Experiments with Hard Probes in the Near Future

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what motivates us?

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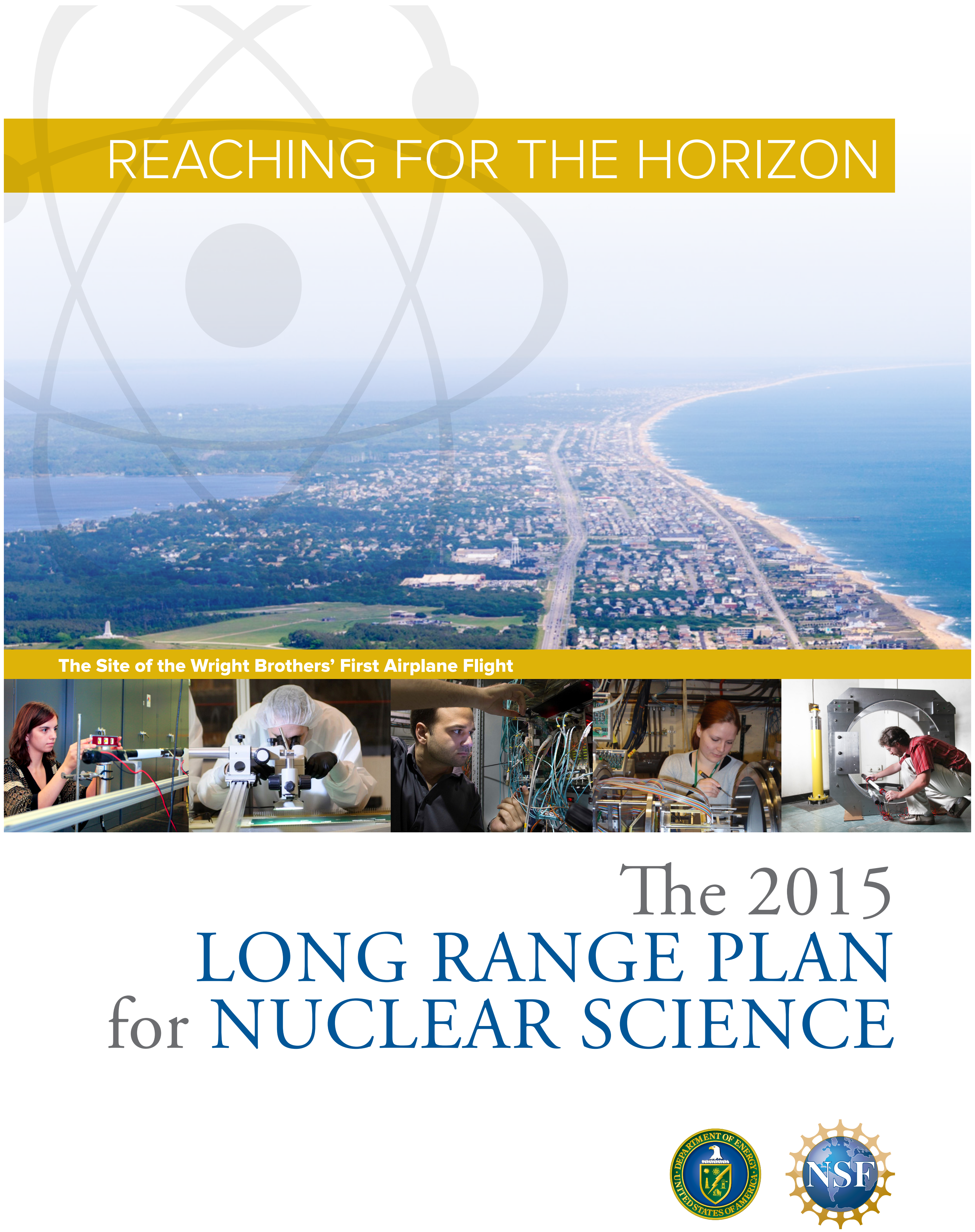
from description to understanding



"To understand the workings of the QGP, there is no substitute for microscopy. We know that if we had a sufficiently powerful microscope that could resolve the structure of QGP on length scales, say a thousand times smaller than the size of a proton, what we would see are quarks and gluons interacting only weakly with each other. **The grand challenge for this field in the decade to come is to understand how these quarks and gluons conspire to form a nearly perfect liquid."**

what do we need to measure?

Long Range Plan: "Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales. The complementarity of the two facilities is essential to this goal

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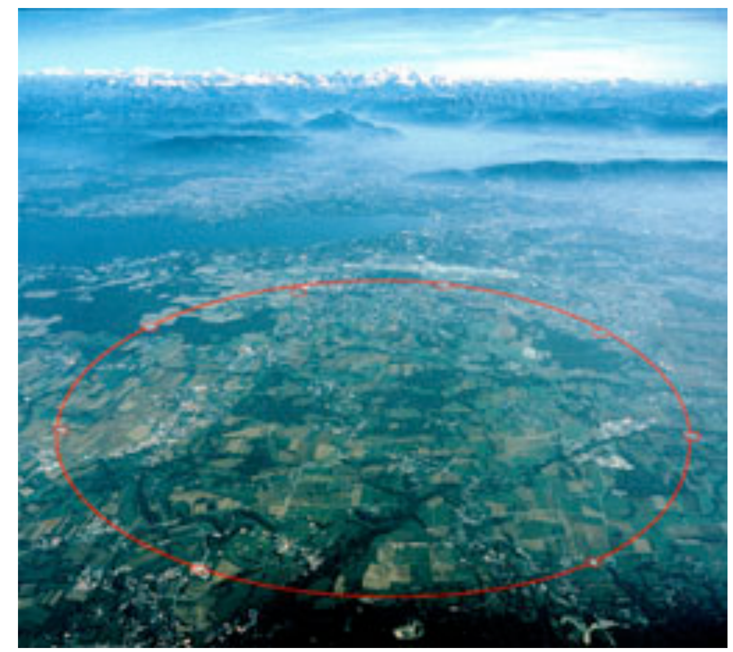

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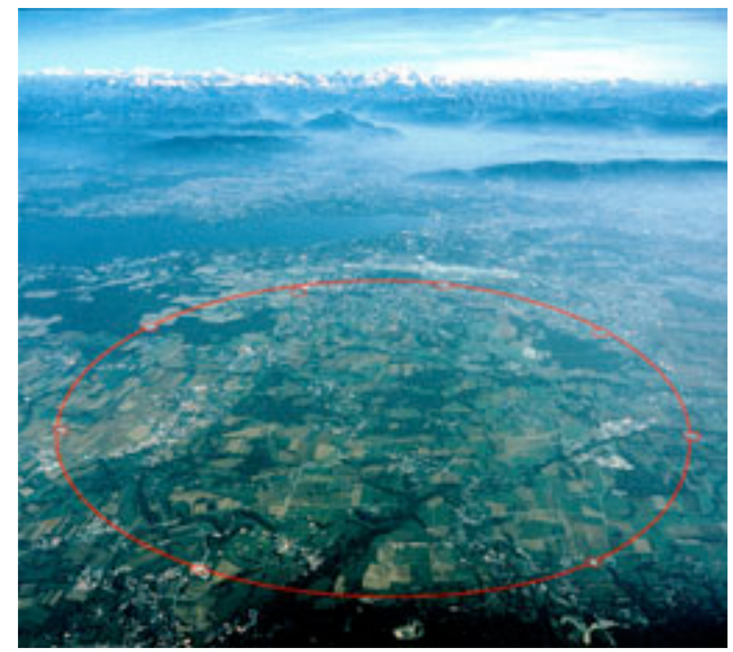
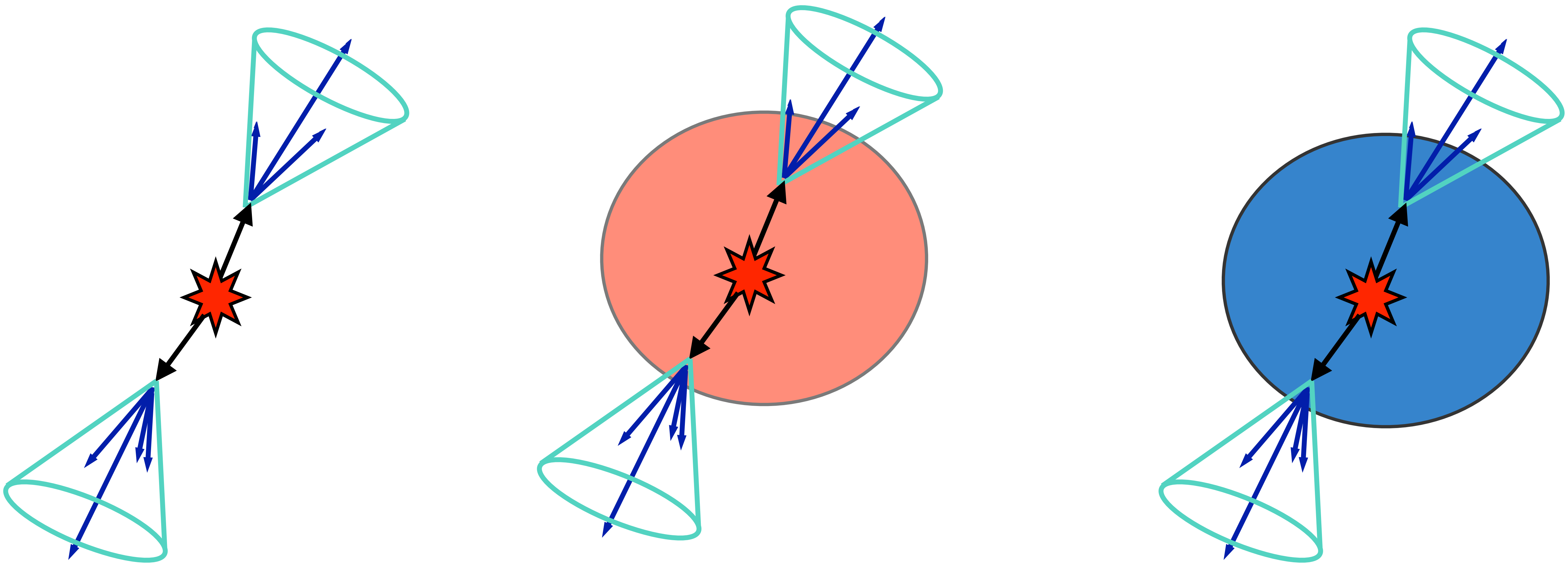


- jets, upsilons and photons with high statistics over a wide kinematic and collision energy range
  - jets from 20 GeV → 1 TeV
  - collision energy from 200 GeV → 5.5 TeV
  - luminosity for precision measurements at both facilities

why two facilities?



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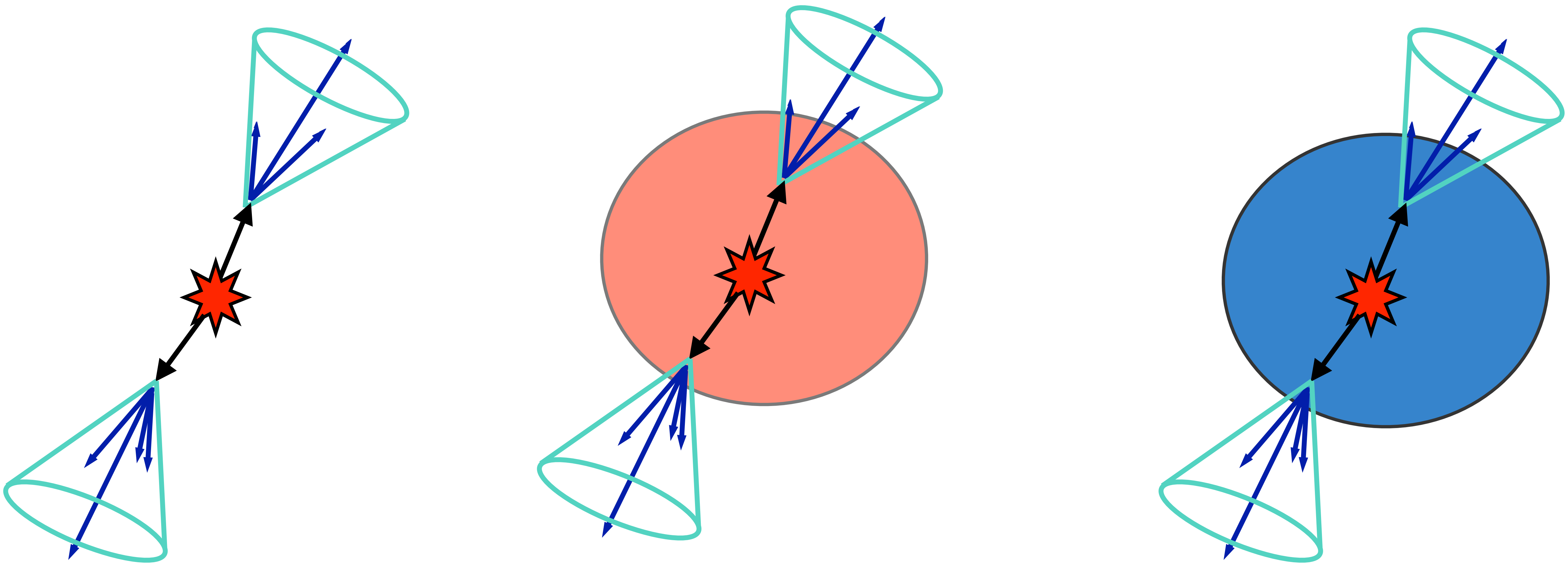

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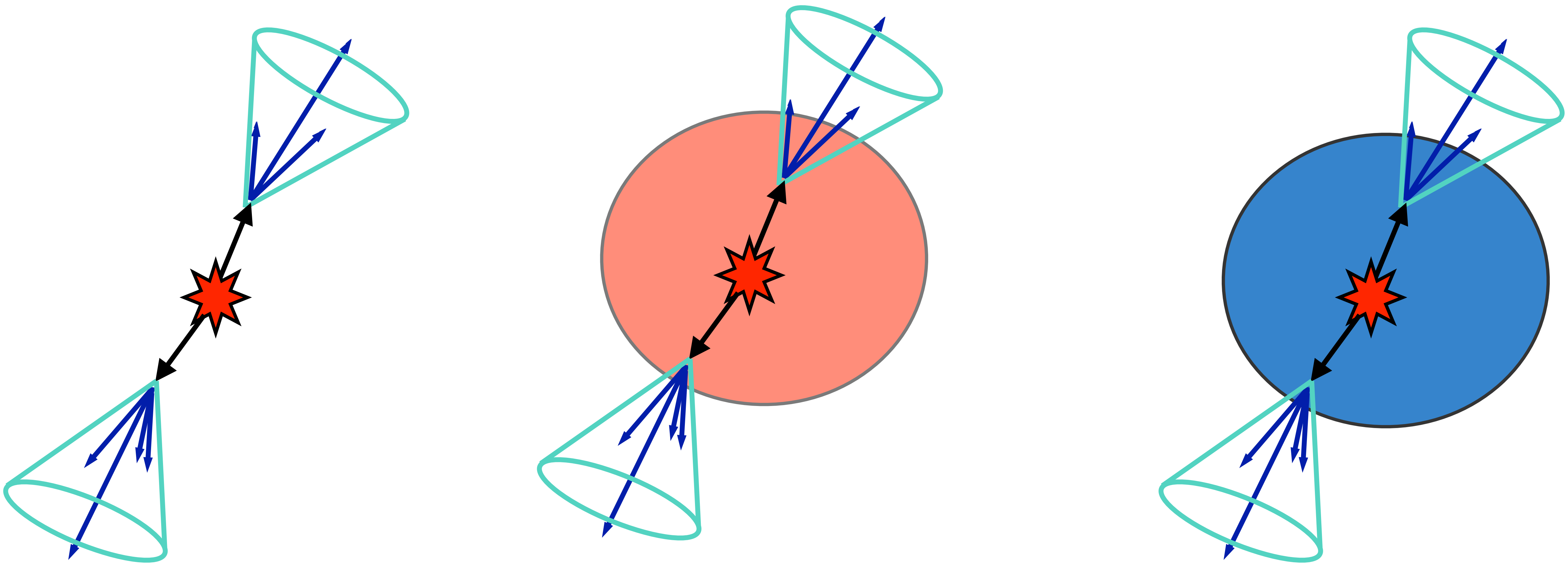

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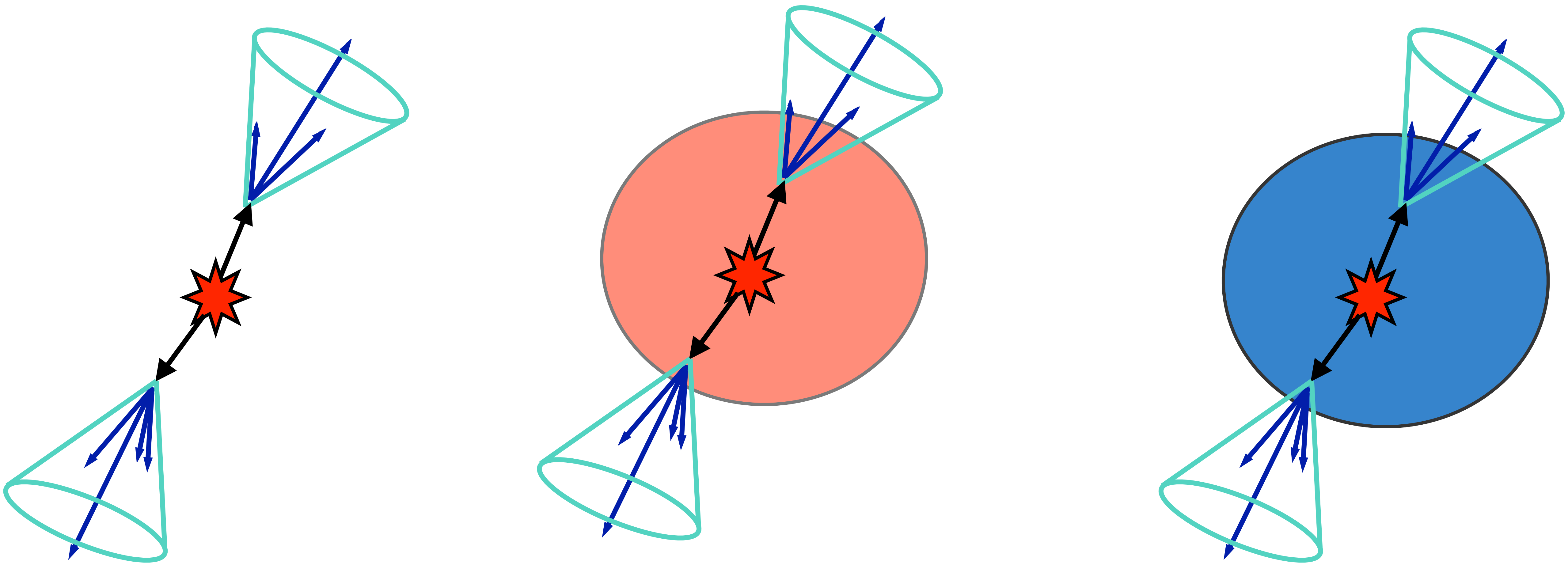

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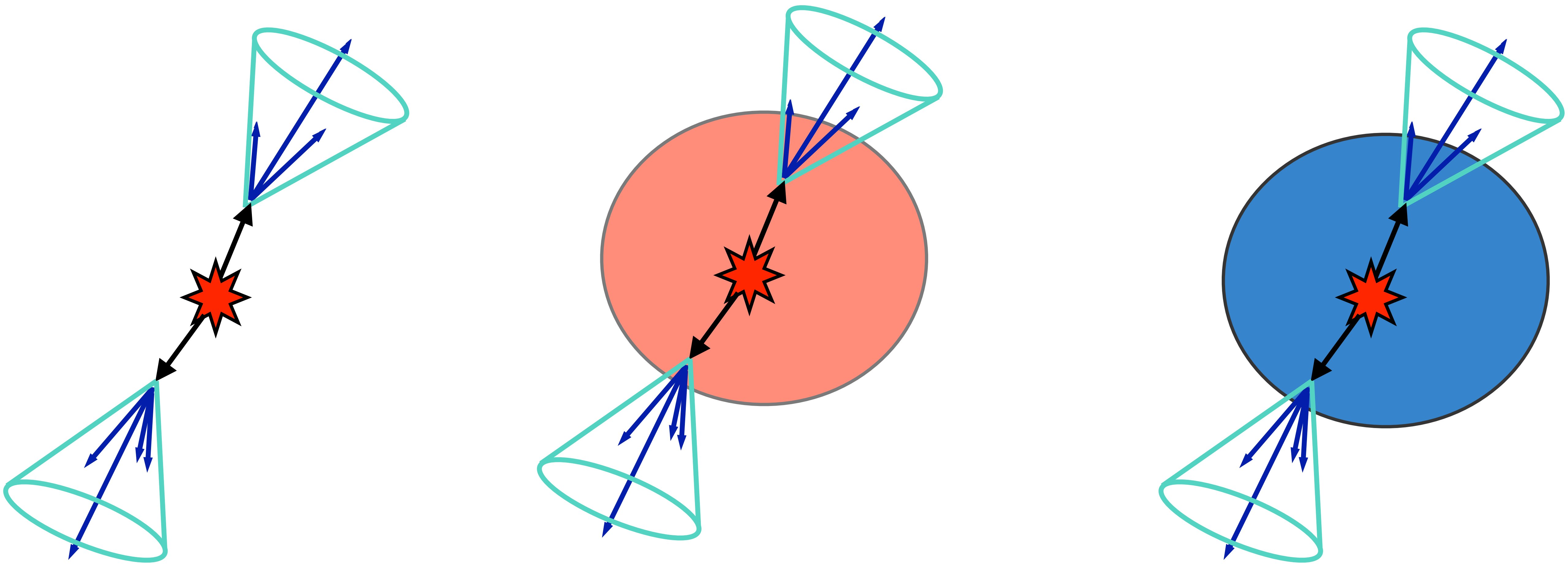

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- the jets are differently sensitive to the medium through their virtuality evolution

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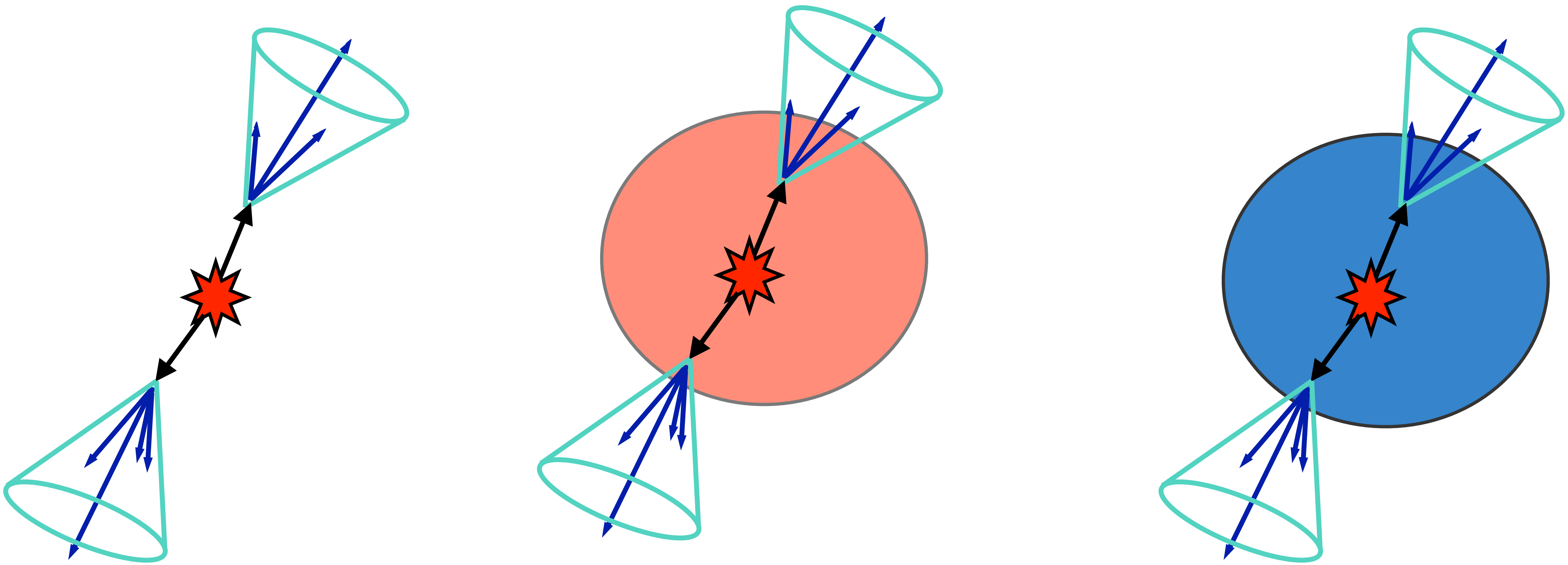

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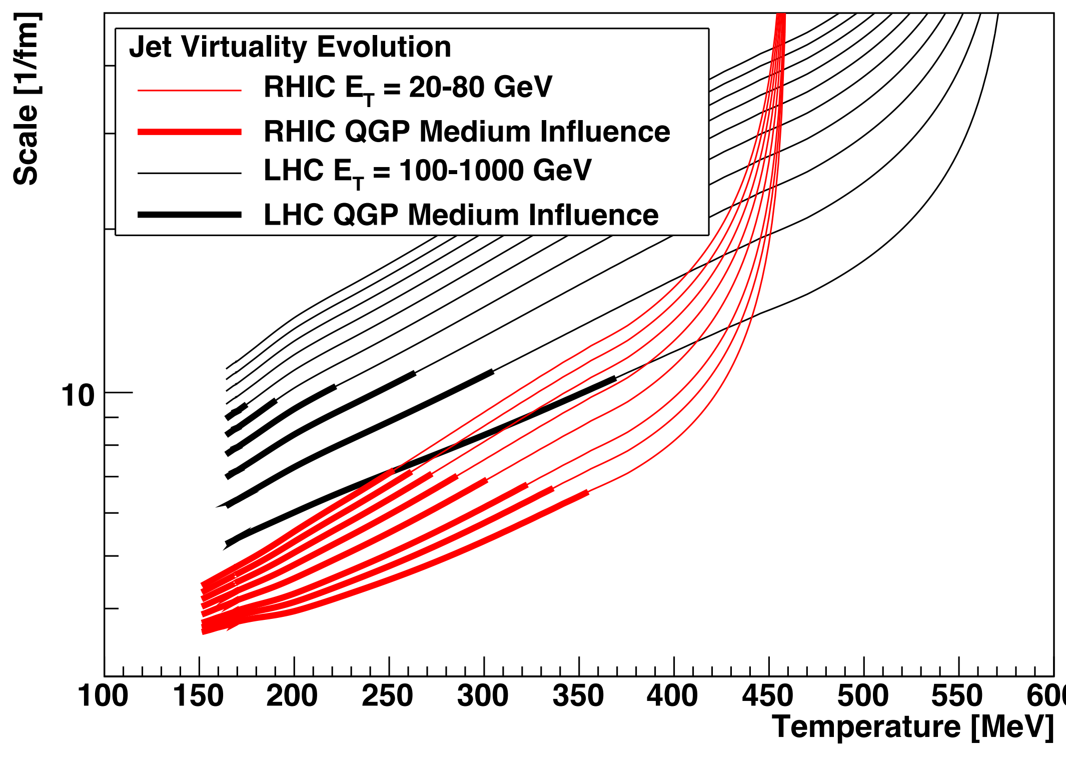
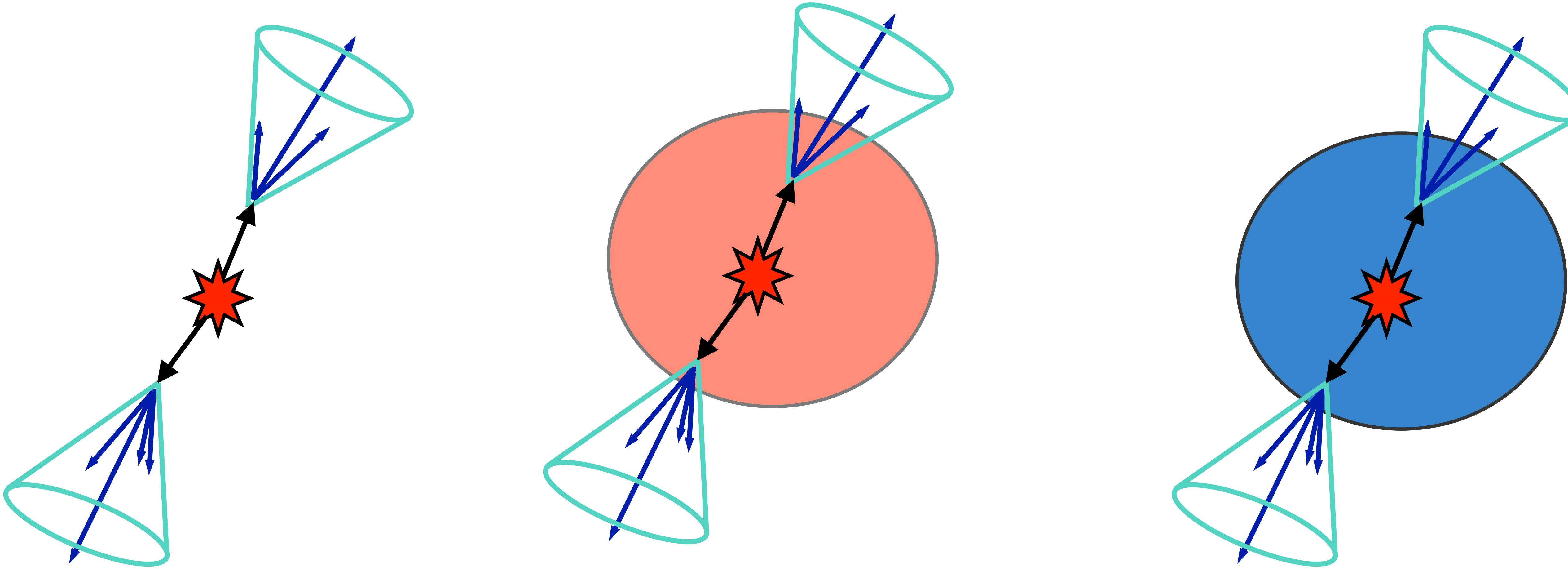


goal



comprehensive set of hard probes observables at RHIC and the LHC along with theoretical models to constrain the microscopic interactions between jets and the QGP

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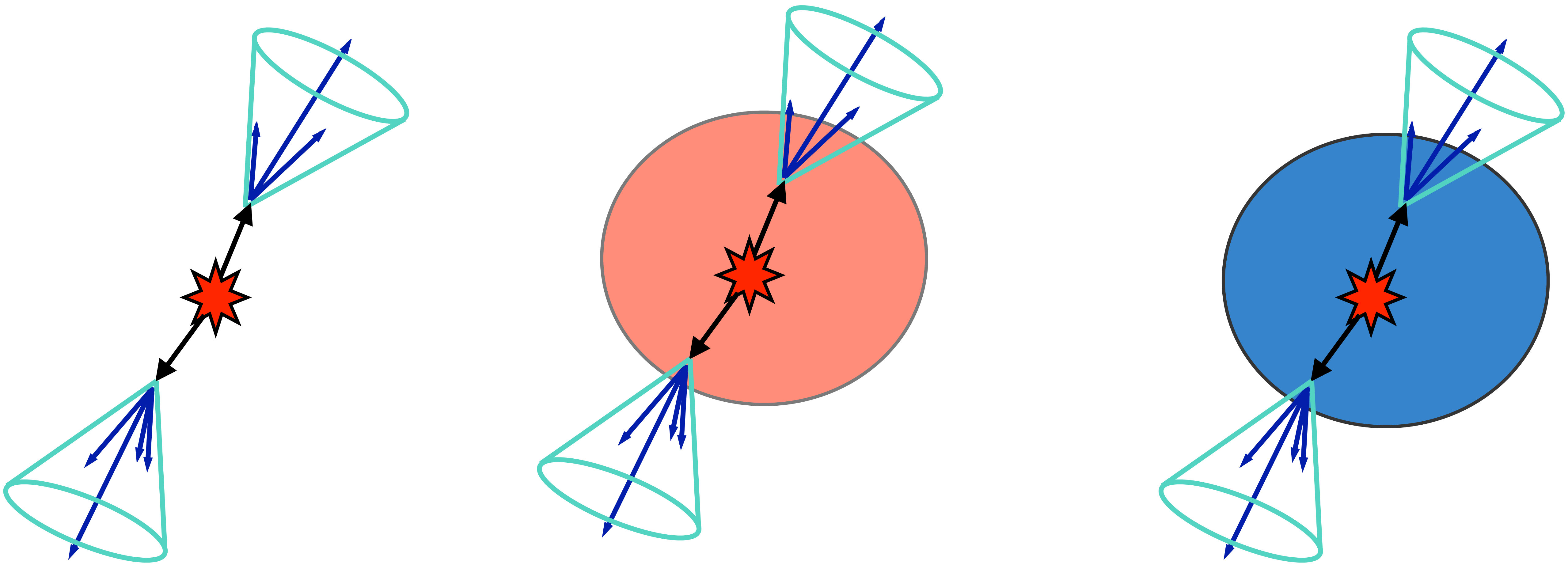

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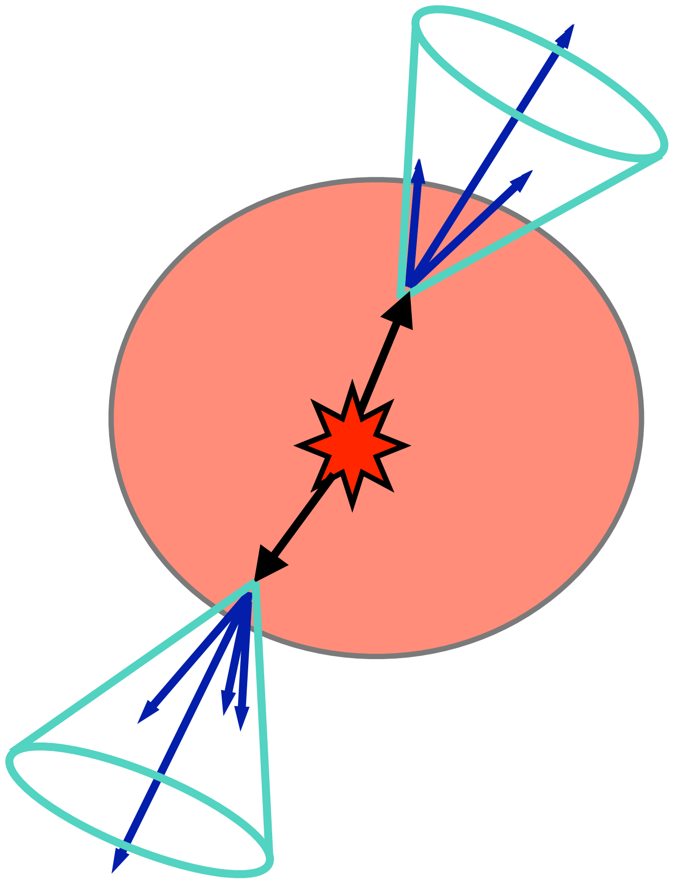
what are we to measure about these jets?



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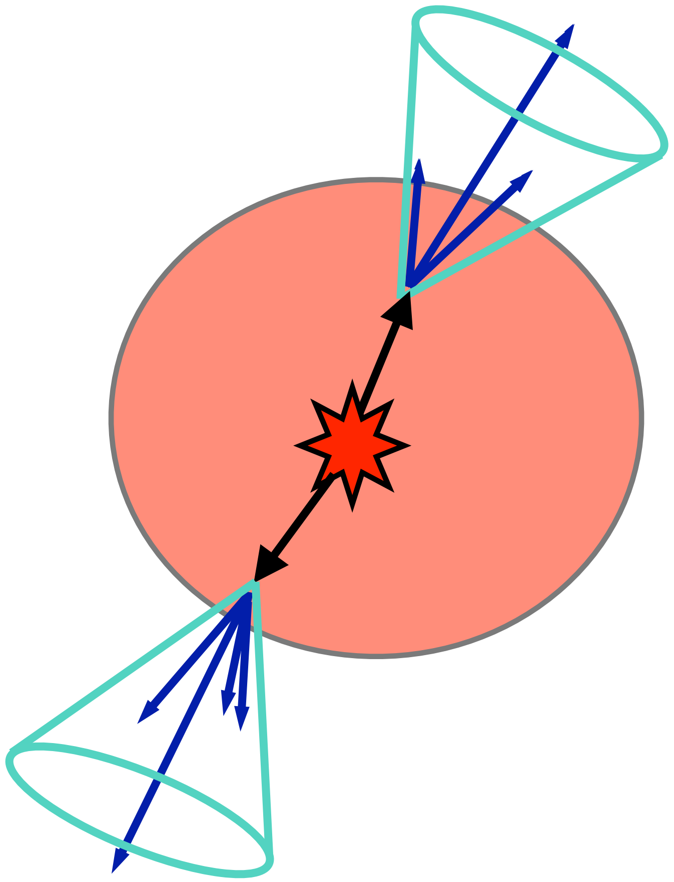

- rate, balance, (sub)structure, correlations…
  - how these depend on how we can classify the jets,
  - how they look different than they do in pp collisions..

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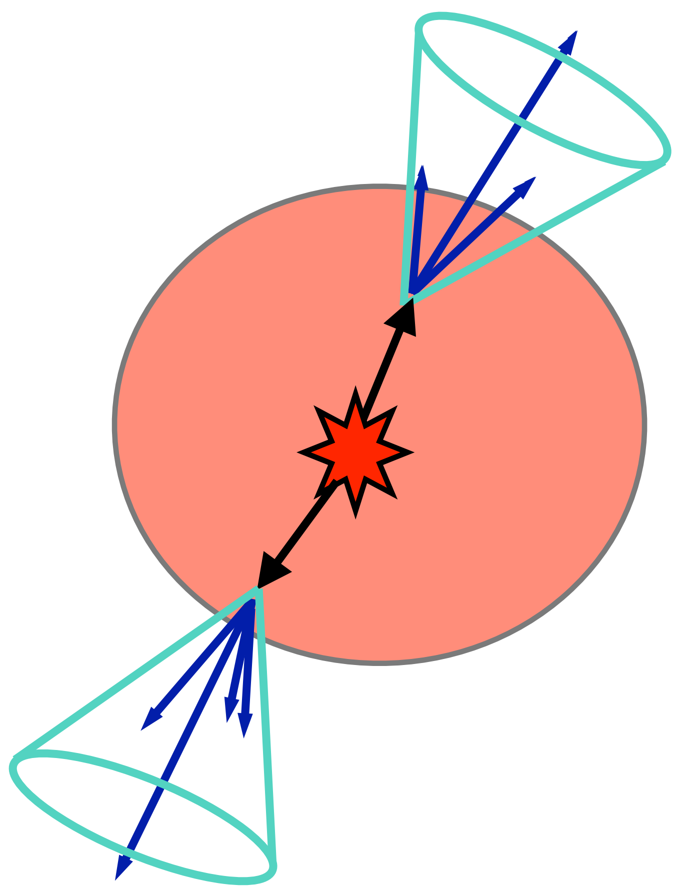

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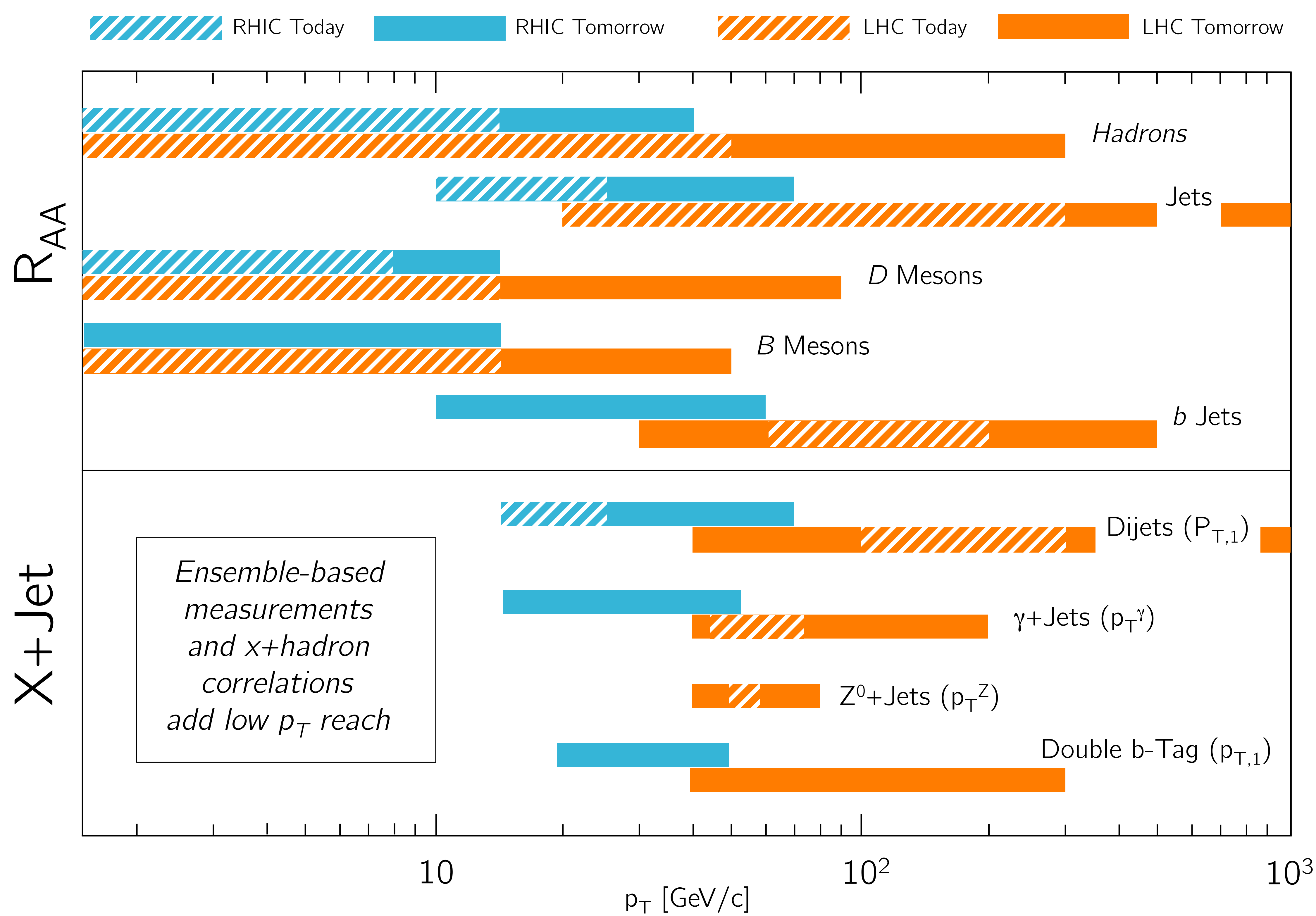
we have a lot of measurements at the LHC & RHIC so our question is: *what further improvements do we need for a quantitative understanding?*

an evolving landscape



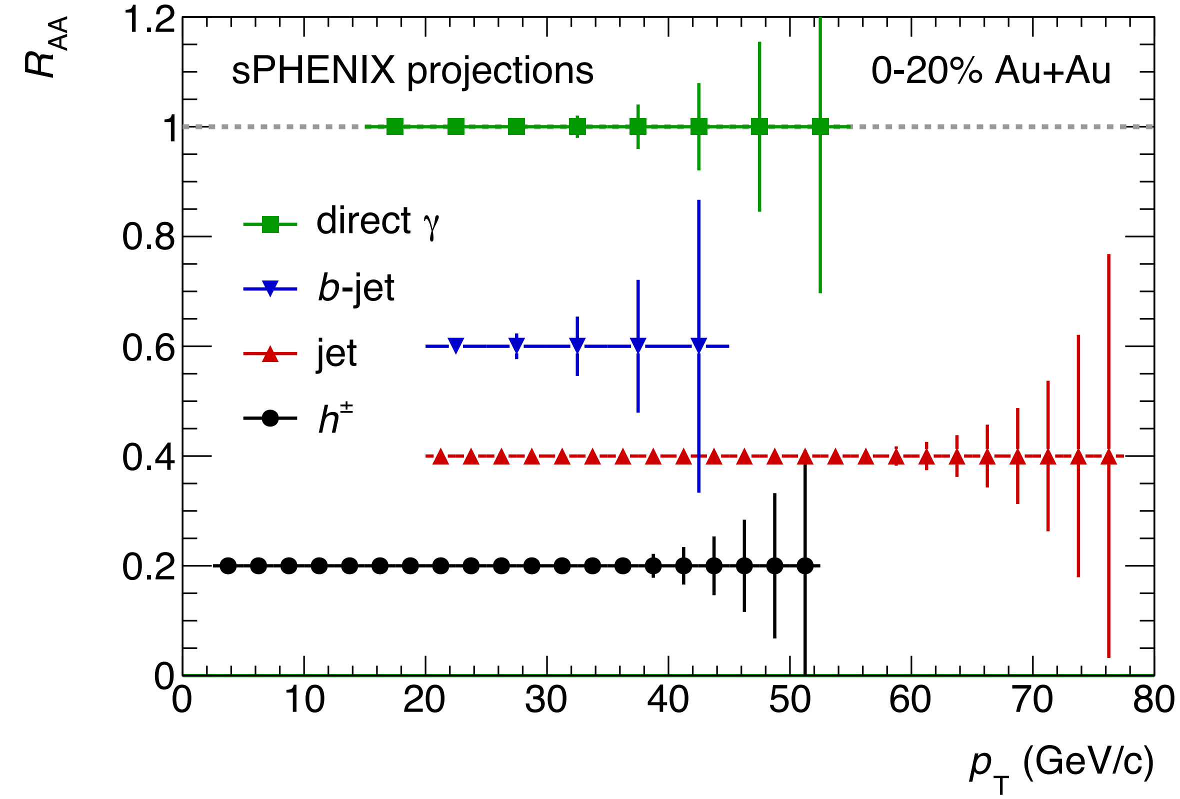
LHC Run 2/3 & sPHENIX

projections from CMS

	2010–2011 2.76 TeV 160 μb^{-1}	HL-LHC 5.5 TeV 10 nb^{-1}
Jet p_T reach (GeV/c)	$\sim$ 300	$\sim$ 1000
Dijet ($p_{T,1} > 120$ GeV/c)	50k	$\sim$ 10M
b-jet ($p_T > 120$ GeV/c)	$\sim$ 500	$\sim$ 140k
Isolated γ ($p_T^\gamma > 60$ GeV/c)	$\sim$ 1.5k	$\sim$ 300k
Isolated γ ($p_T^\gamma > 120$ GeV/c)	–	$\sim$ 10k
W ($p_T^W > 50$ GeV/c)	$\sim$ 350	$\sim$ 70k
Z ($p_T^Z > 50$ GeV/c)	$\sim$ 35	$\sim$ 7k

current 5 TeV results:
~5% of total expected Run 2 + 3 statistics

sPHENIX projections



sPHENIX in 22 weeks AuAu
100 B MB events
rare triggers sample 600 B

LHC Run 2/3 & sPHENIX

projections from CMS

Jet p_T reach
Dijet ($p_{T,1} > 1$
b-jet ($p_T > 12$
Isolated γ ($p_T^{\gamma} >$
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W ($p_T^{W} > 50$
Z ($p_T^{Z} > 50$

~5% of to

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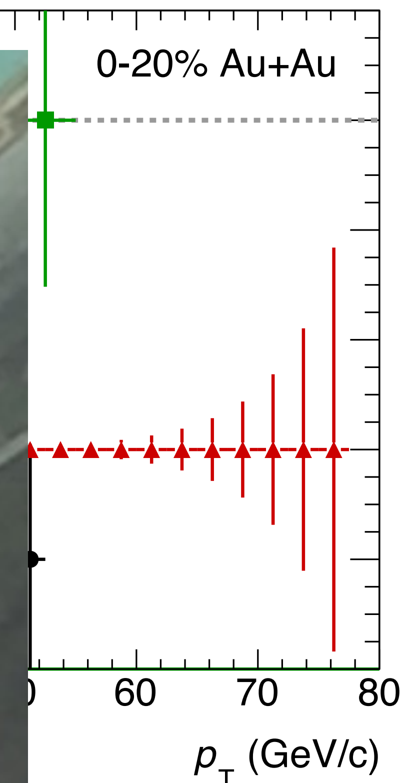

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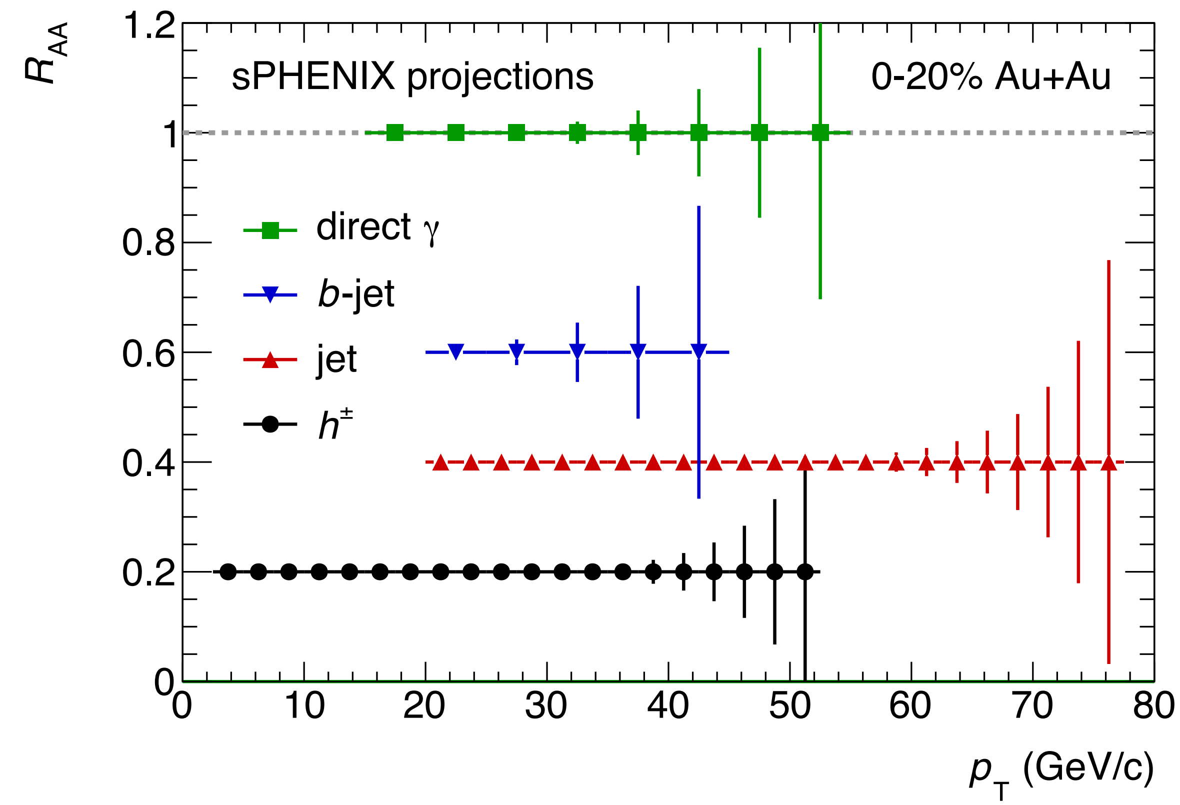

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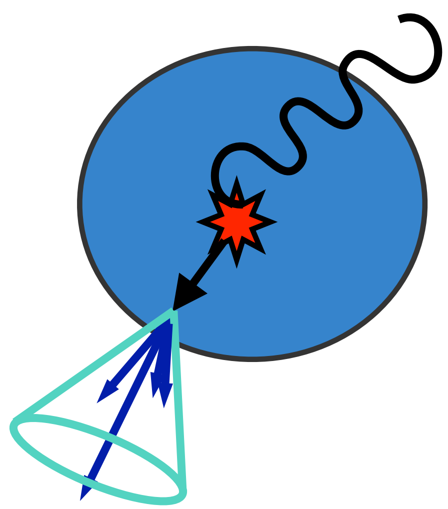
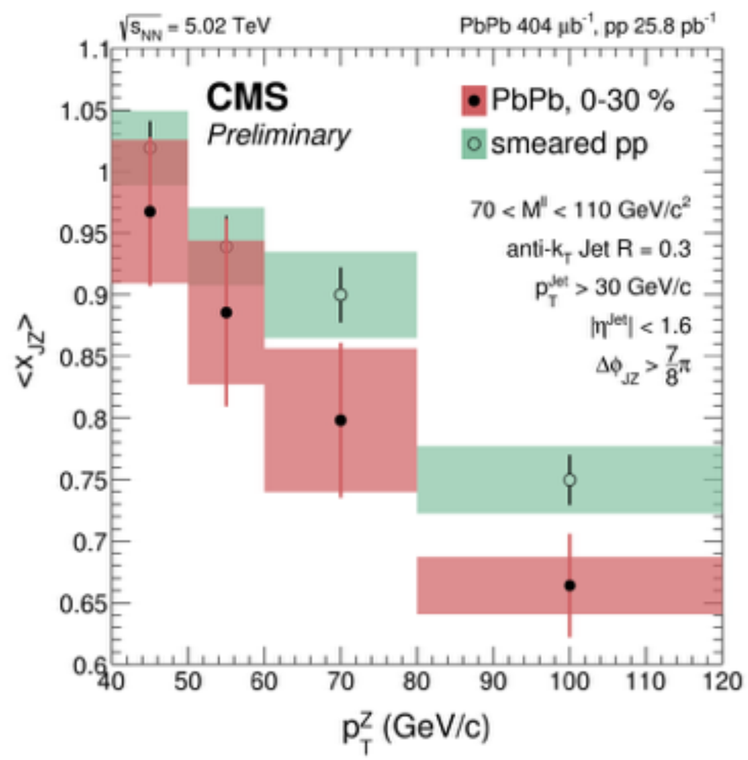
what physics is delivered by this abundance of data?

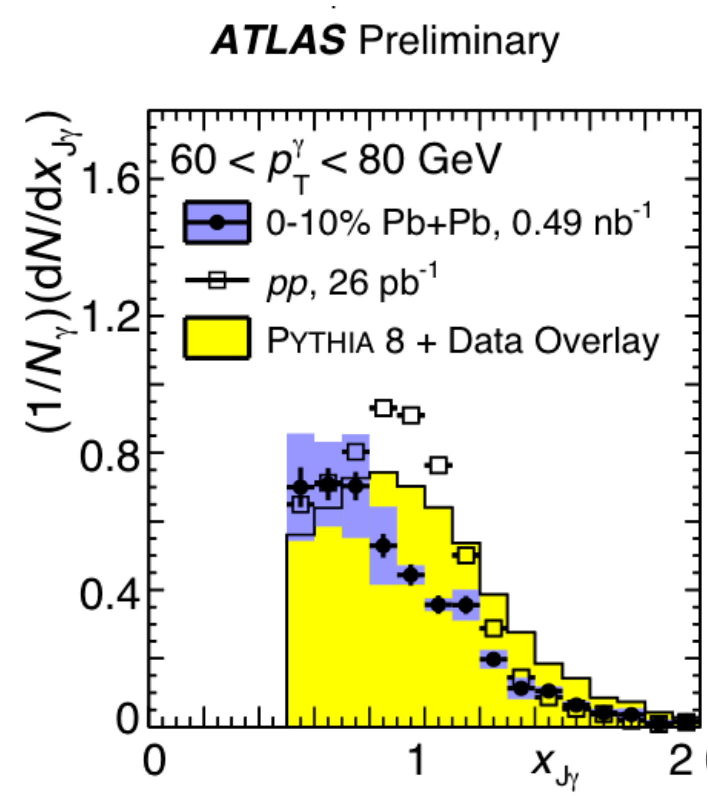
jet-boson correlations

jet-boson correlations

now







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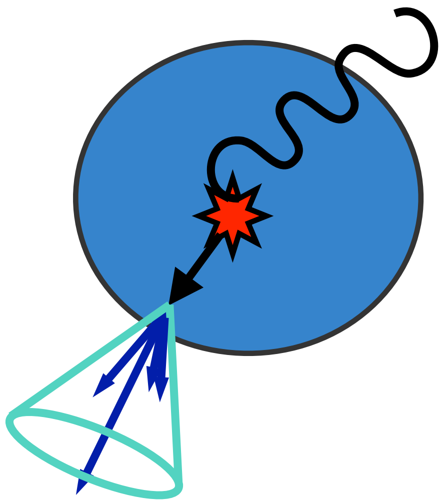
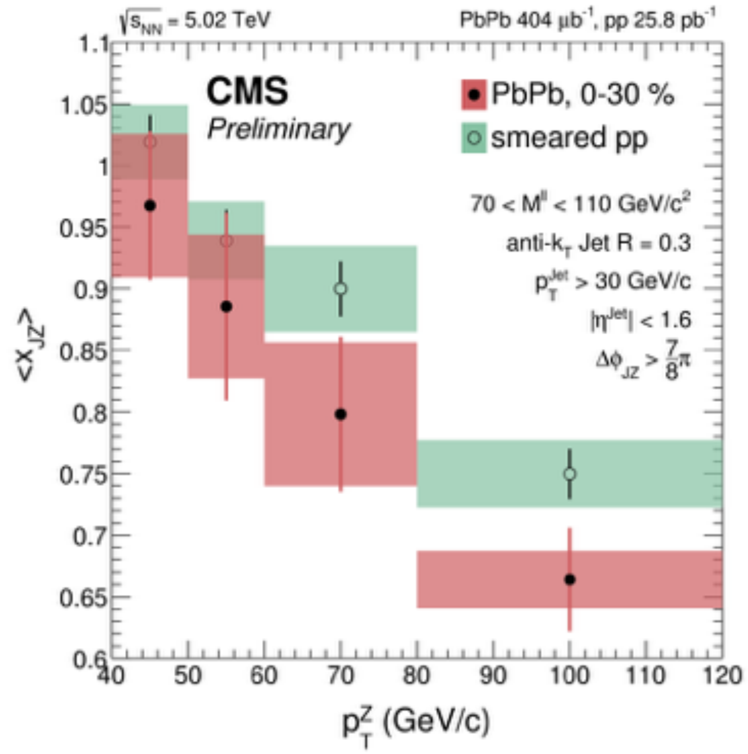
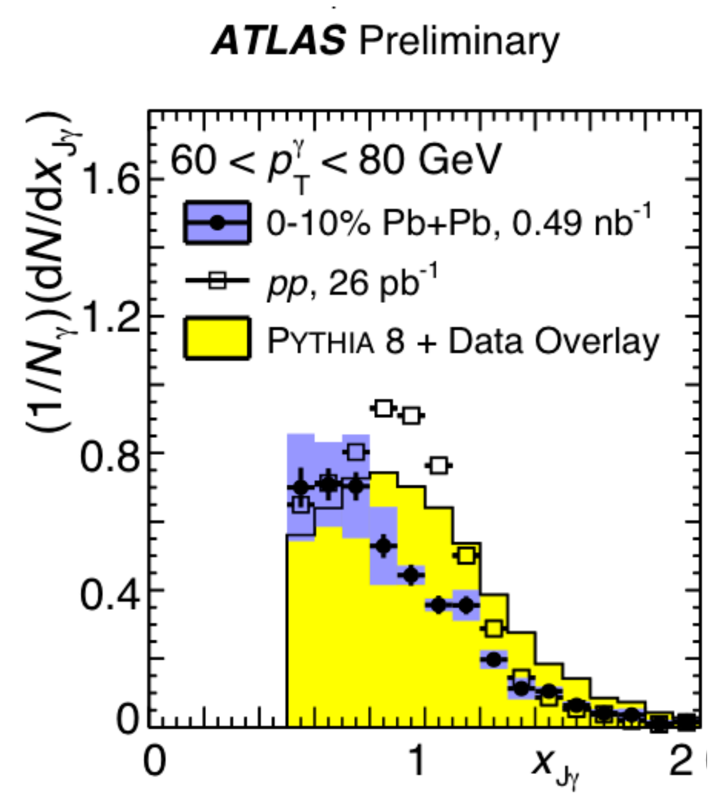
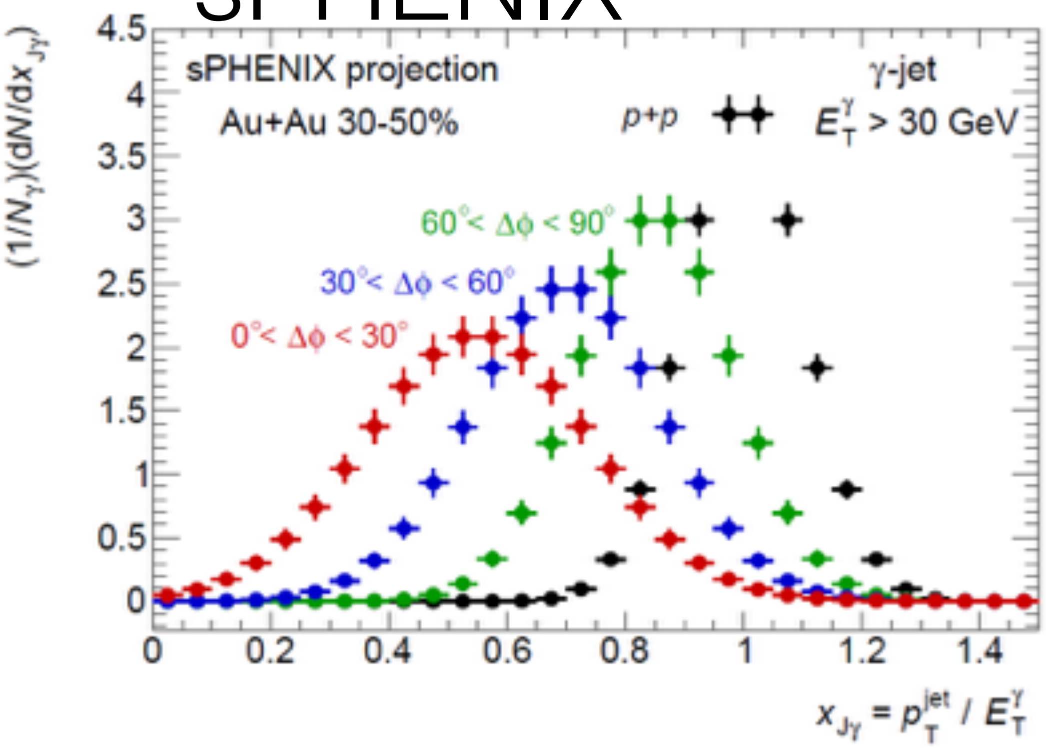


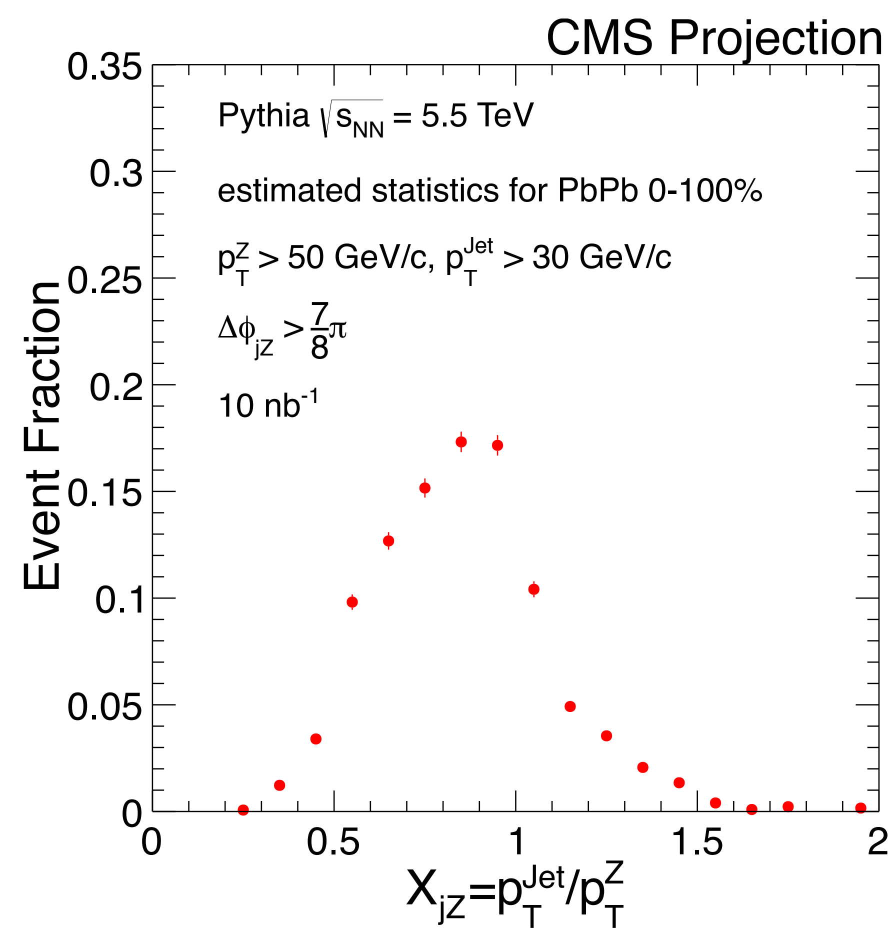




future

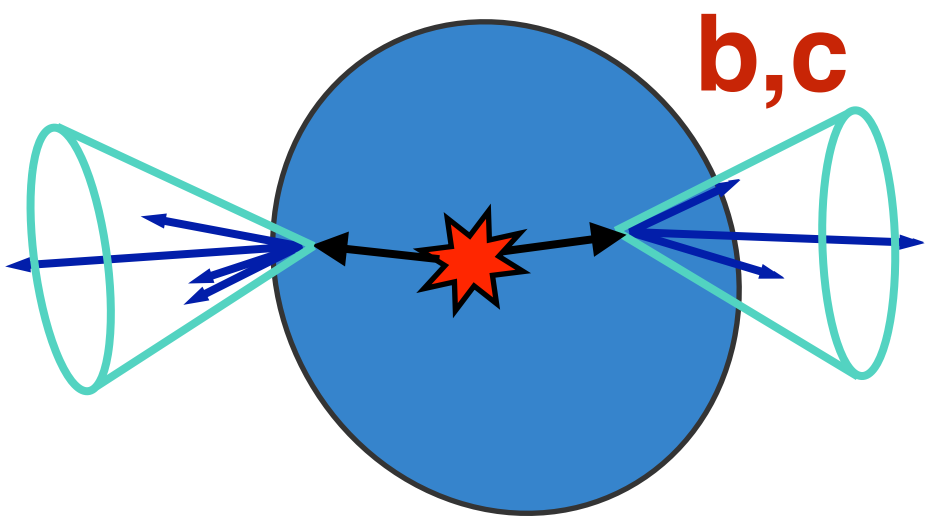
sPHENIX



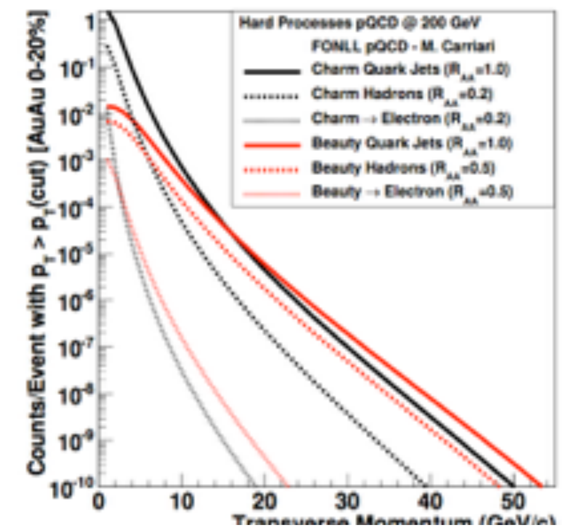


precision,
reaction plane
dependence,
RHIC, …

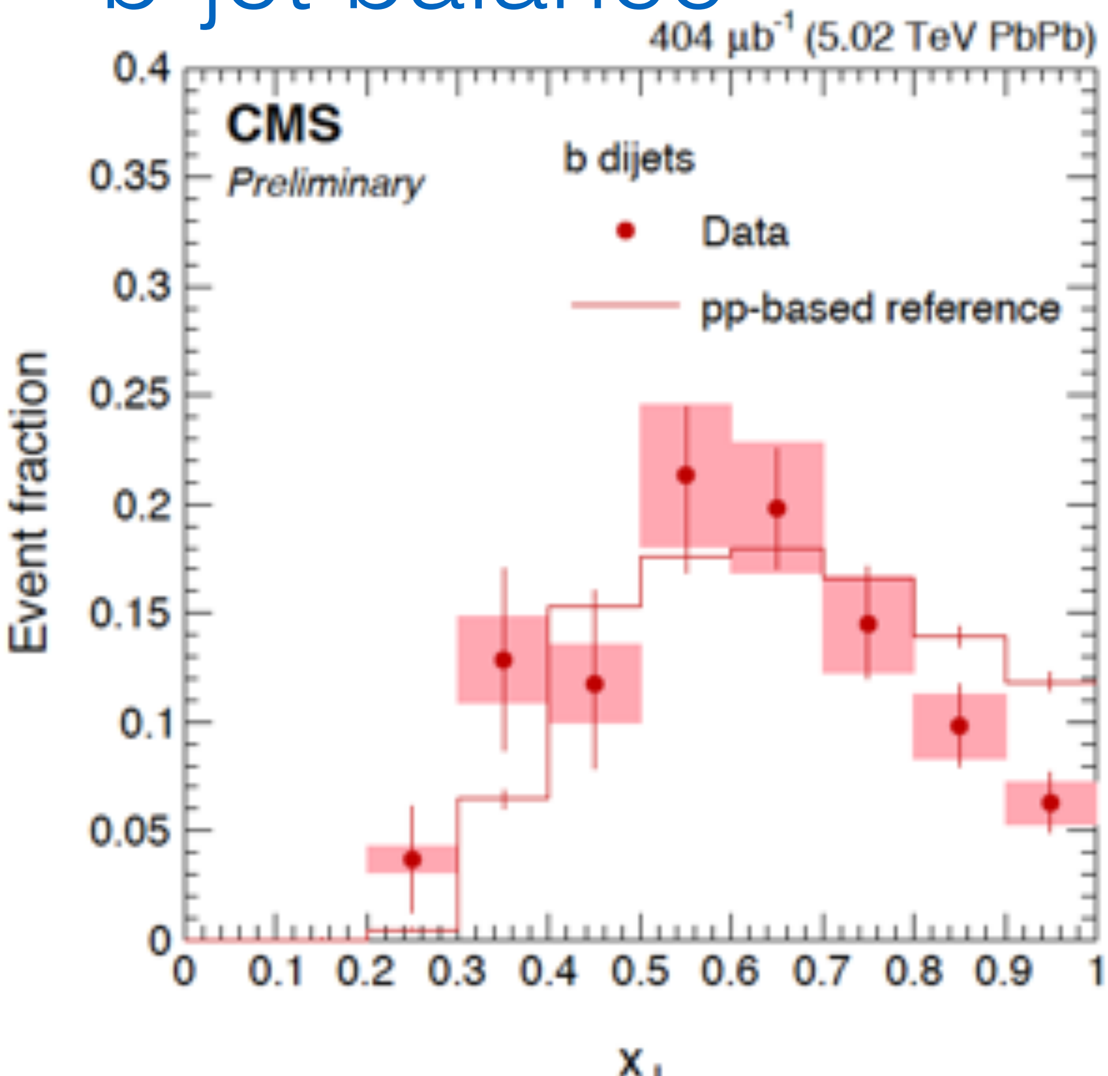
jet tagging: heavy quarks



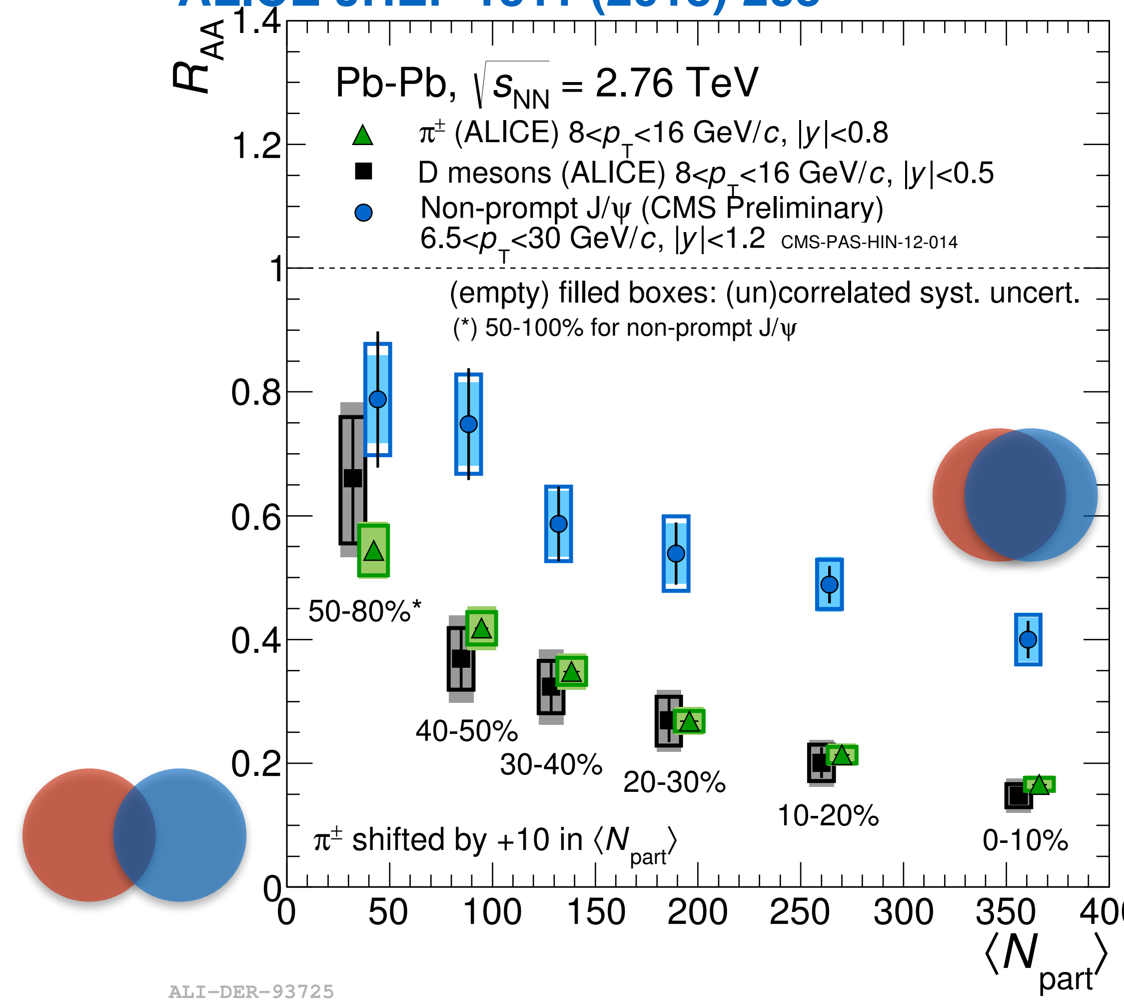
heavy flavor rates in sPHENIX



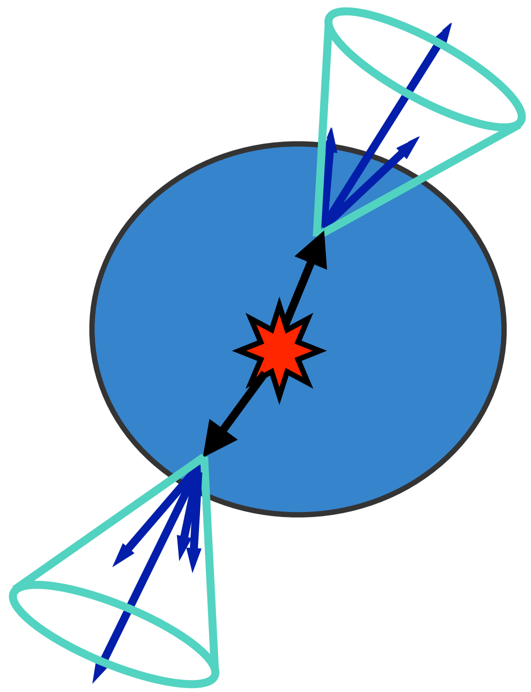
b-jet balance

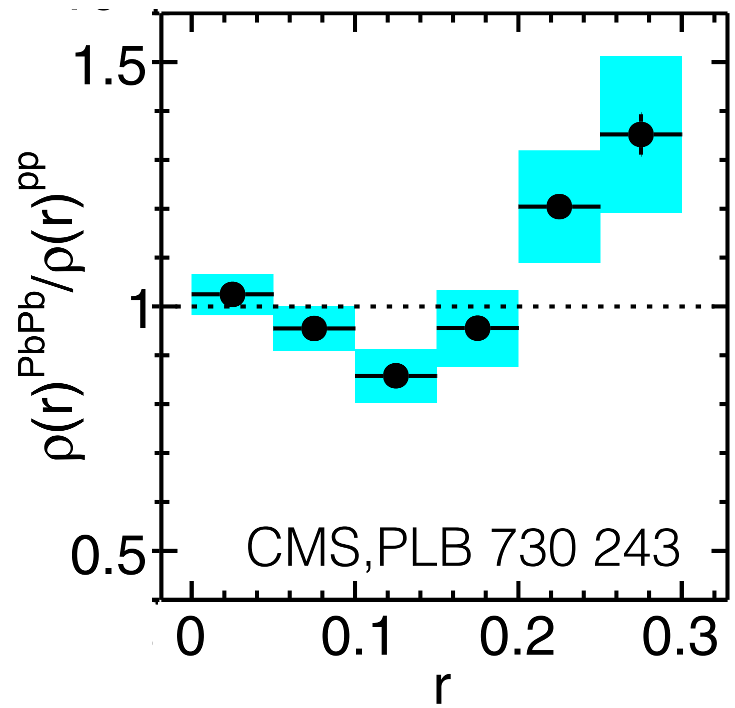


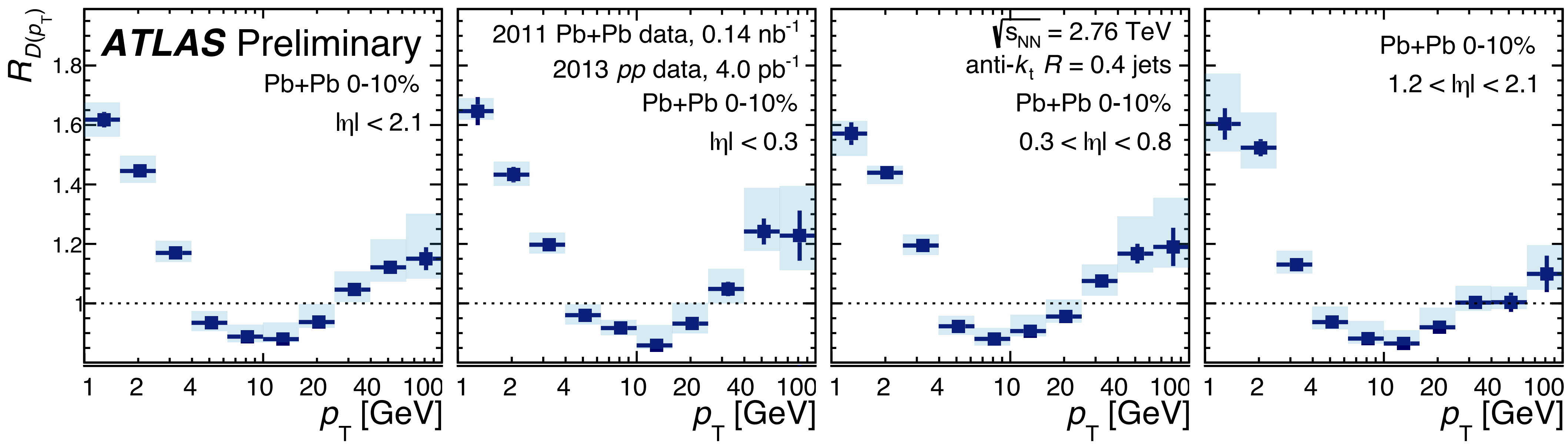
ALICE JHEP 1511 (2015) 205



energy within the jets





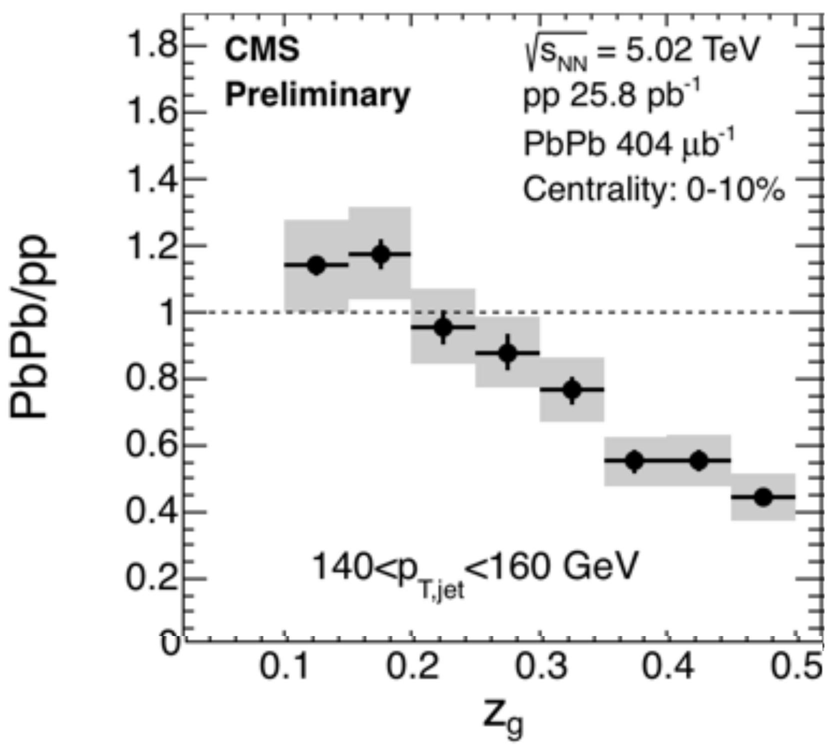


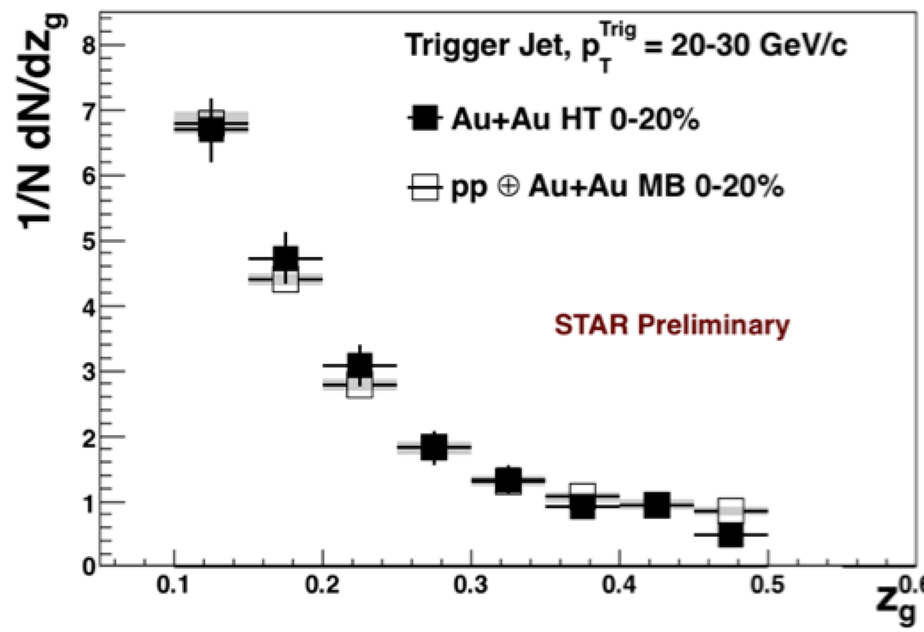
potentially very discriminating, especially when combined with, e.g, photon tagging

requires good control of JES and tracking in the cores of jets

correlations within and between jets

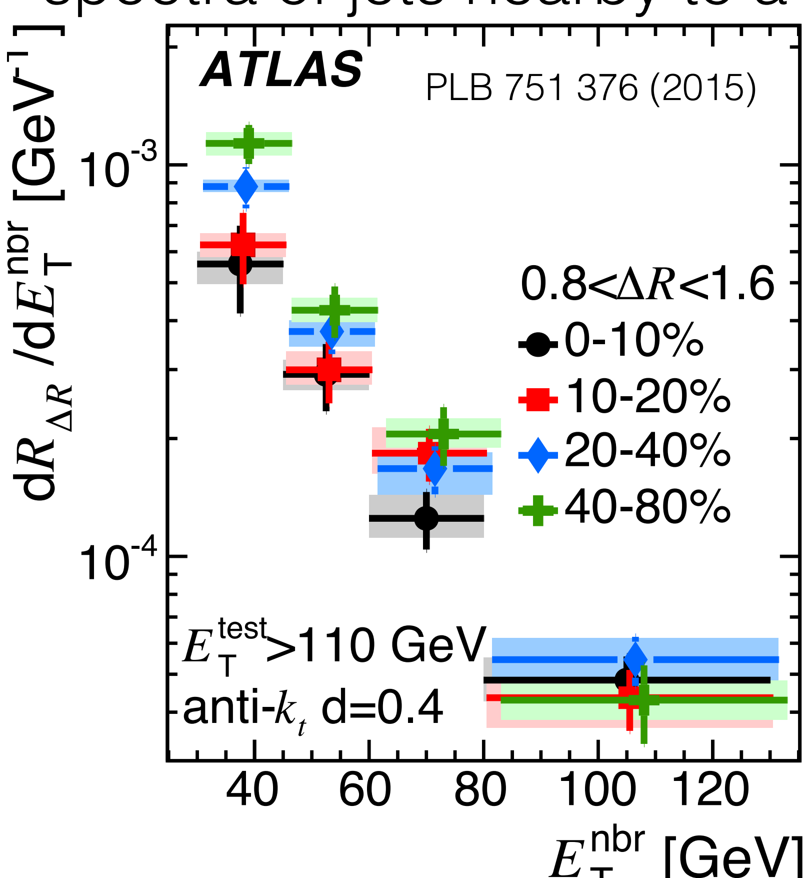
modification to the energy distribution between subjets inside a jet





different observations between CMS & STAR:
differences in jet reconstruction, underlying event, collision energy, triggering, jet p_T
important to minimize the differences to isolate the physics we're interested in

spectra of jets nearby to a "test" jet

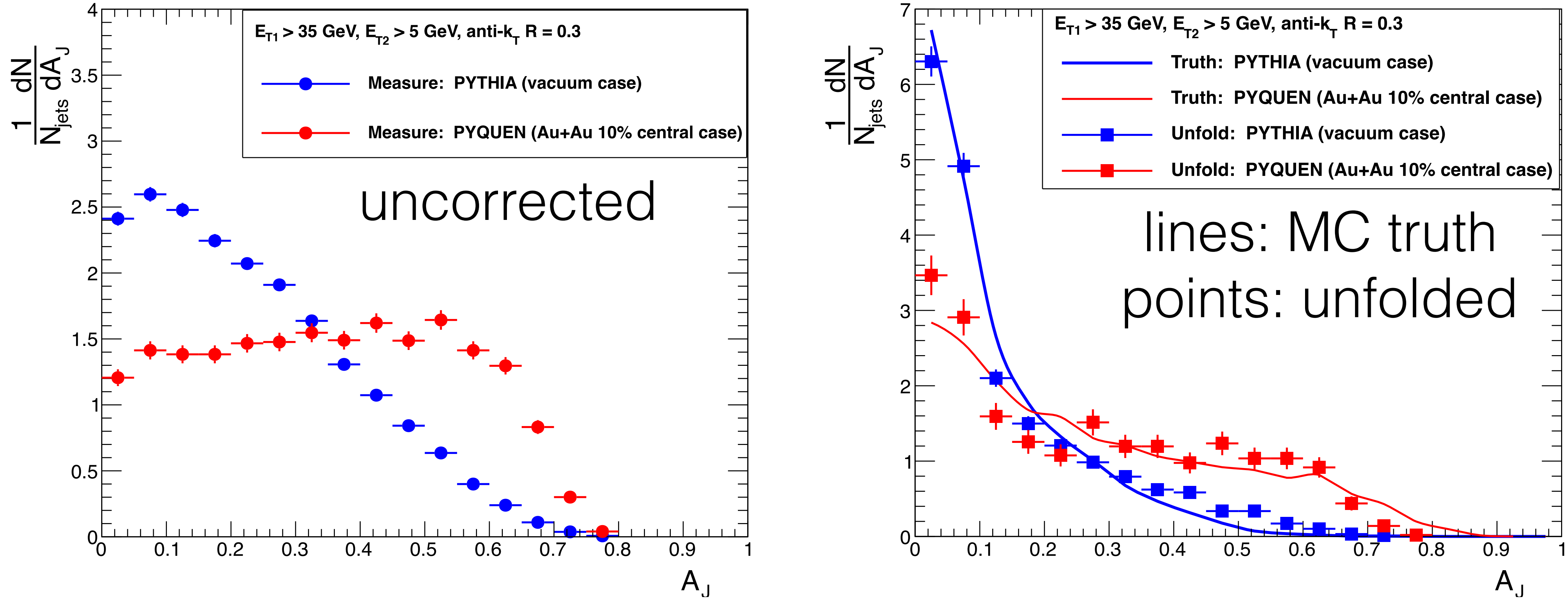


obviously exciting and promising new class of discriminating observables!

quantitative measurements

quantitative measurements

sPHENIX simulation



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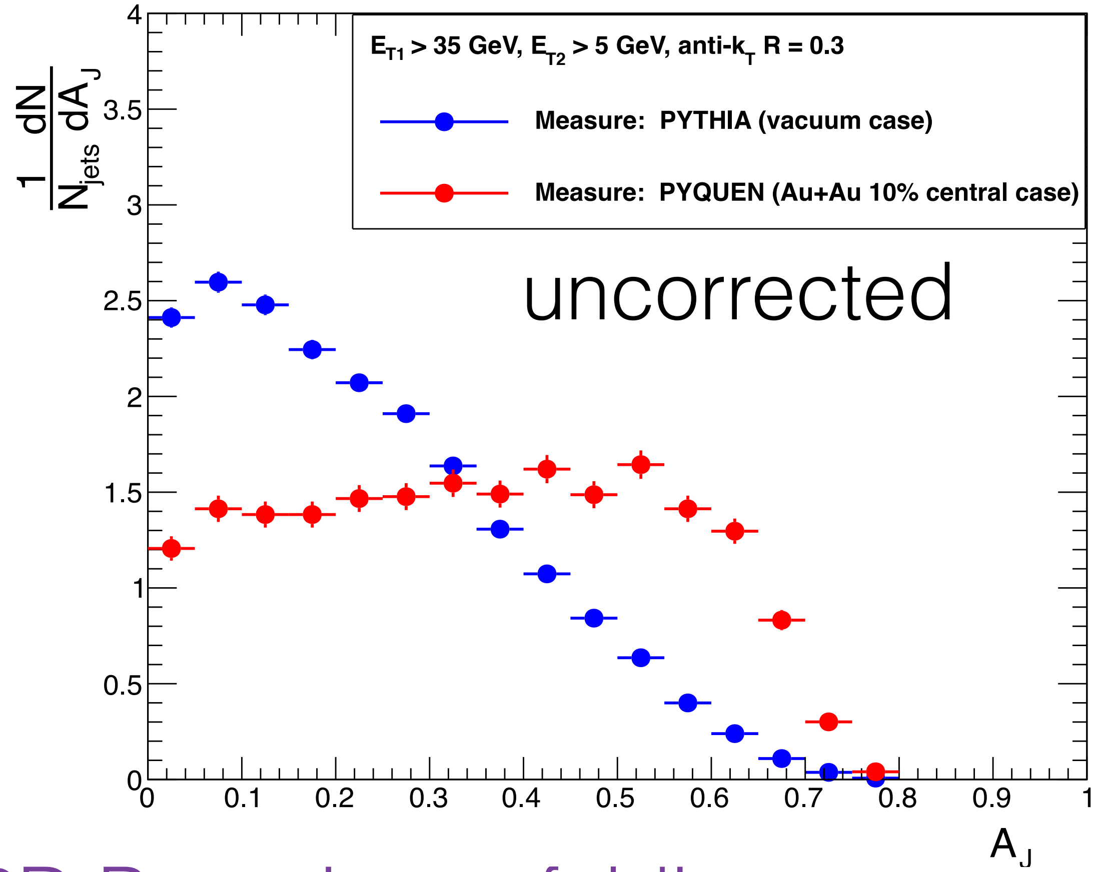
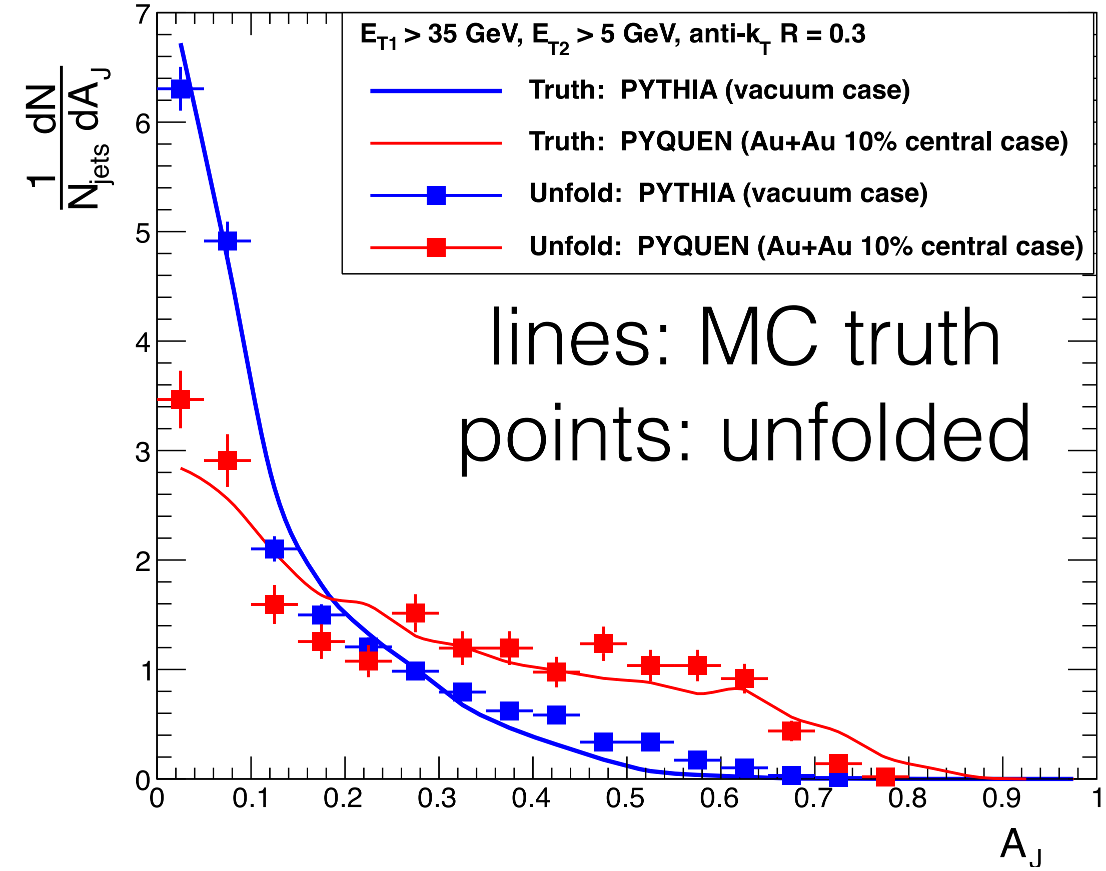
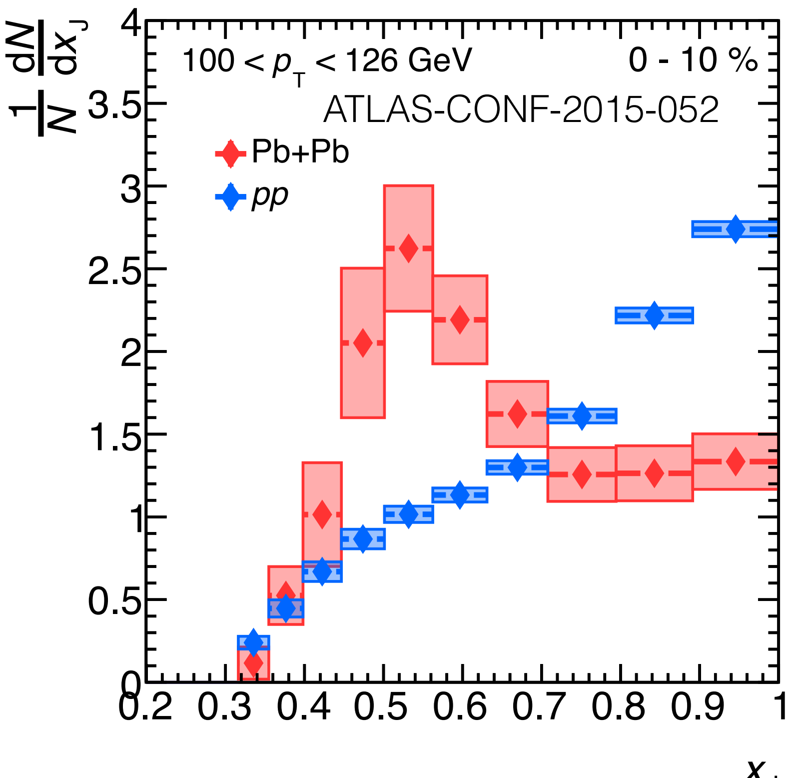




w/ 2D Bayesian unfolding



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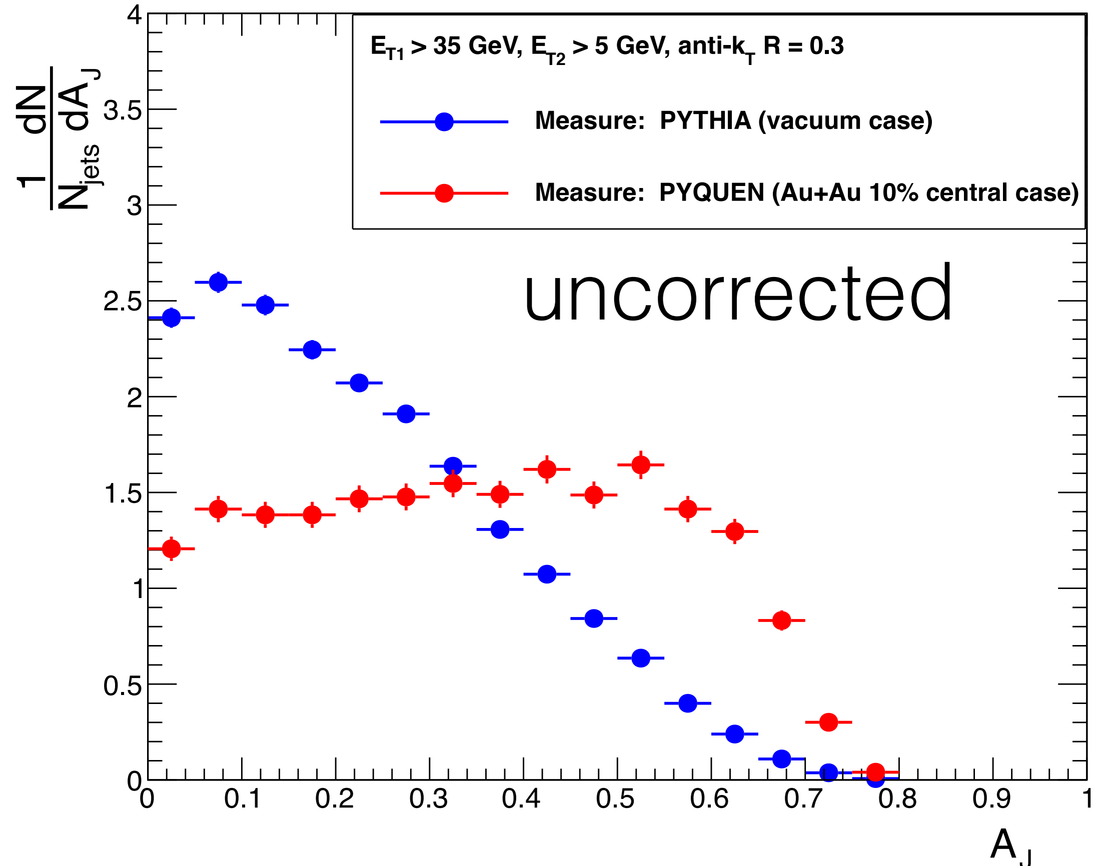

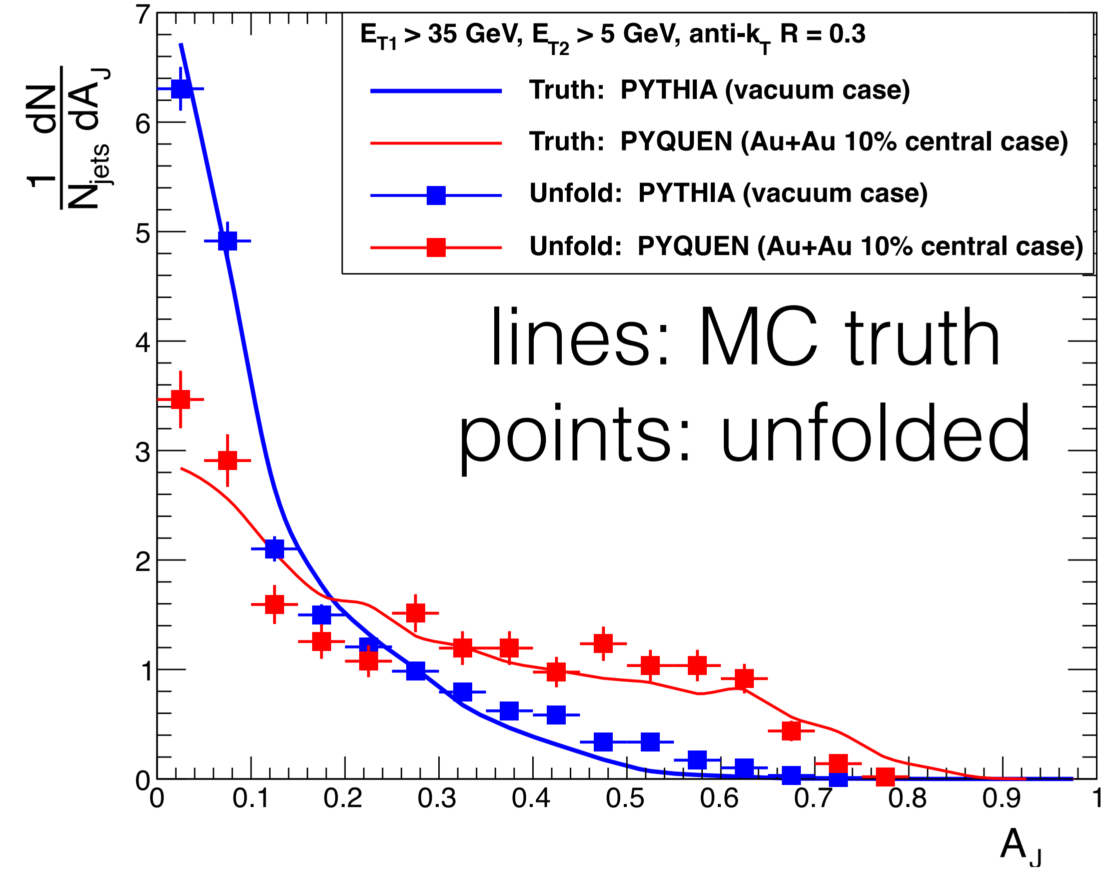

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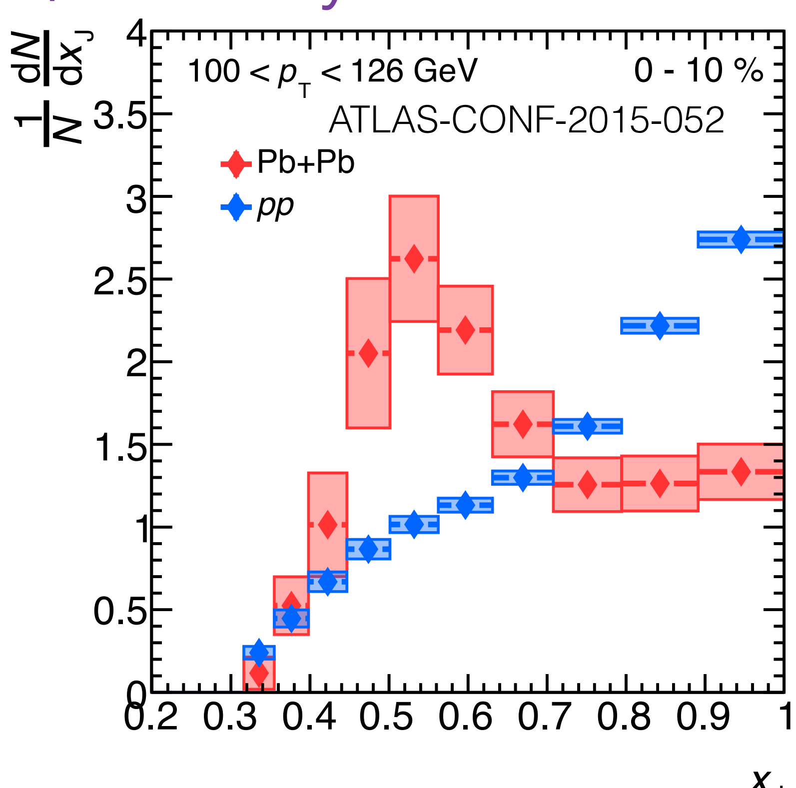
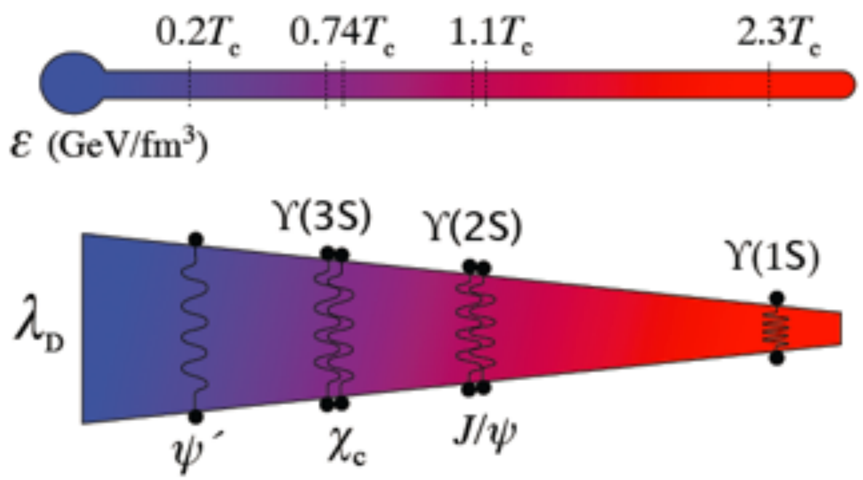


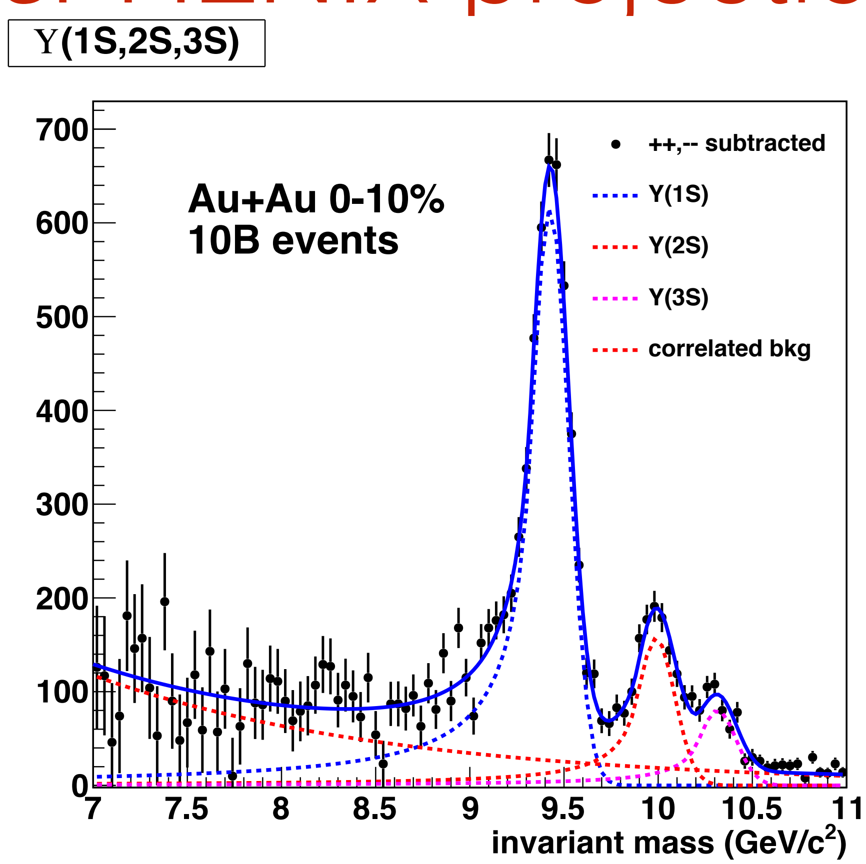
unfolding necessary for quantitative comparisons between experiments and for theoretical comparisons!

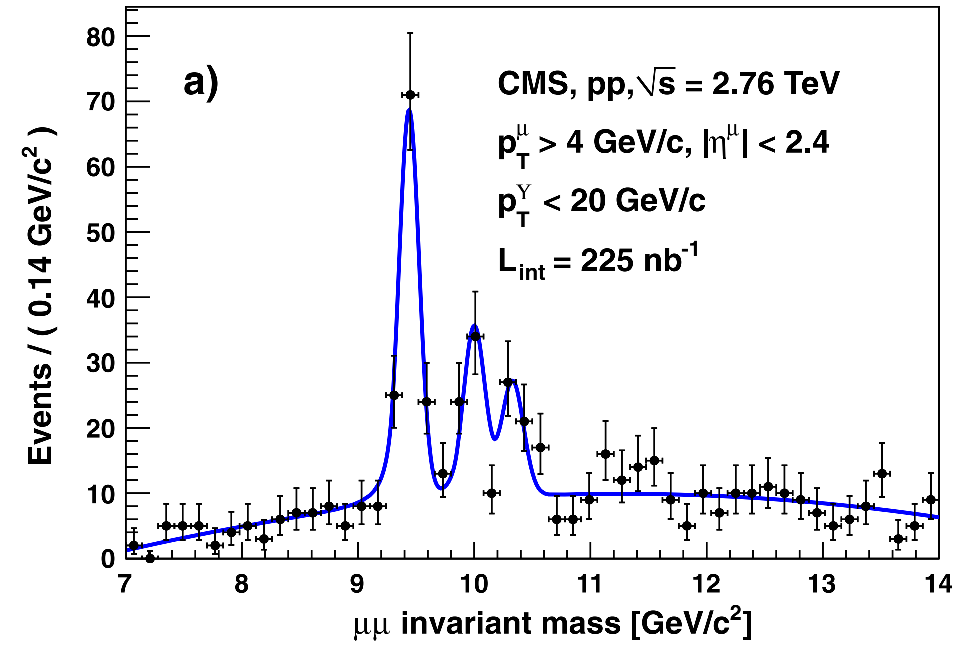
upsilons

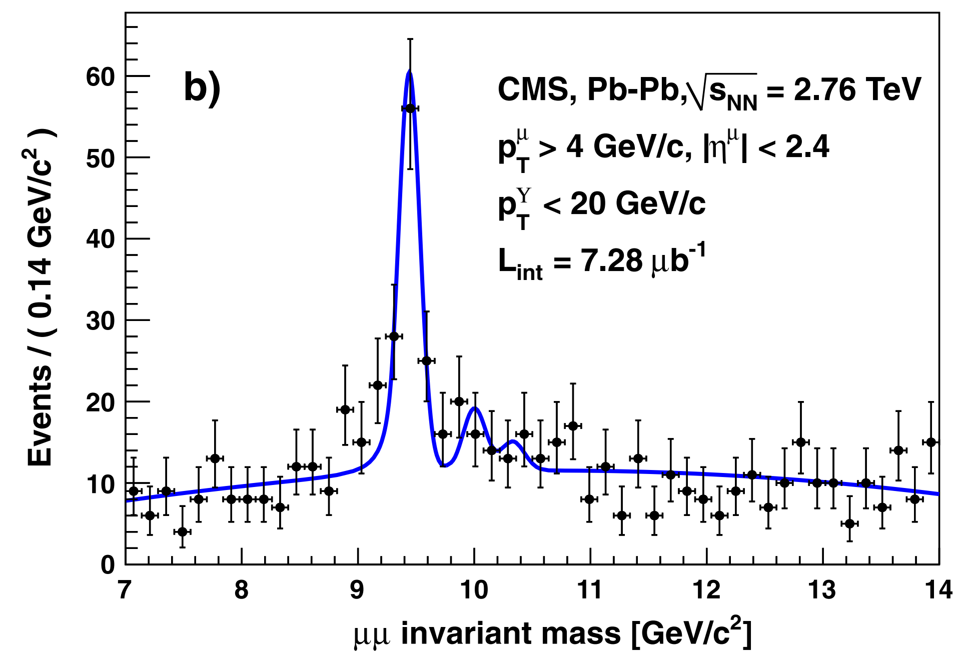
separation of 1S, 2S & 3S states
temperature dependence of screening is key!



sPHENIX projection







PRL 107 052302

requires excellent tracking & EM calorimetry
for electron ID & mass resolution

pA: crucially important

pA at the LHC & RHIC has been enormously successful & surprising; **necessary** for sPHENIX to measure full suite of pp/pA/AA

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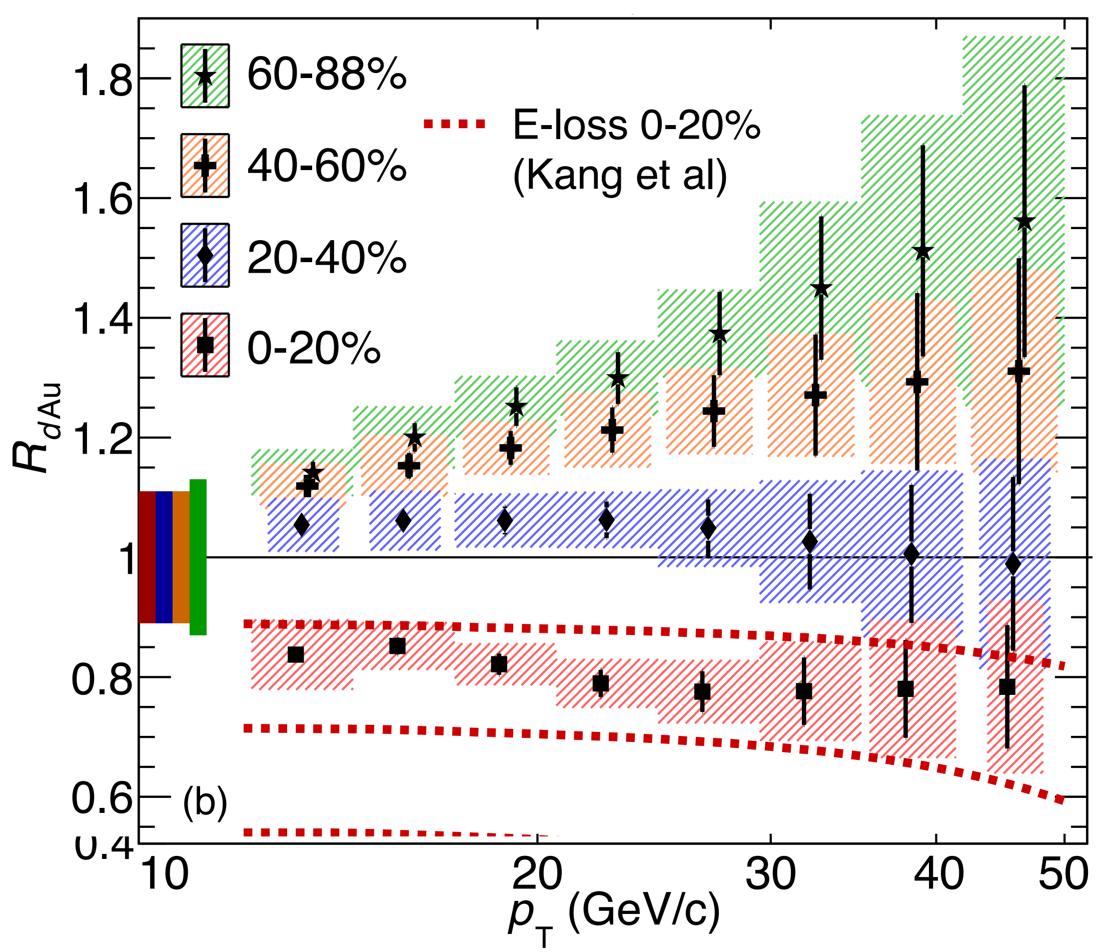
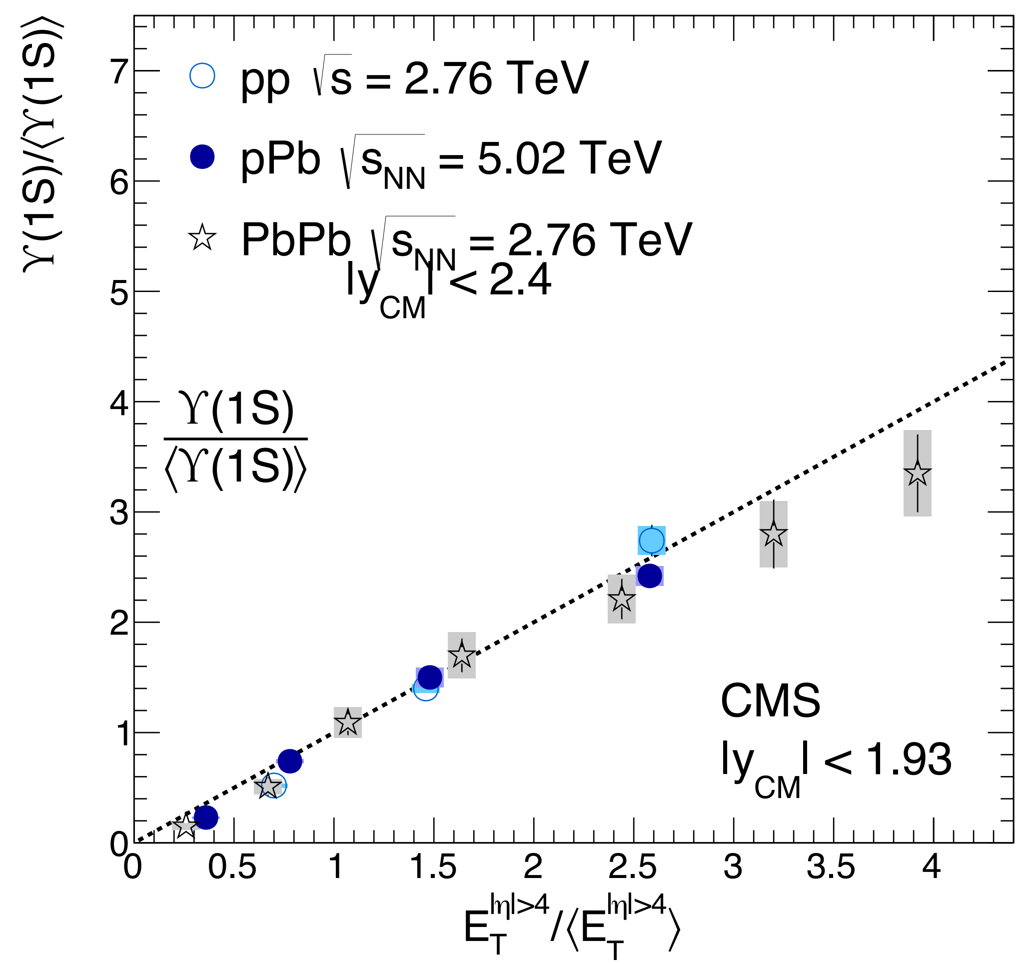
PHENIX, PRL 116 122301



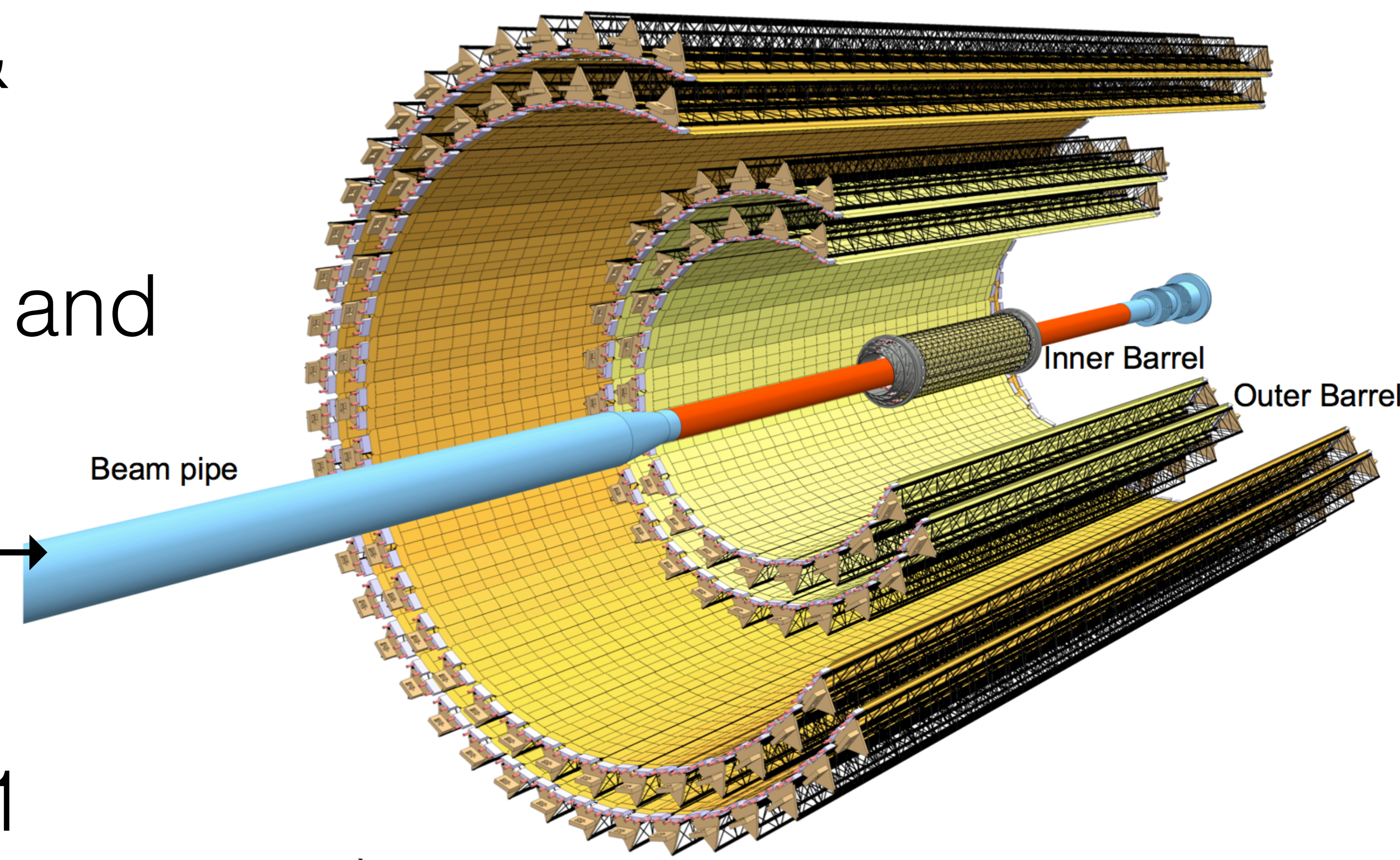
CMS, HIN-13-003



+large vN, plus many other great measurements….

LHC upgrades

- ALICE inner tracking & TPC upgrades
  - motivated by low p_T charm & bottom measurements
    - requires excellent tracking and PID
  - hard observables to trigger → upgrade read out to 50kHZ
- ATLAS IBL installed during LS1
  - ATLAS & CMS trigger LS2
  - ATLAS ZDC development ongoing



what detector do we need?

Long Range Plan: "Probe the inner workings of QGP by resolving its properties at shorter and shorter length scales. The complementarity of the two facilities is essential to this goal, as is a state-of-the-art jet detector at RHIC, called sPHENIX."

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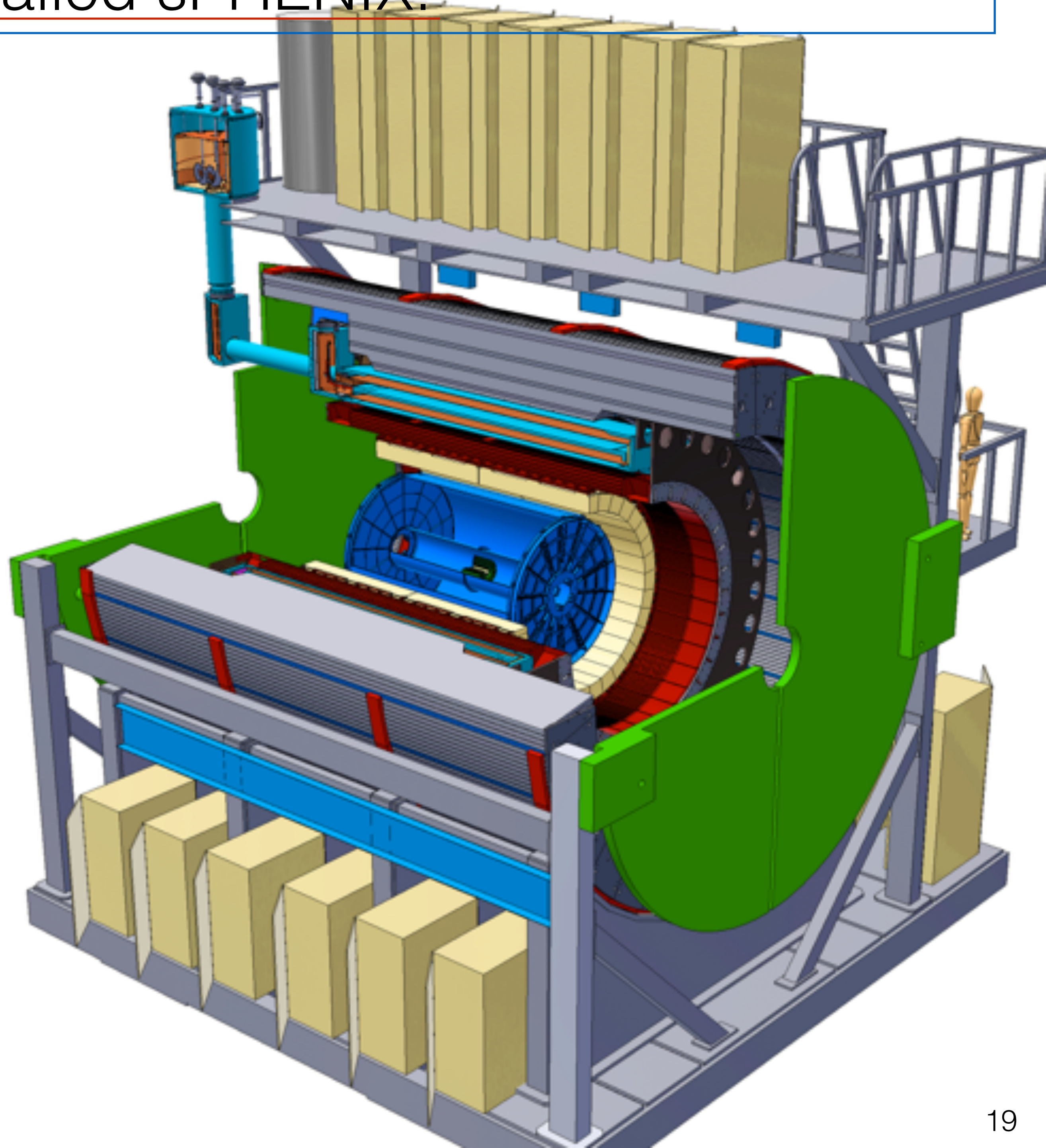

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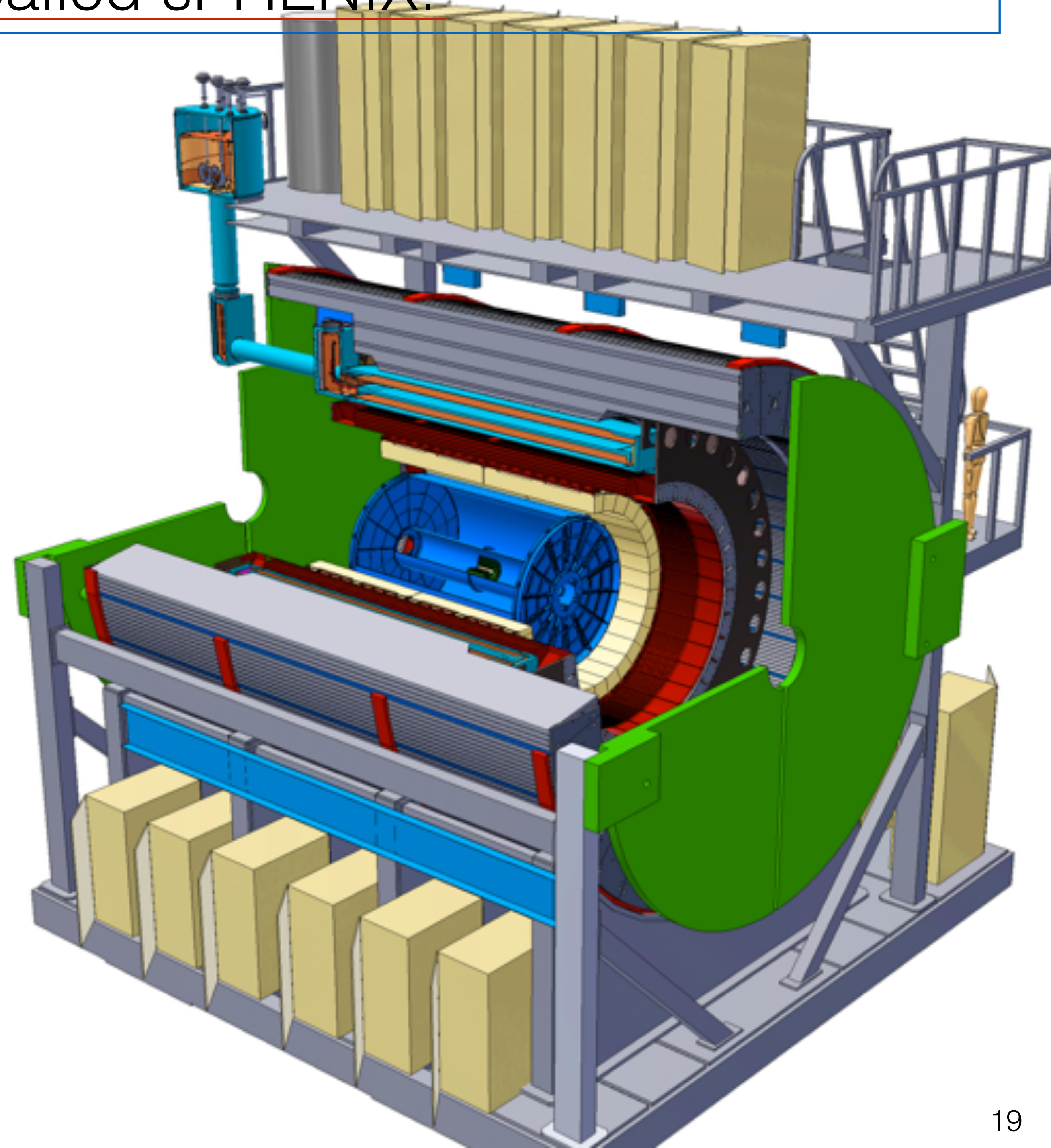
- large uniform acceptance for jets, photons and upsilons
- excellent tracking and full hadronic and electromagnetic calorimetry
- first data: 2022
- 200 collaborators / 60 institutions



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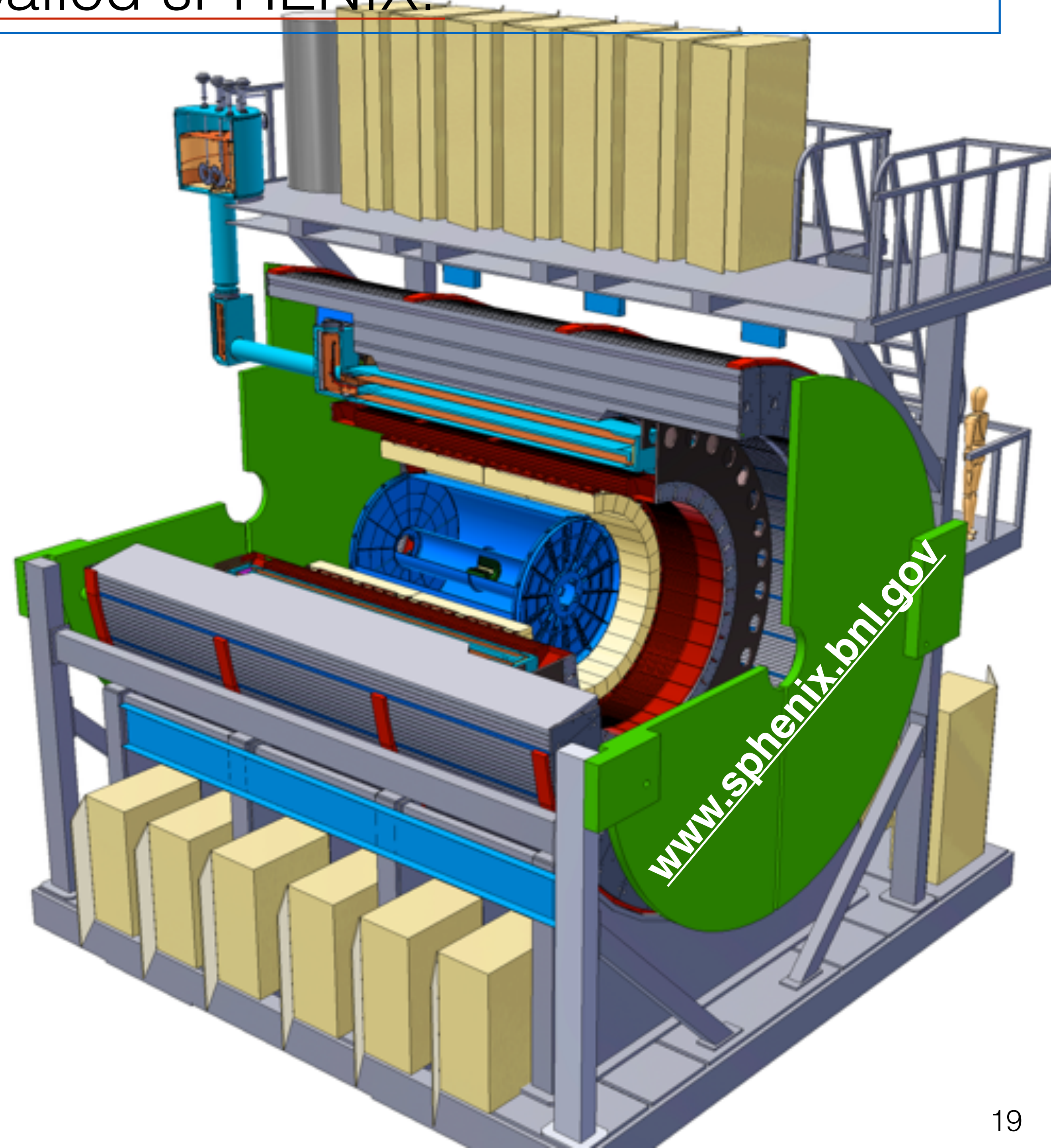
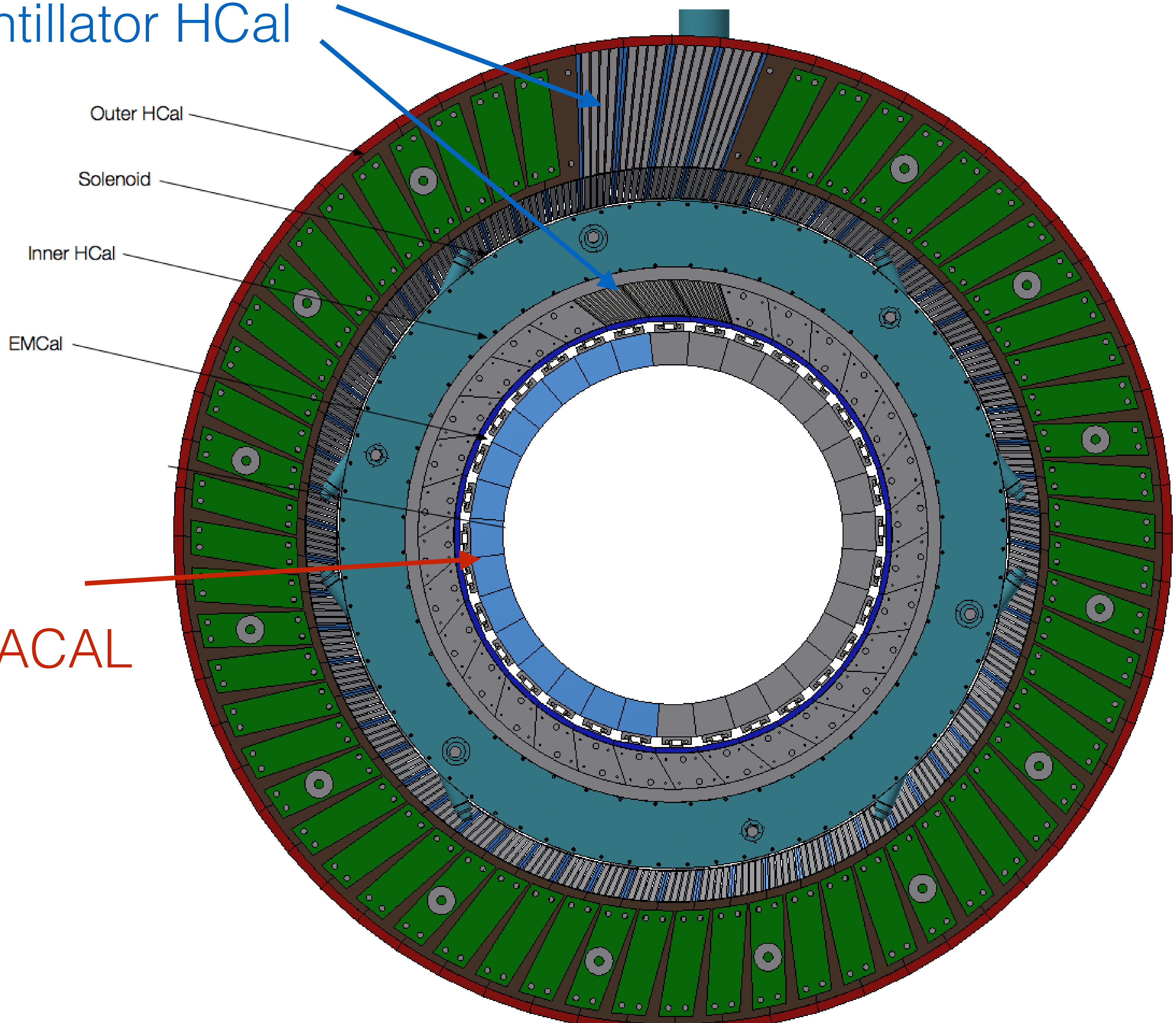


sPHENIX: calorimeters

steel / scintillator HCal

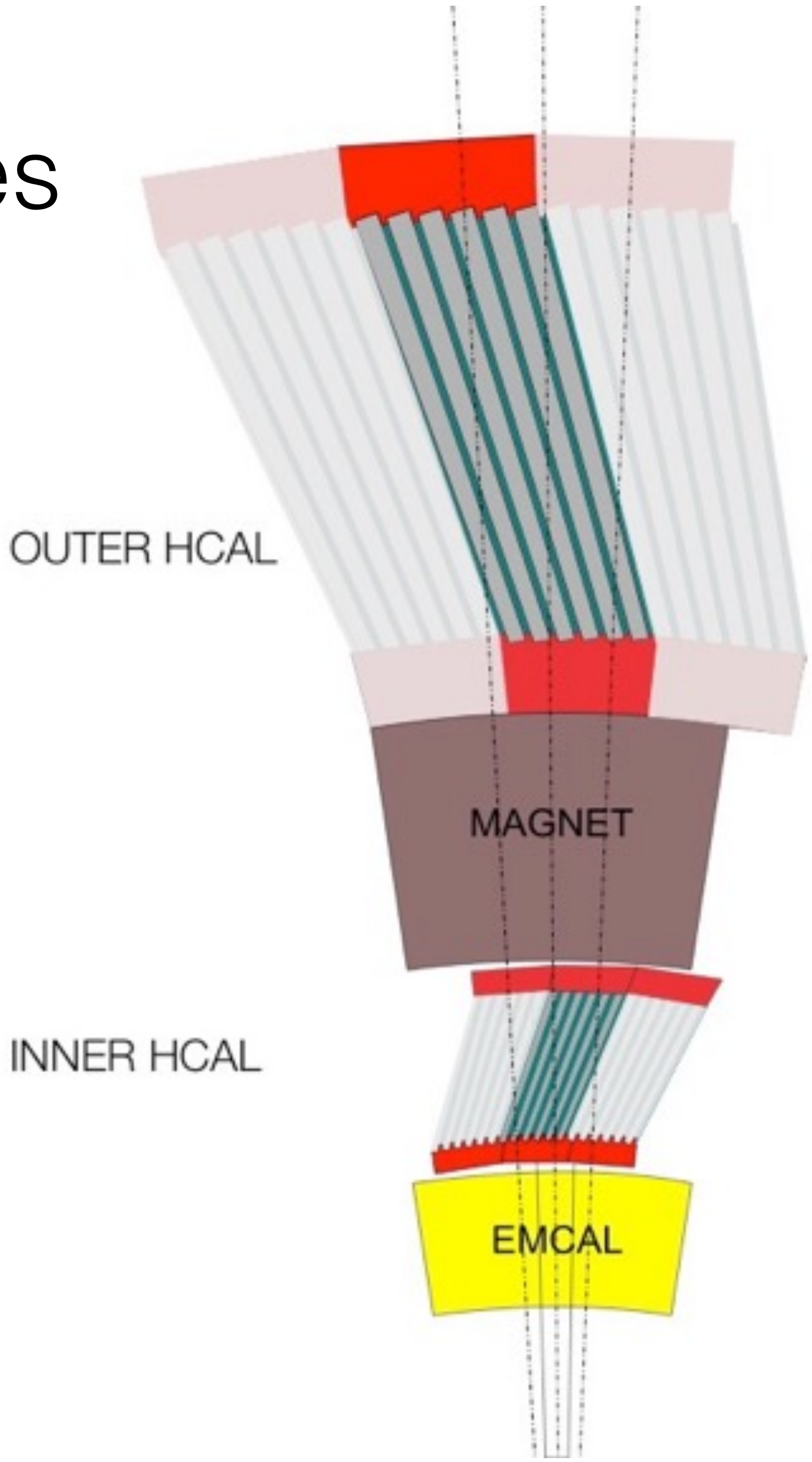


WSciFi SPACAL

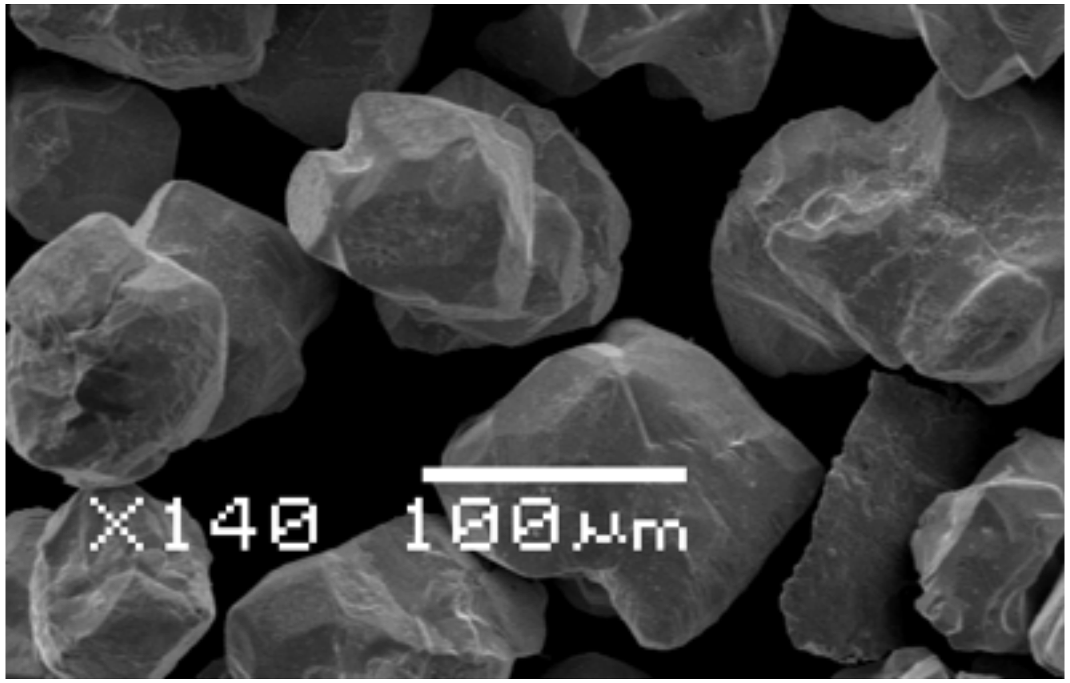
hadronic calorimeter

alternating steel scintillating plates

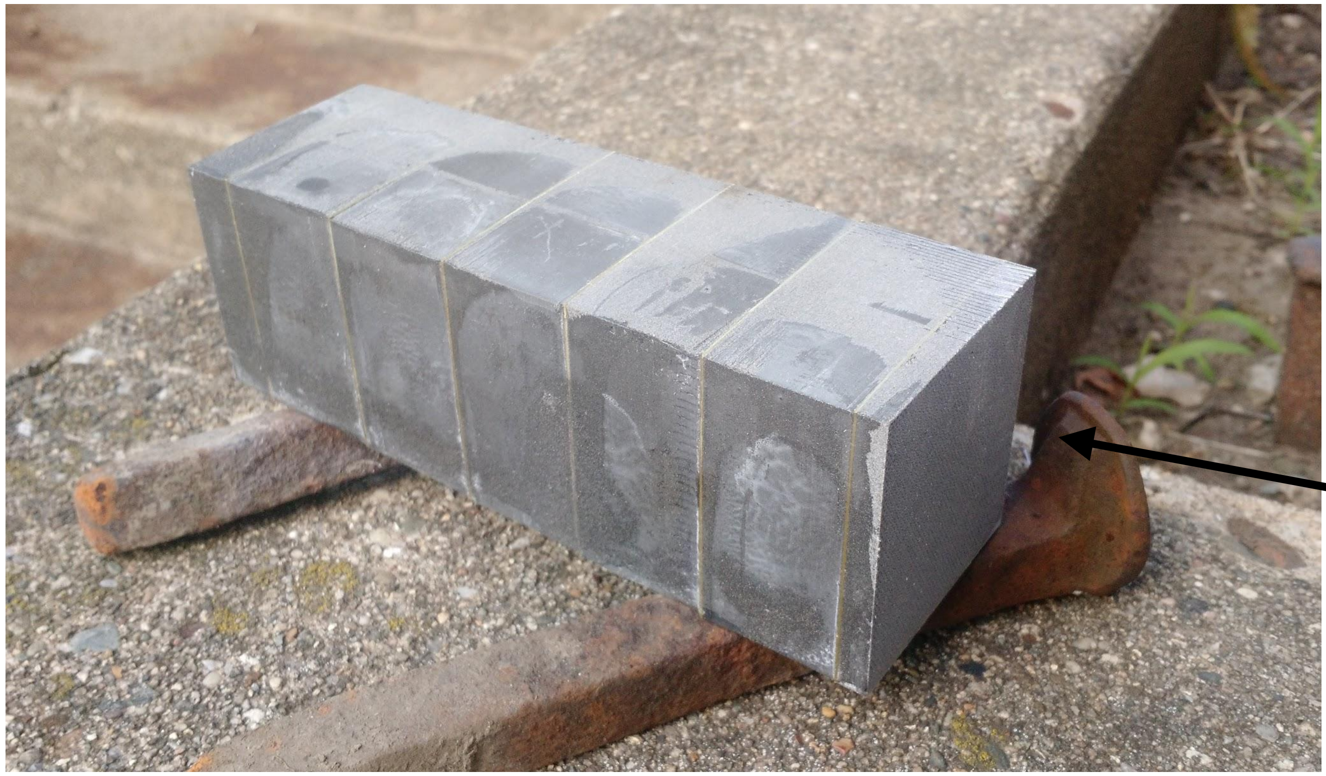
prototype assembled at BNL



sPHENIX EMCal



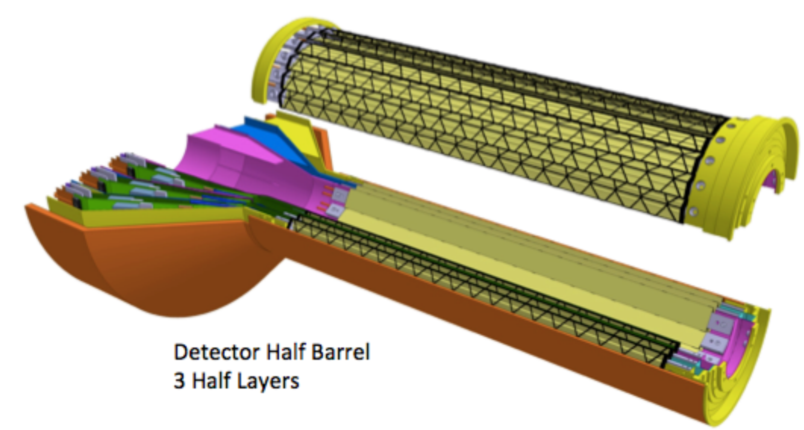
scintillating fibers embedded in tungsten powder

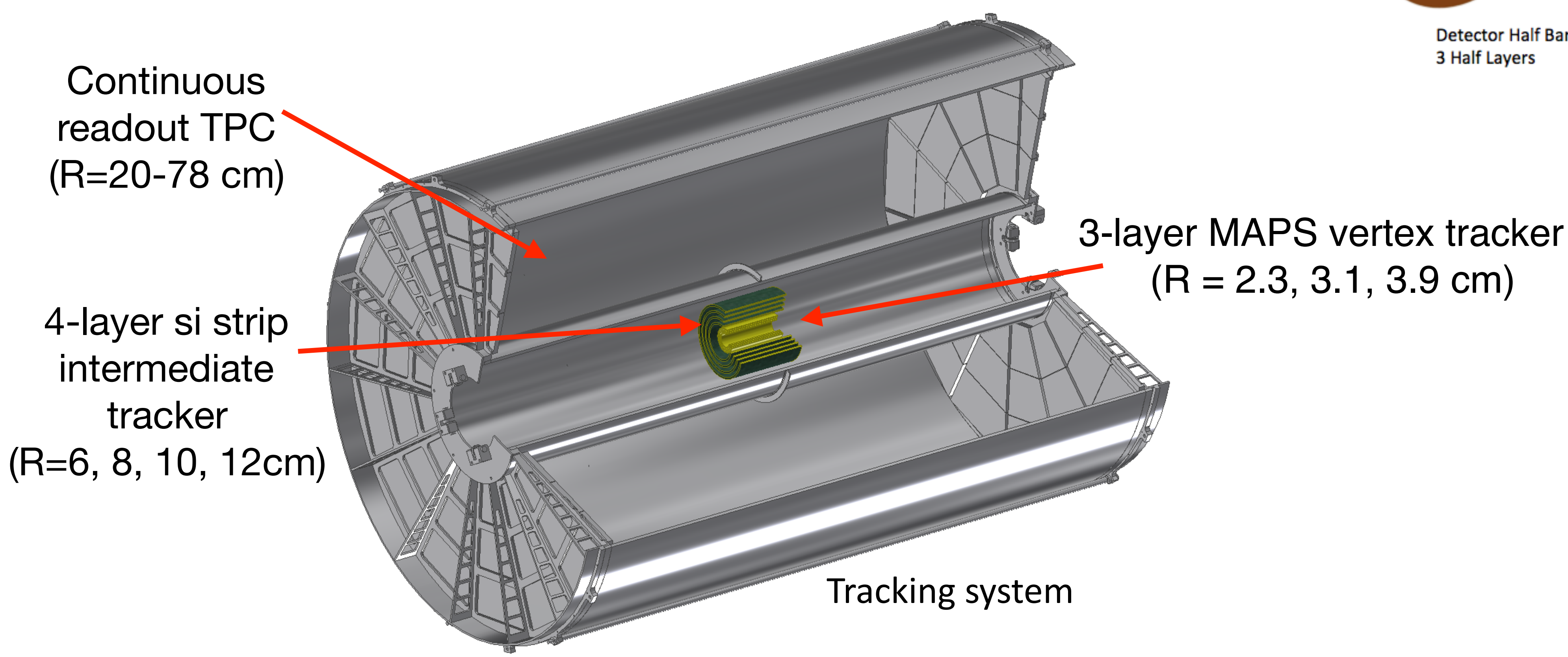


first 2D projective tungsten SPACALs being produced

sPHENIX tracking

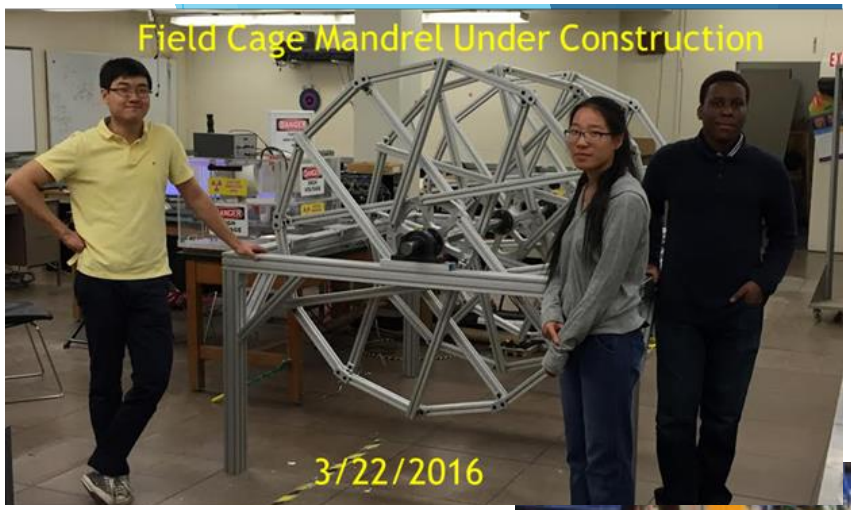
- very successful tracker review in September 2016
- planned design:
  - 3 layers MAPS, using ALICE stave design
  - 4 layer intermediate silicon tracker
  - outer TPC



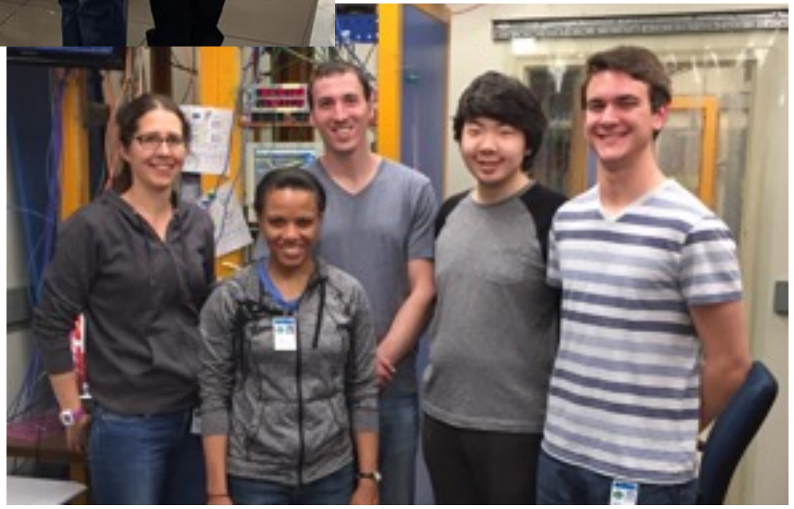


sPHENIX activity

- Babar magnet successful low power cold tests @ BNL
- FNAL EMCal/HCal test beam: April 2016 and January 2017

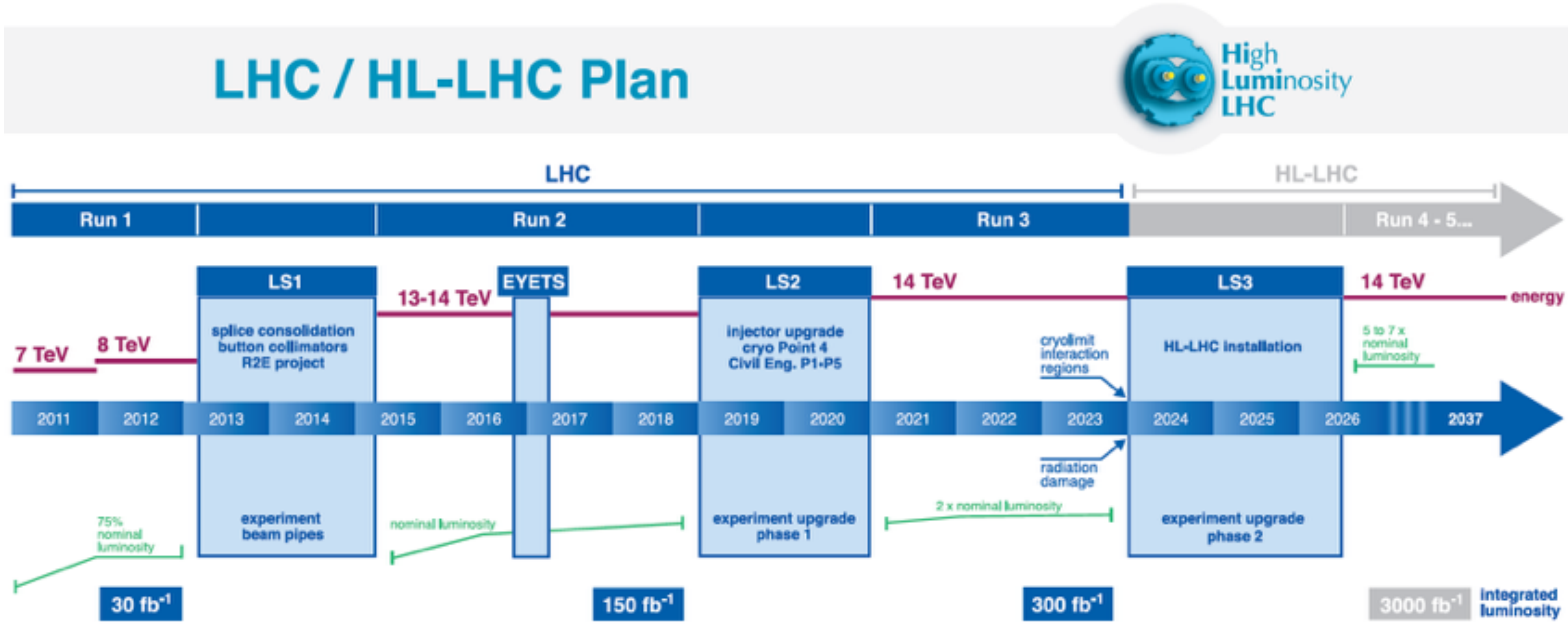


TPC work at Stony Brook

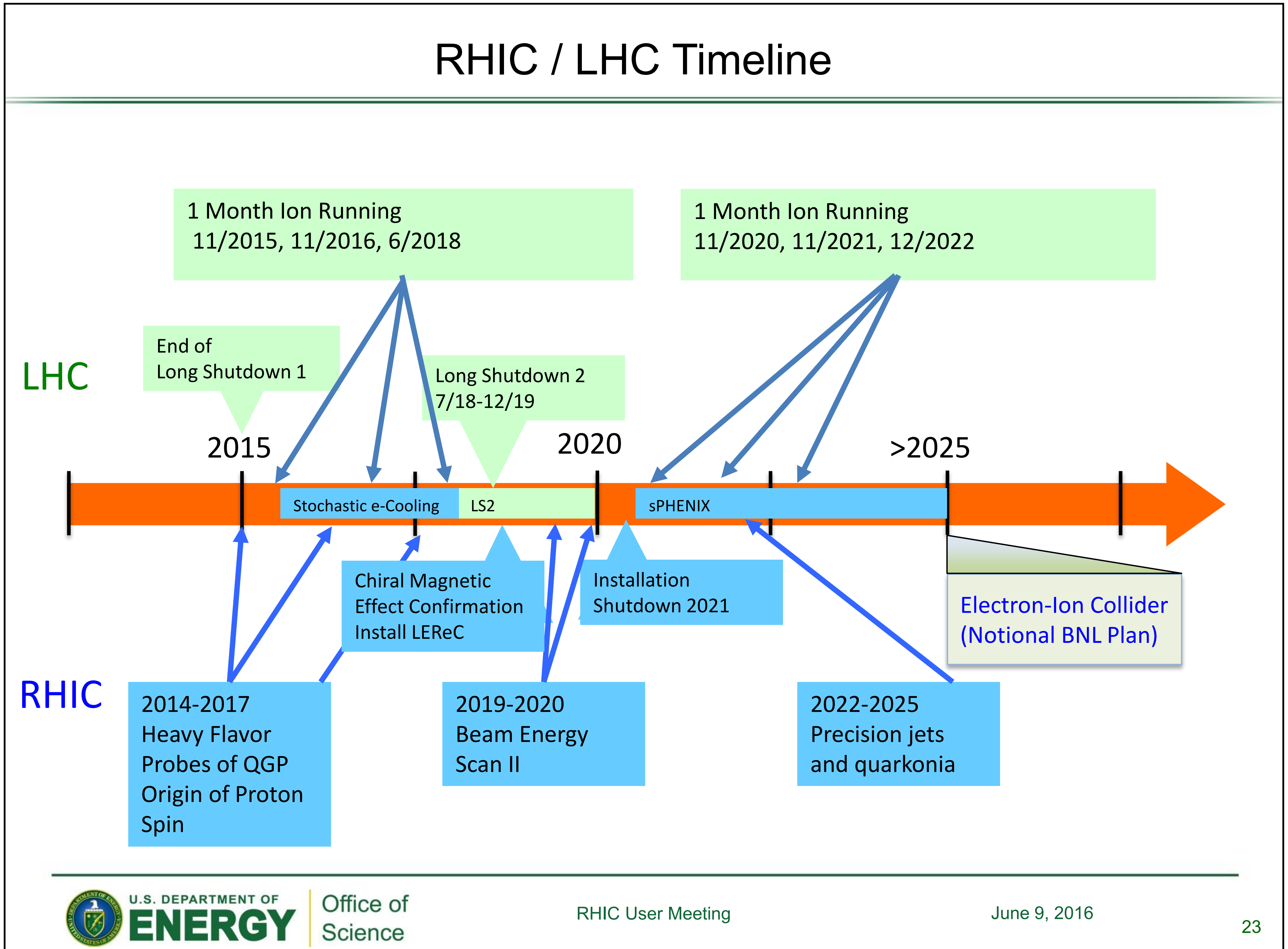


Illinois group at Fermilab

LHC Upgrades



Precision Era of Hard Probes in Heavy Ions



sPHENIX & LHC Run 3 →
era of precision hard probes!

an exciting future!

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