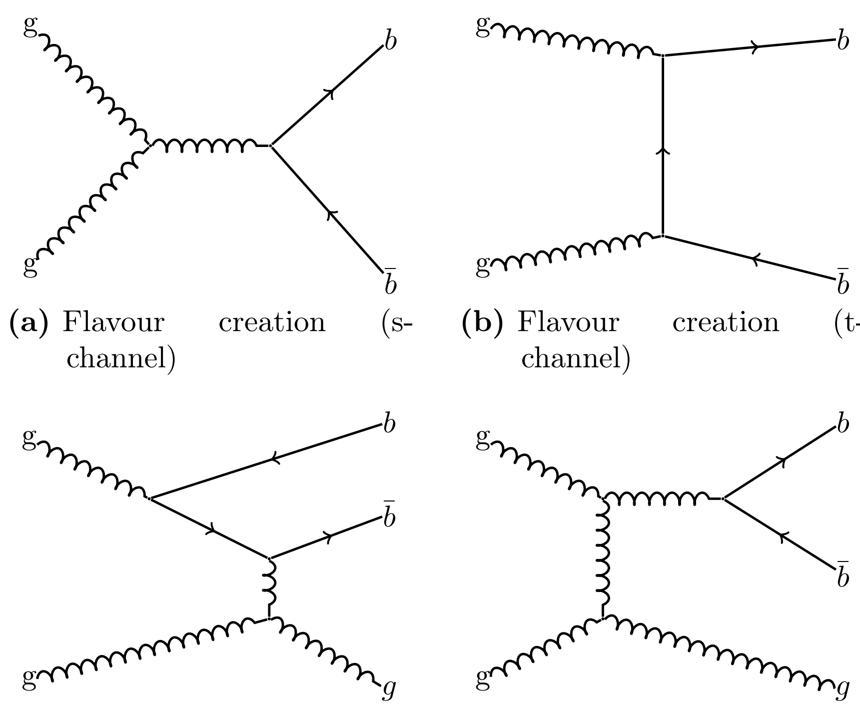
paraphrasing G M, "I think we're collecting all the charm that's being delivered."

Initial stages physics via triggering in p+p, p+Pb

gluon nPDFs through dijet η distribution, vector bosons (W/Z/γ) and di-b-jets



(CMS) Eur. Phys. J. C 74 (2014) 2951



(a) Flavour creation (s-channel)
(b) Flavour creation (t-channel)
(c) Flavour Excitation
(d) Gluon Splitting

Process	N_{evts} at 5.02 TeV	N_{evts} at 8.16 TeV	Gain	Reference
Z bosons	3 900	24 000	6.1	[5]
W bosons	21 000	130 000	6.1	[6]
J/ψ ($p_T > 8.5$ GeV)	13 000	93 000	7.2	[4, 7]
$\psi(2s)$ ($p_T > 8.5$ GeV)	500	3 600	7.2	[7]
$\Upsilon(1s)$ ($p_T > 0$ GeV)	4 500	32 000	7.1	[8]
$\Upsilon(2+3s)$ ($p_T > 0$ GeV)	2 000	14 000	7.0	[8]
DPS: W+ 2 jets ($p_T > 20$ GeV)	980	7 000	7.1	[9, 10]
Drell–Yan ($p_T^1 > 9$ GeV, $p_T^2 > 6$ GeV)	700	4 000	5.7	[11]
$\gamma\gamma$ ($p_T^1 > 25$ GeV, $p_T^2 > 22$ GeV)	150	1 000	6.7	[12]
4 jets ($p_T^1 > 100$ GeV, $p_T^{2,3,4} > 64$ GeV)	–	190 000	–	[13]
tt–bar	7	90	13.3	[14, 15]

ATLAS input to LHCC, May 2016

Complex events – e.g. 4-jet sensitivity to MPI
Blok, Strikman, Wiedemann, EPJ *C*, 73(6):1, 2013

Meanwhile, at RHIC in the 2020s …

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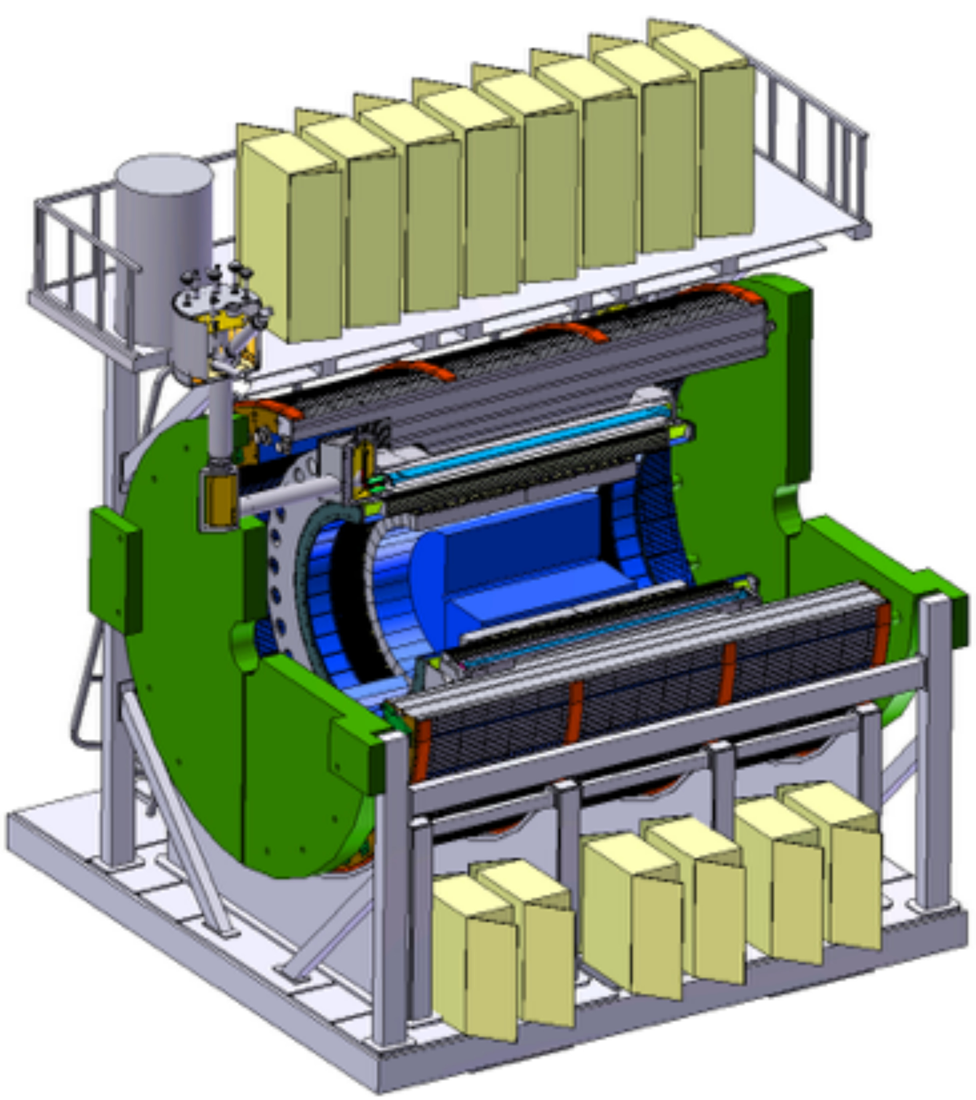
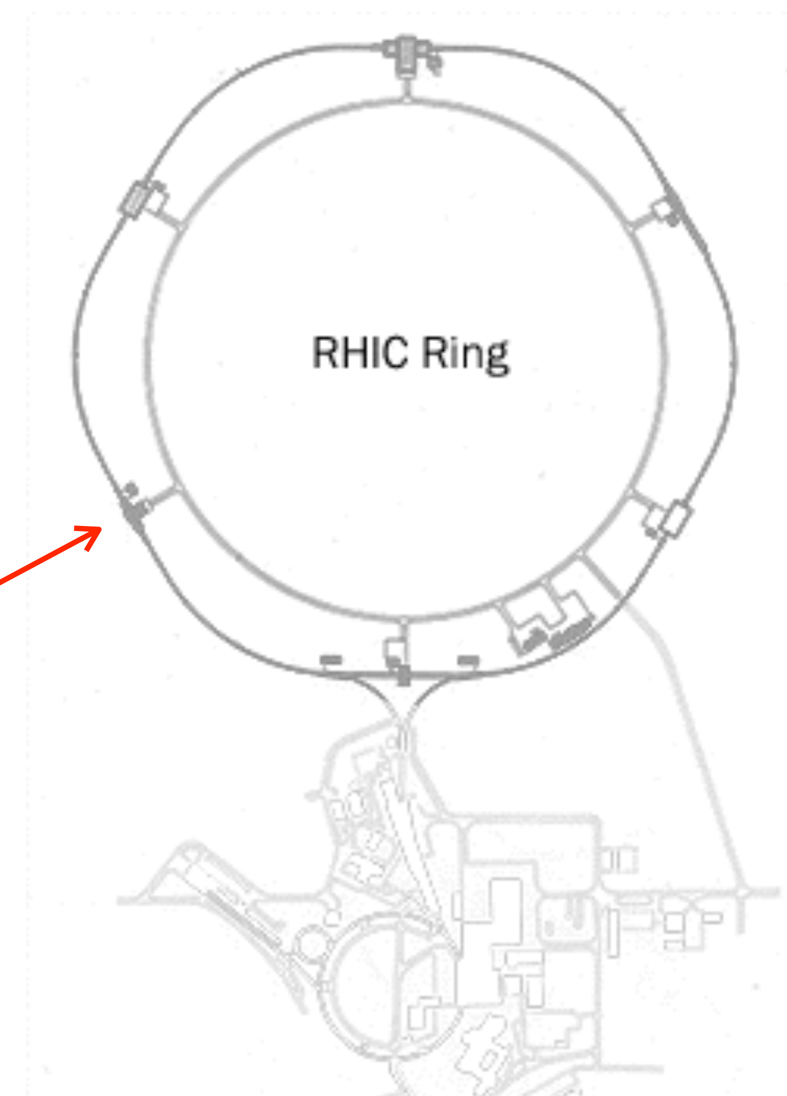
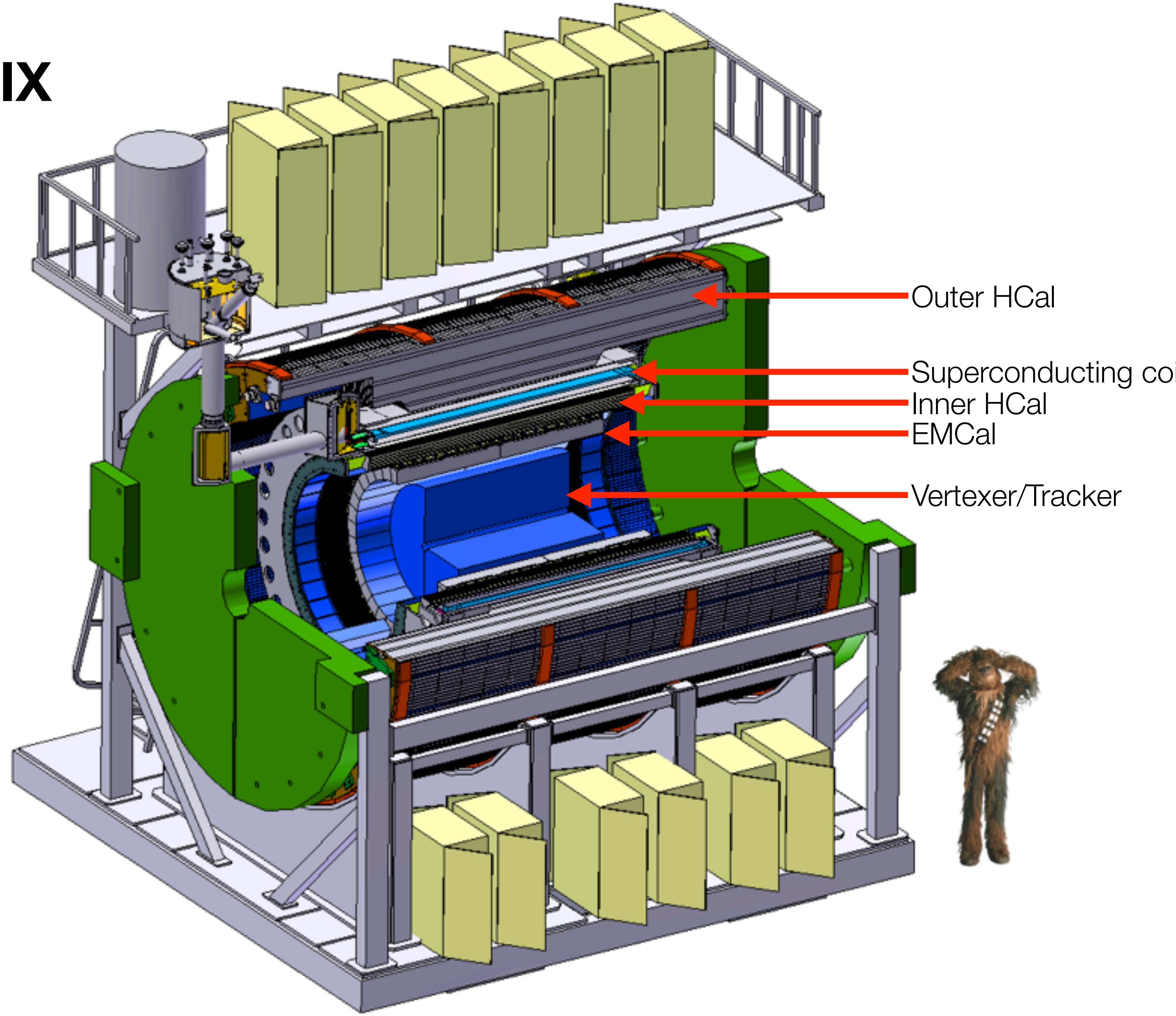
sPHENIX: A fantastic[*] high-rate capable detector at RHIC IP8, built around the former BaBar 1.5 T superconducting solenoid, with full electromagnetic and hadronic calorimetry and precision tracking and vertexing, with a core physics program focused on light and heavy-flavor jets, direct photons, Upsilons and their correlations in p+p, p+A, and A+A to study the underlying dynamics of the QGP – physics delivered by 22 weeks of Au+Au, 10 weeks each of p+p and p+A (@ 200 GeV).





[*] *full disclosure:* co-spokespersons G. Roland, D. Morrison

sPHENIX

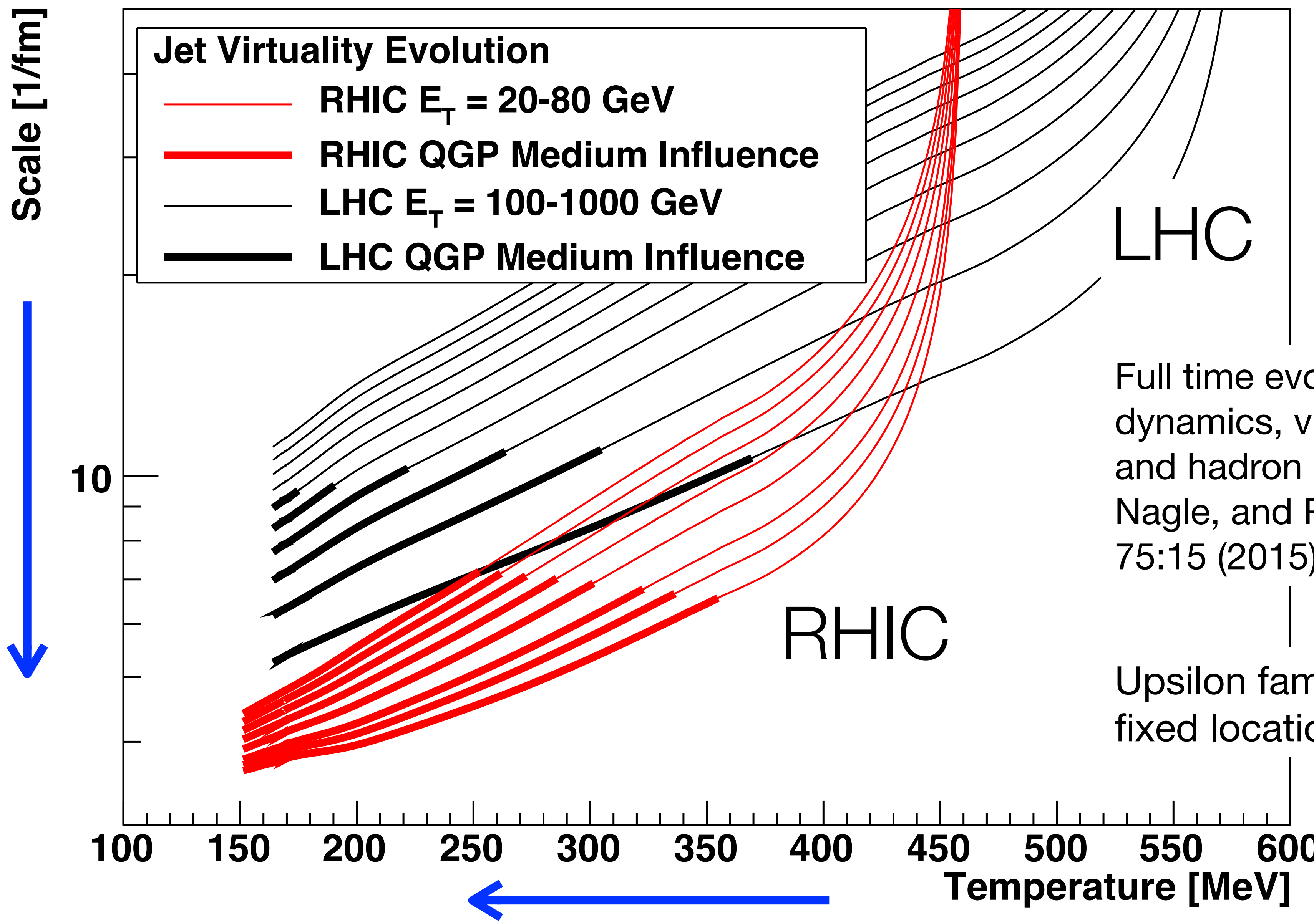

Outer HCal
Superconducting coil
Inner HCal
EMCal
Vertexer/Tracker

“q-hat corrections, Sudakov, 40 GeV jets, sPHENIX”

– from my notes of A. Mueller’s IS2016 talk

sPHENIX in one plot

Initial hard scattered parton virtuality in units of 1/fm as a function of the local temperature of the QGP medium

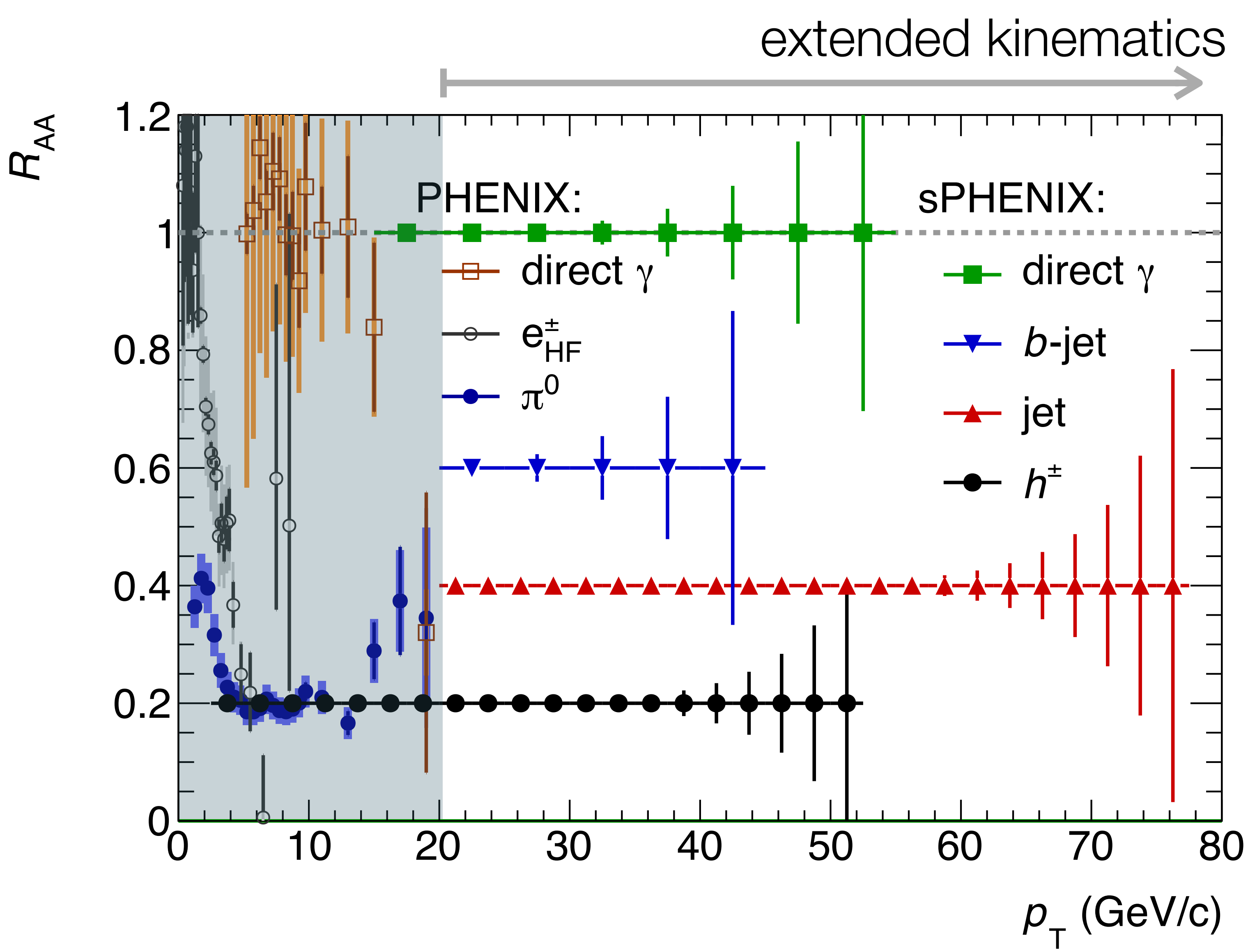


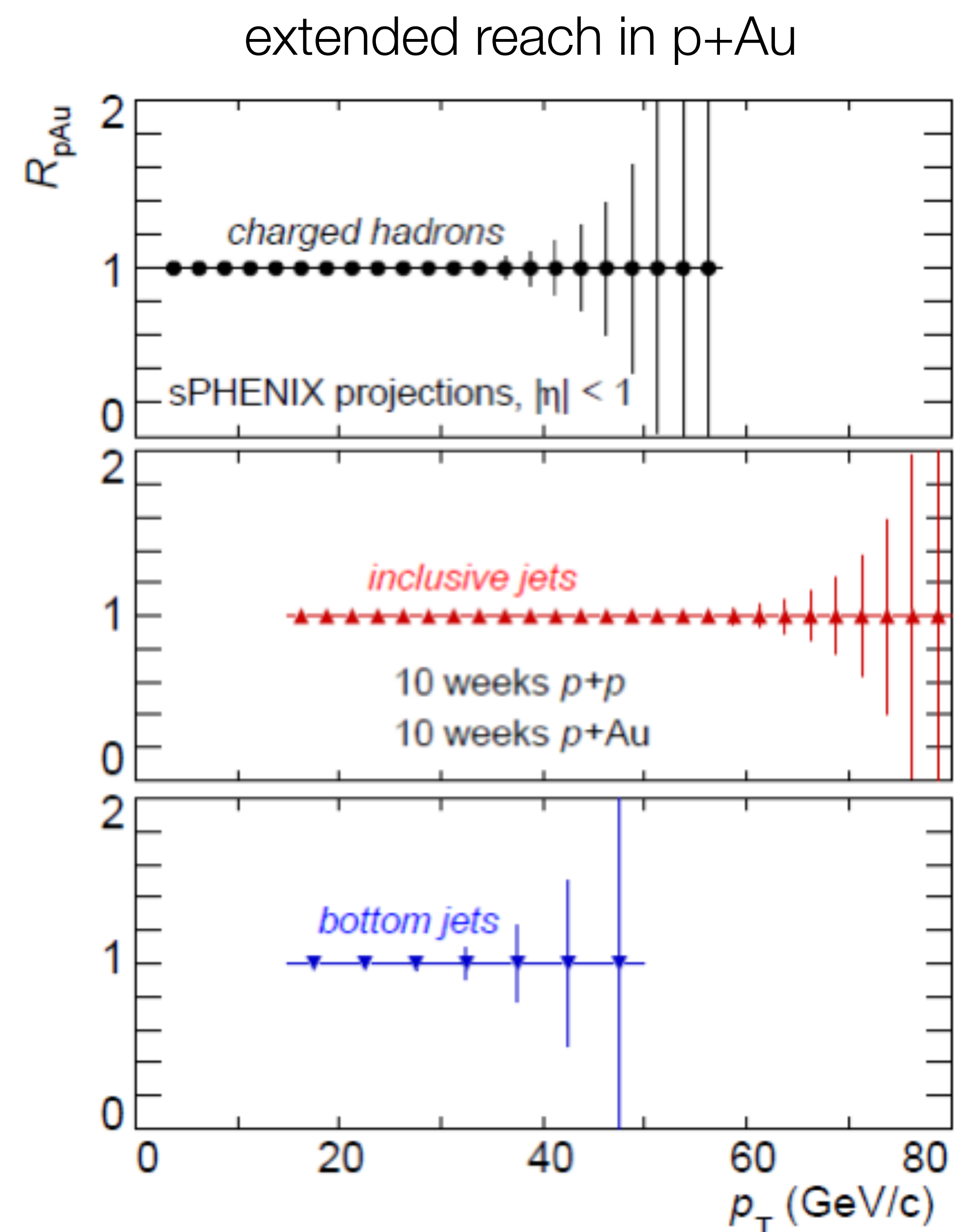
Full time evolution of pre-equilibrium dynamics, viscous hydrodynamics, and hadron cascade M. Habich, J. Nagle, and P. Romatschke, EPJC, 75:15 (2015)

Upsilon family 1S, 2S, 3S establish fixed locations in this space

Vacuum virtuality evolution initially, with medium influence becoming significant as virtuality of parton shower and medium become comparable

sPHENIX reach exploits RHIC luminosity

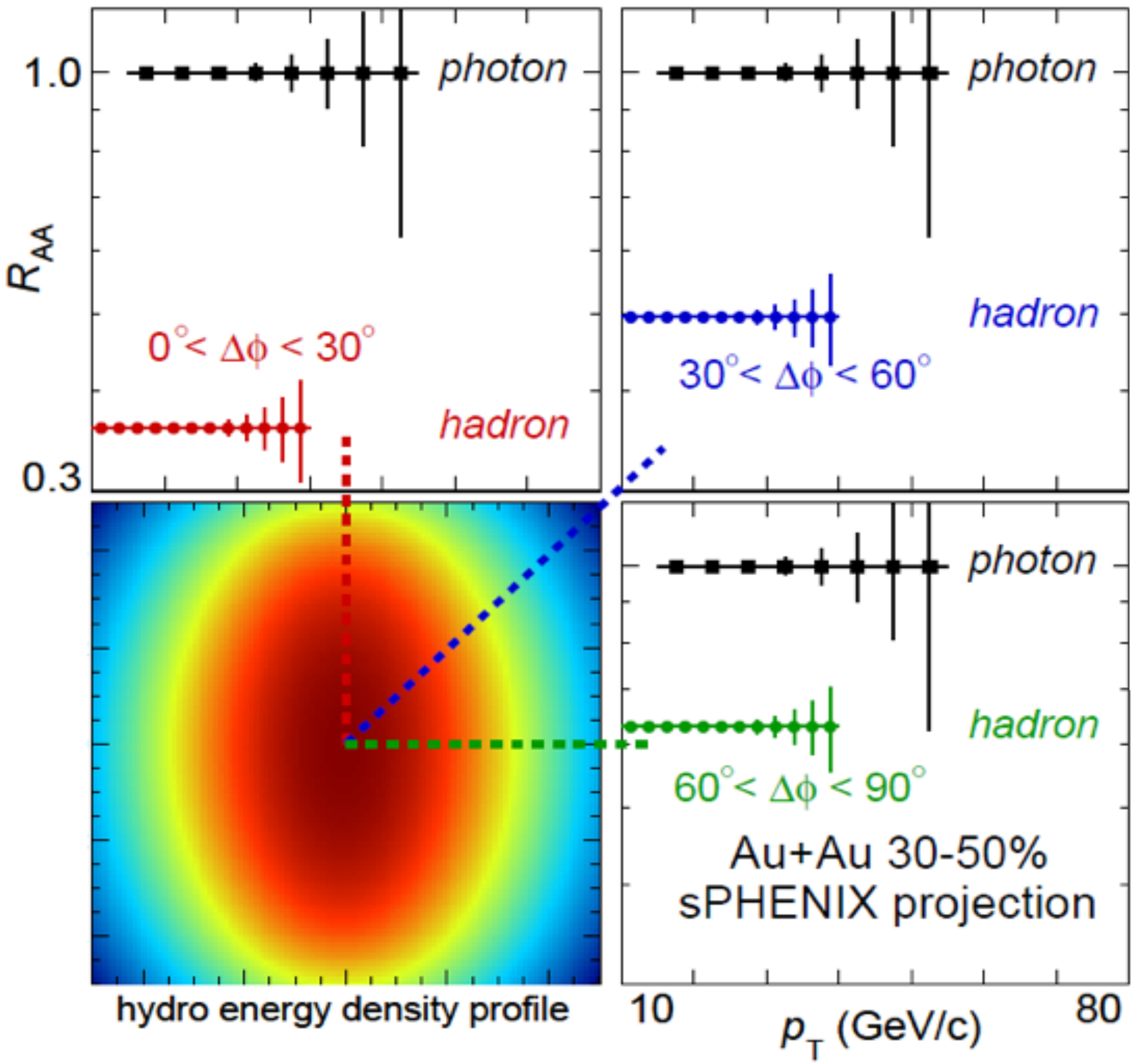




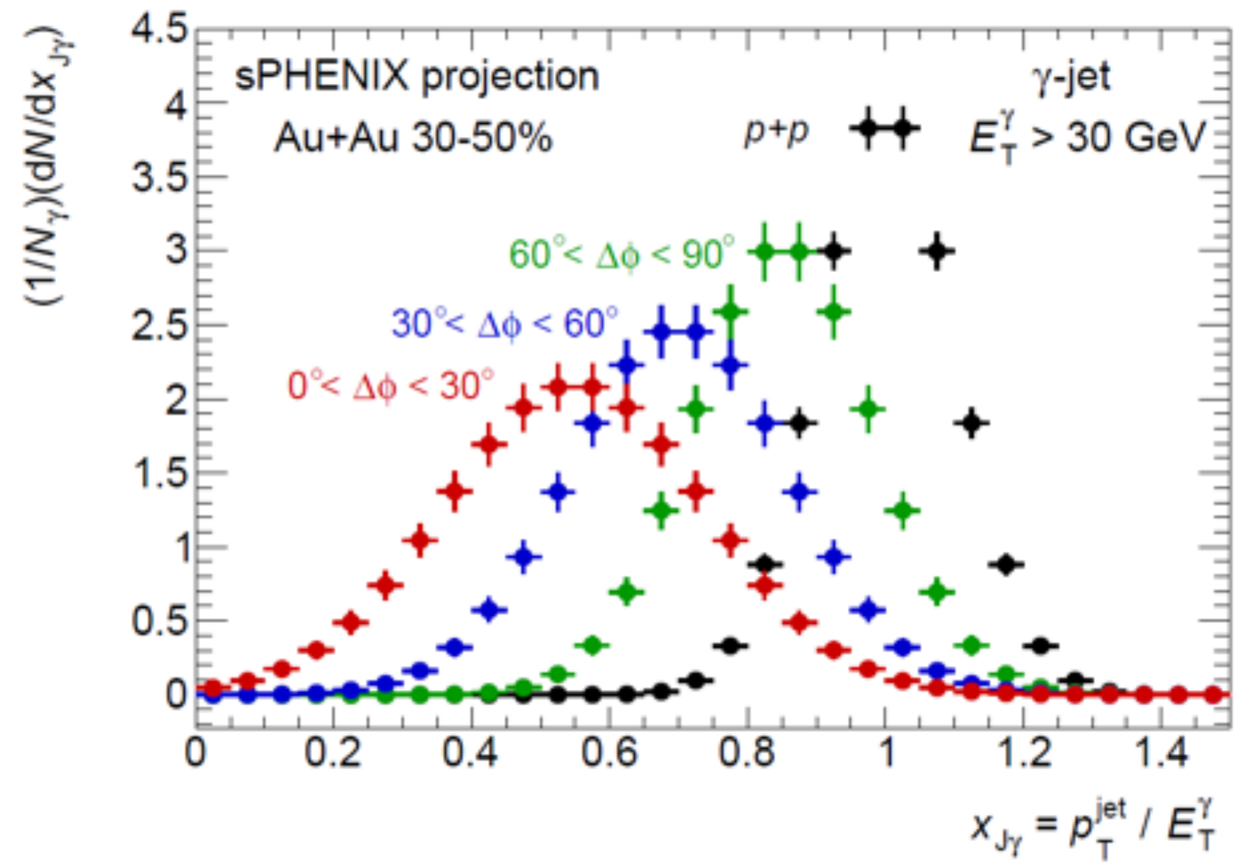
for measurements able to use full vertex range
– can sample 0.6 trillion events

RHIC luminosity: more differential measurements

direct photons, charged hadrons

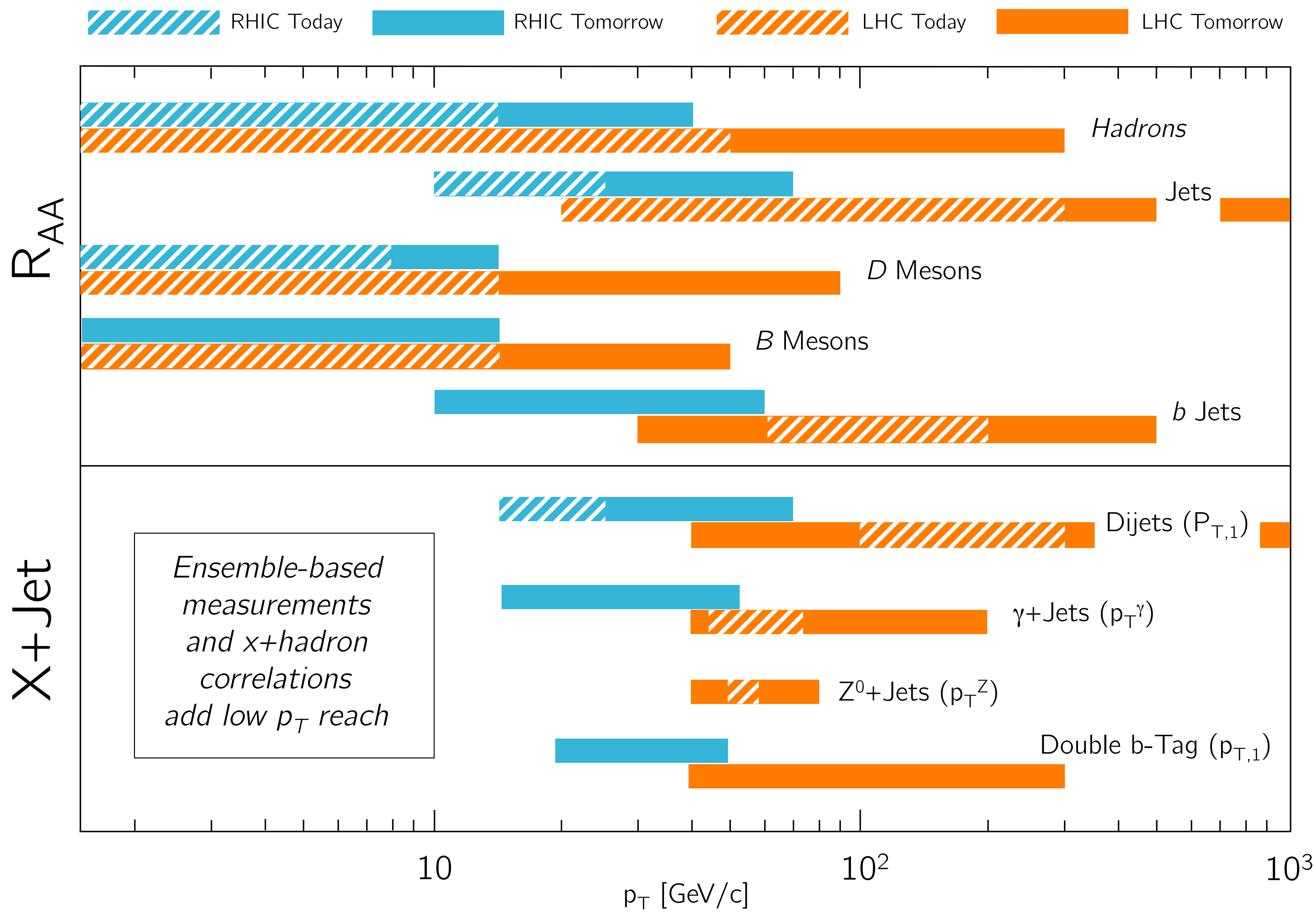


γ-jet



statistical uncertainties based on sPHENIX run plan

RHIC/LHC measurements in 2020s



Looking forward to the near future

- detectors: as you'd hope, lower mass, higher granularity, larger η coverage, faster readout – but these represent major technical accomplishments
- triggering: much more complex decisions possible – utility is already on display
- fully exploiting luminosity – complementary strategies being pursued, high throughput readout and/or highly complex triggering
- physics relevant to initial stages particularly benefits from these developments
- PHENIX ending data taking; sPHENIX preparing to move in