Heavy Flavor Measurements at sPHENIX

~ A Precision Era of QGP Studies ~

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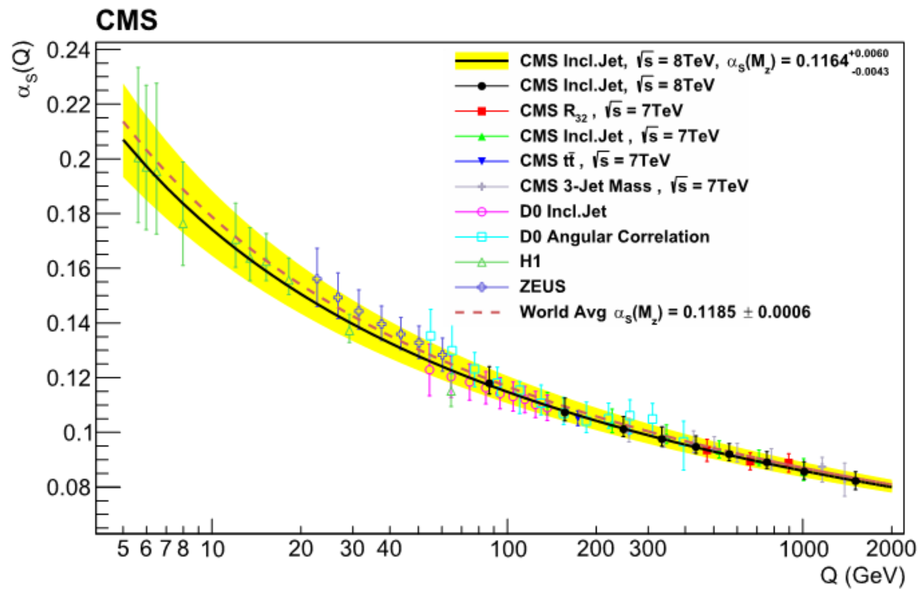
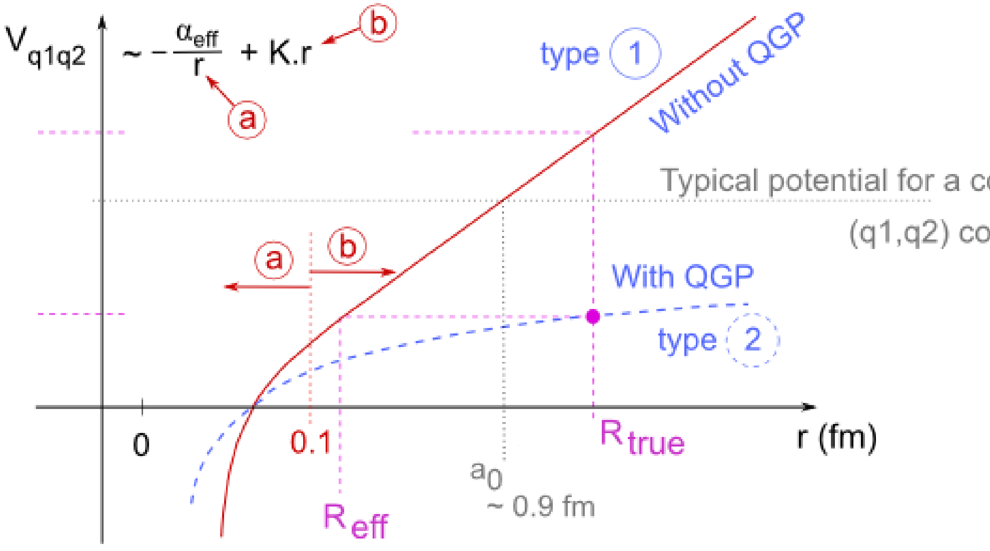
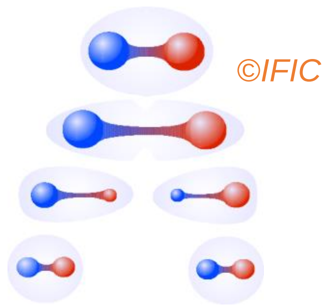
Quantum Chromodynamics (QCD)

- QCD is a non-Abelian gauge field theory (Yang-Mills theory), describing the fundamental interactions between quarks and gluons.
- It has unique features: **(1) asymptotic freedom & (2) color confinement**



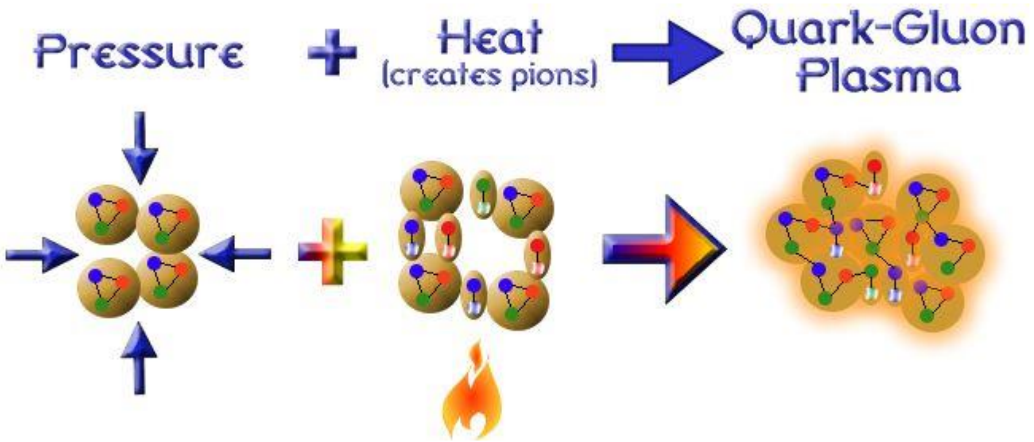


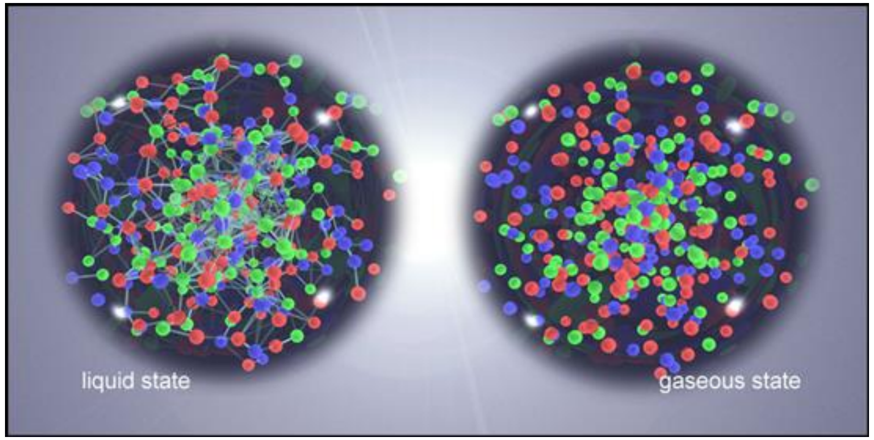
Antonin Maire, CERN-THESIS-2011-263



Quark-Gluon Plasma

- QCD matter undergoes phase transition **w/ high pressure and/or high density.**
  - → Outcome of many-body interaction, rich & non-trivial phenomenology
  - → Interplay of perturbative & non-perturbative aspects
- Such a new form of QCD matter is called **the Quark-Gluon Plasma (QGP).**
- Early measurements at RHIC revealed that **QGP is strongly interacting liquid state** instead of gaseous state.





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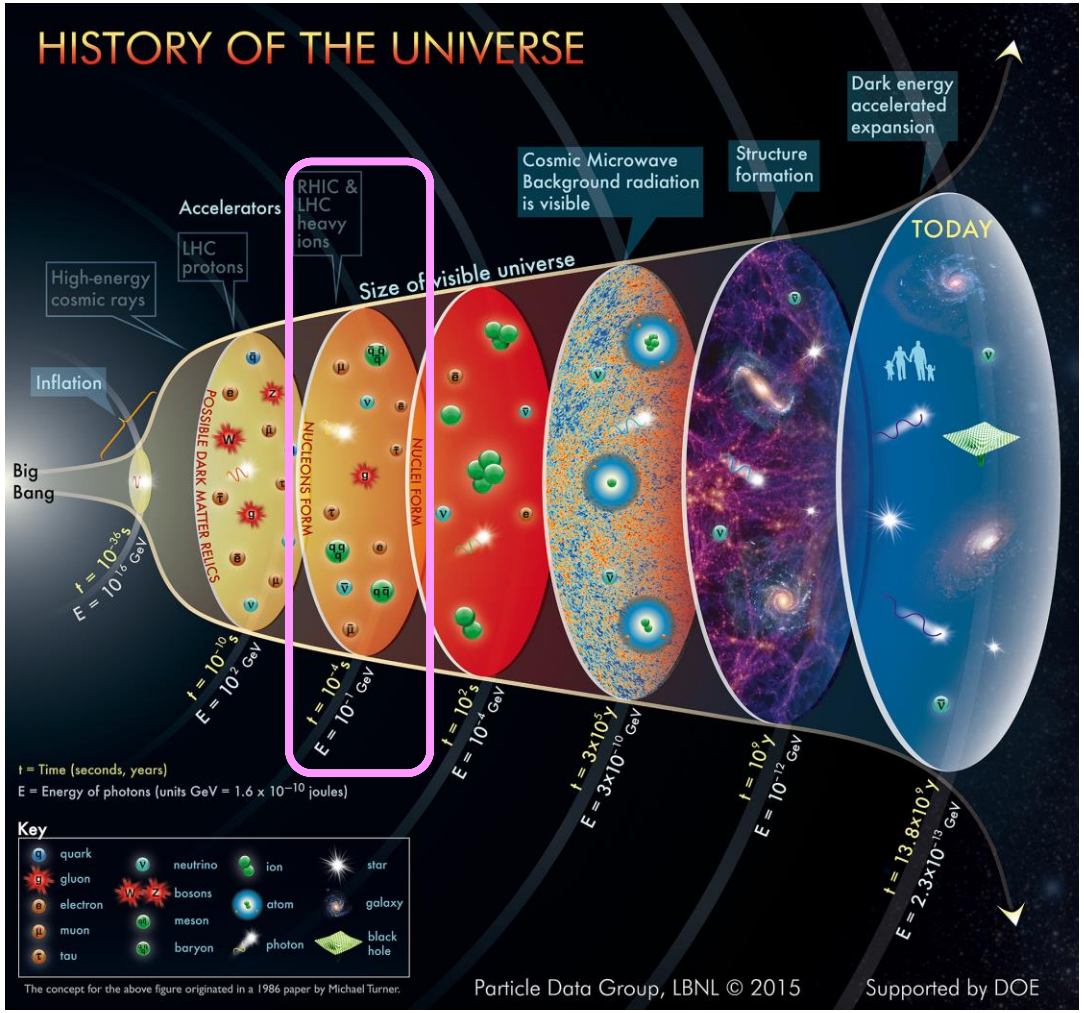
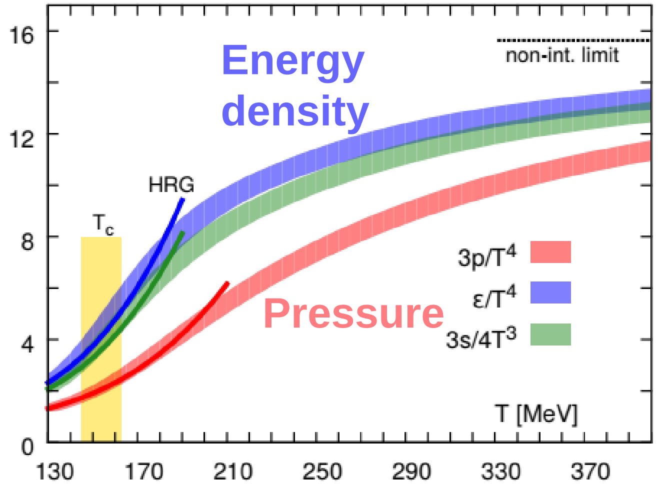
Evolution of the Universe

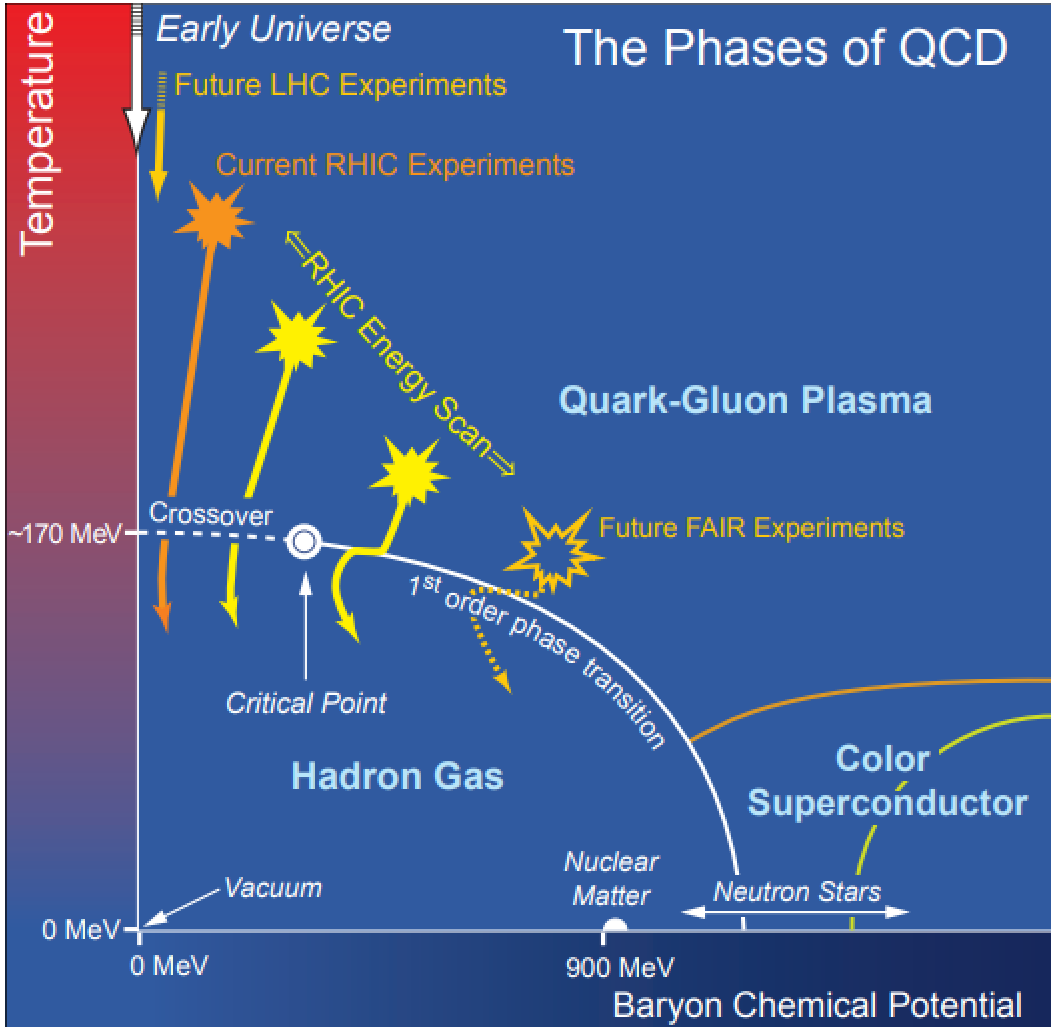


- QGP has an impact on **the formation of large scale structure of the Universe.**
- If the phase transition was the first order, the Universe would have been significantly more non-uniform.
  → Lattice QCD predicts a cross-over at zero chemical potential



PRD 90, 094503

QCD Phase Structure

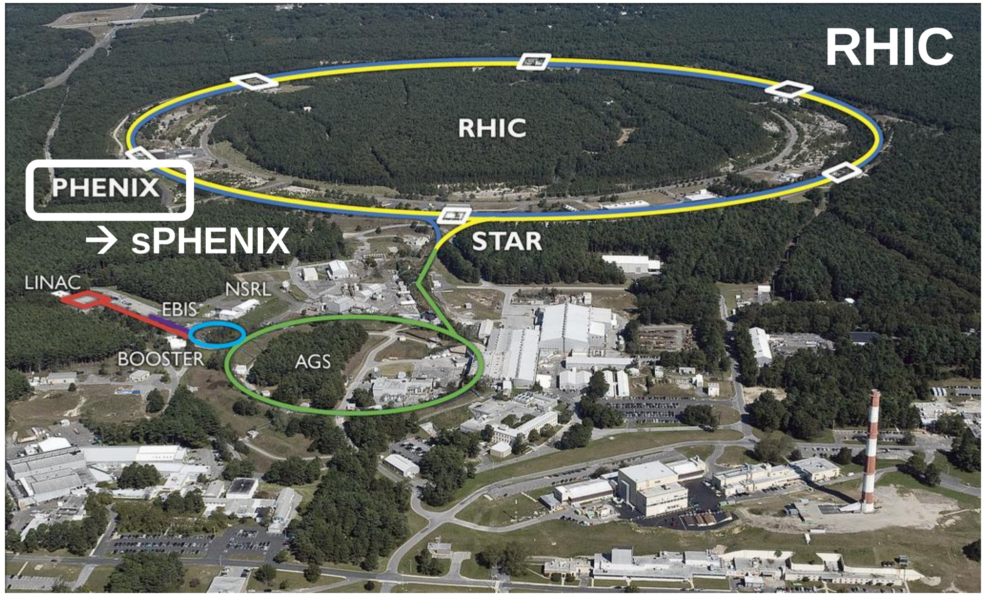


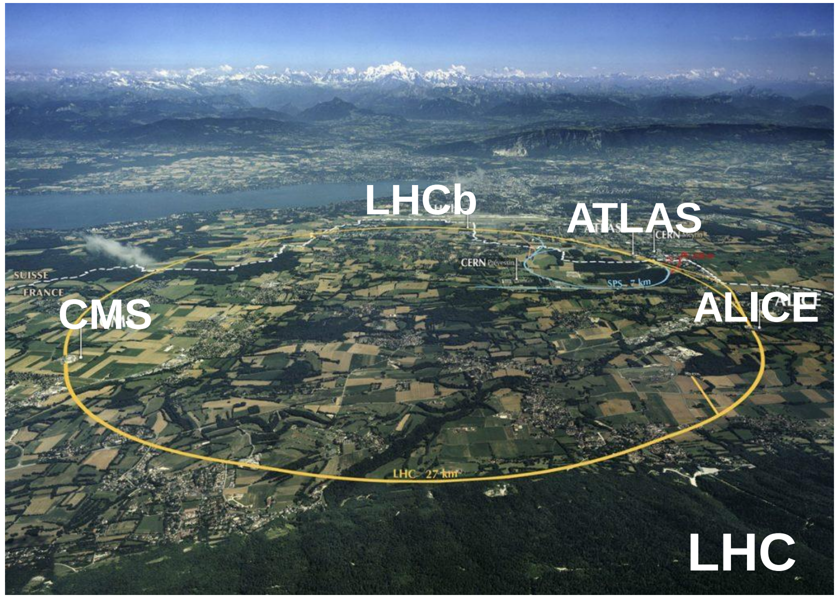
- **The QCD phase structure is crucial to understand the evolution of the Universe.**
- Lattice QCD predicts that the transition was a smooth cross over.

Two outstanding questions:

- **What is the inner workings of QGP? →** sPHENIX & other RHIC/LHC experiments @ energy frontier
- **Where is the critical point then?** → RHIC Beam Energy Scan & future experiments (NICA, FAIR) *[not this talk]*

Heavy Ion Colliders

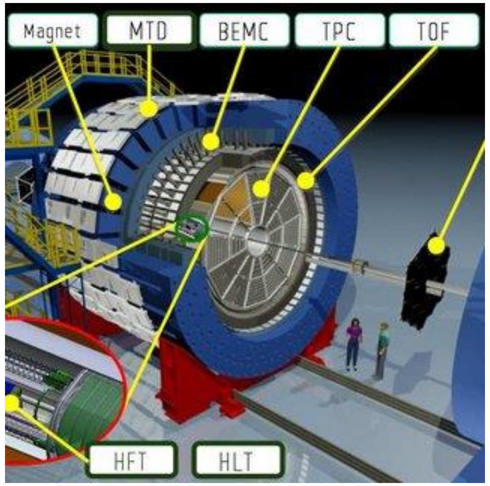




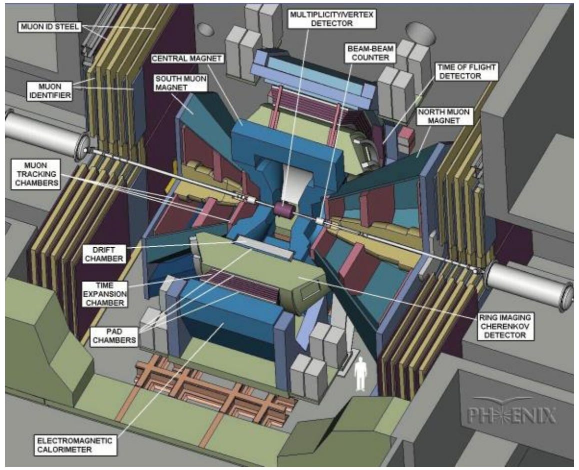
- **High energy frontier: RHIC ($\sqrt{s_{AuAu}}$=200 GeV), LHC ($\sqrt{s_{PbPb}}$=2.76, 5.02 TeV)**
- Low energy: RHIC Beam Energy Scan I&II [3-19.6 GeV], future facilities (NICA in JINR [3-11 GeV], FAIR in GSI [1-3 GeV])

RHIC Experiments

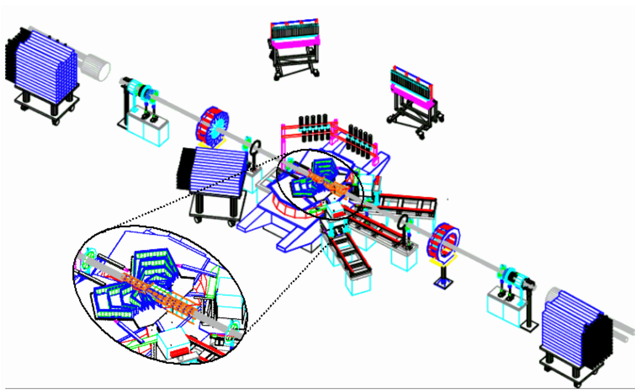
STAR (ongoing)



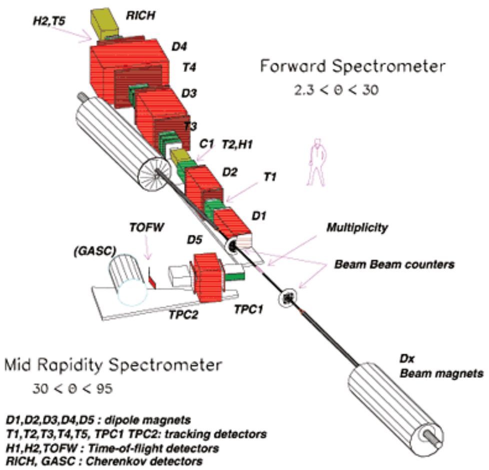
PHENIX (→ sPHENIX)



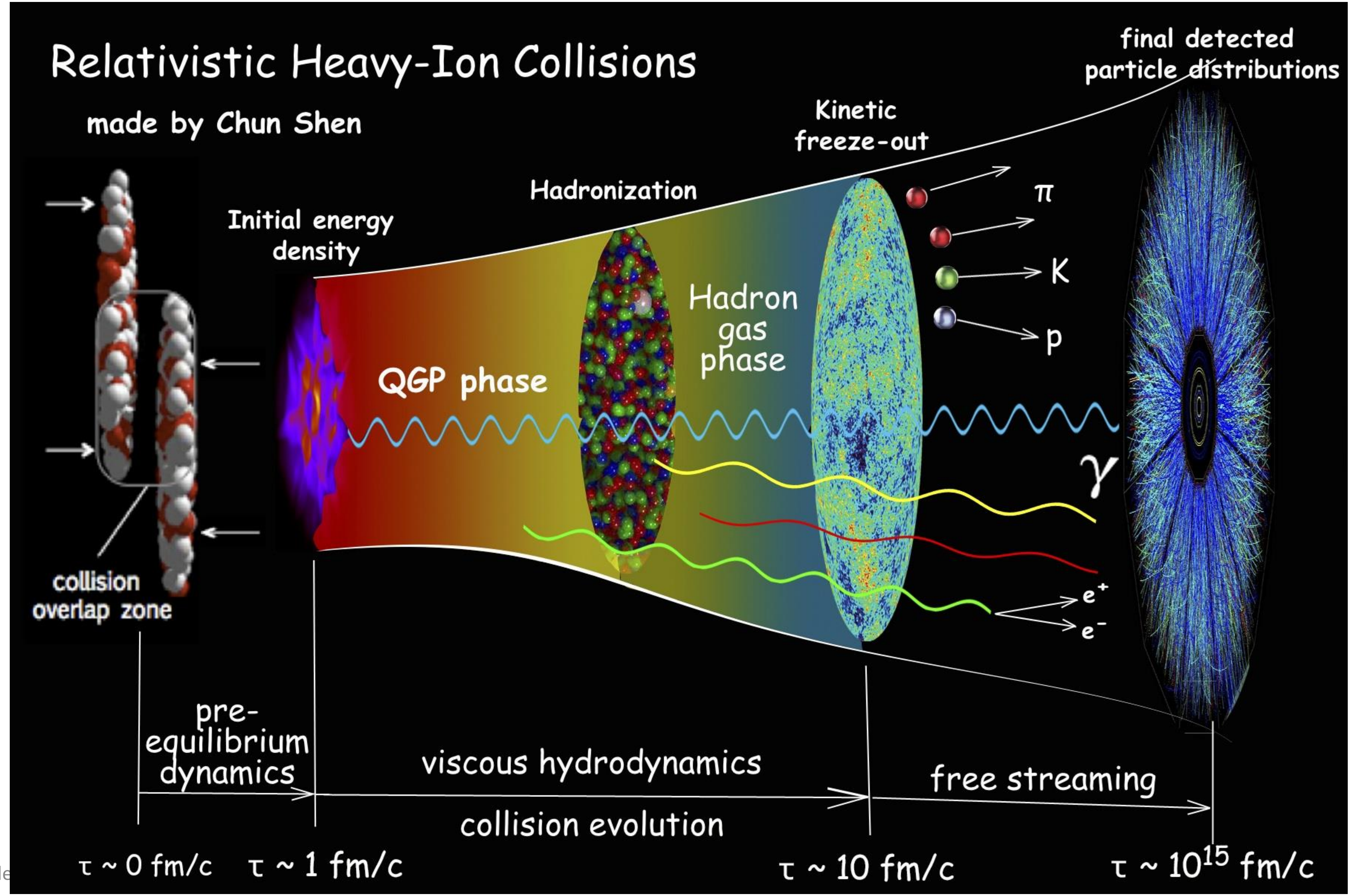
PHOBOS



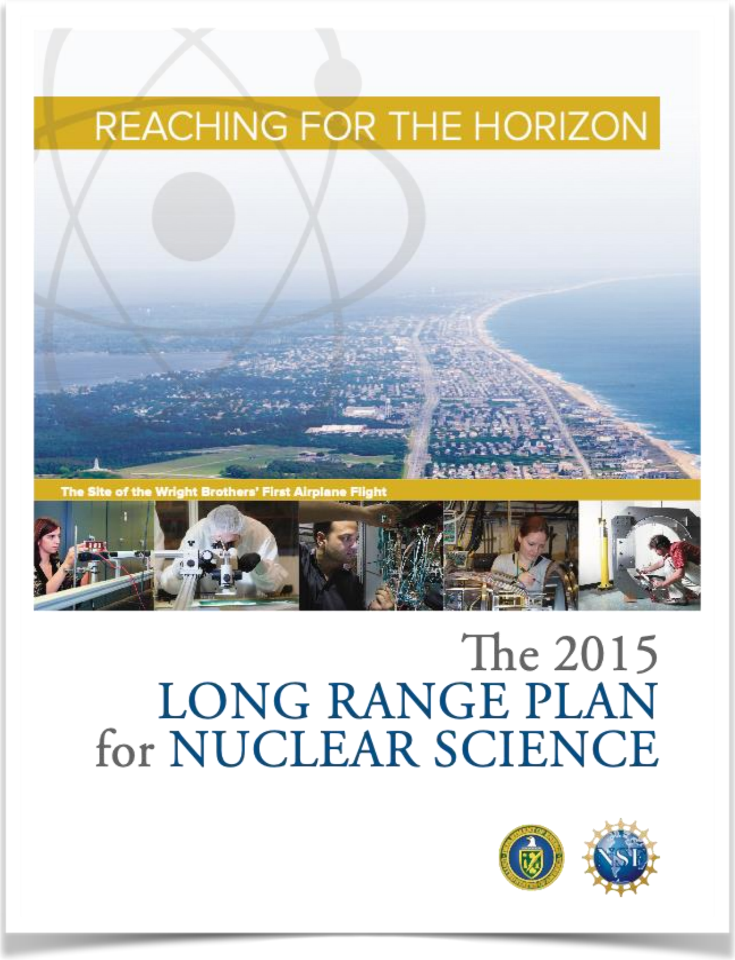
BRAHMS

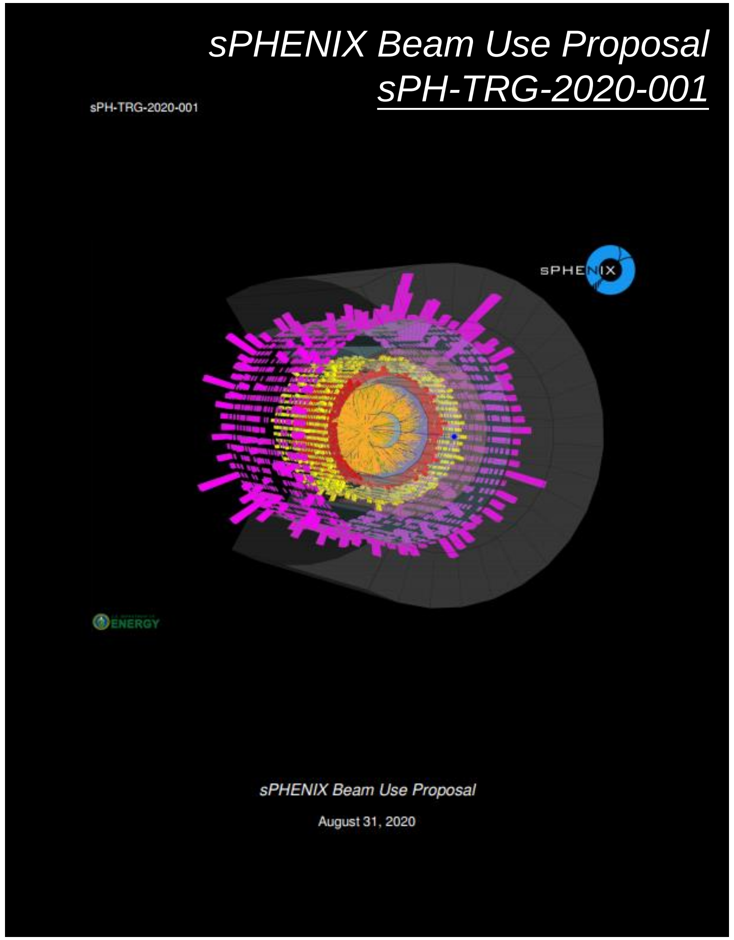


- STAR is currently the only operating experiment at RHIC & will continue along with sPHENIX.
- PHENIX ended its operation in 2016. **sPHENIX is its upgrade w/ a fully new detector.**
- Phobos for examining a very large number of rare Au-Au collisions (4π silicon multiplicity counters).
- BRAHMS for measuring charged hadrons over a wide range of rapidity and transverse momentum.


Relativistic Heavy-Ion Collisions
made by Chun Shen
final detected particle distributions
Kinetic freeze-out
Hadronization
Initial energy density
Hadron gas phase
QGP phase
π
K
p
γ
e+
e−
collision overlap zone
pre-equilibrium dynamics
viscous hydrodynamics
free streaming
collision evolution
τ ~ 0 fm/c
τ ~ 1 fm/c
τ ~ 10 fm/c
τ ~ 10^15 fm/c

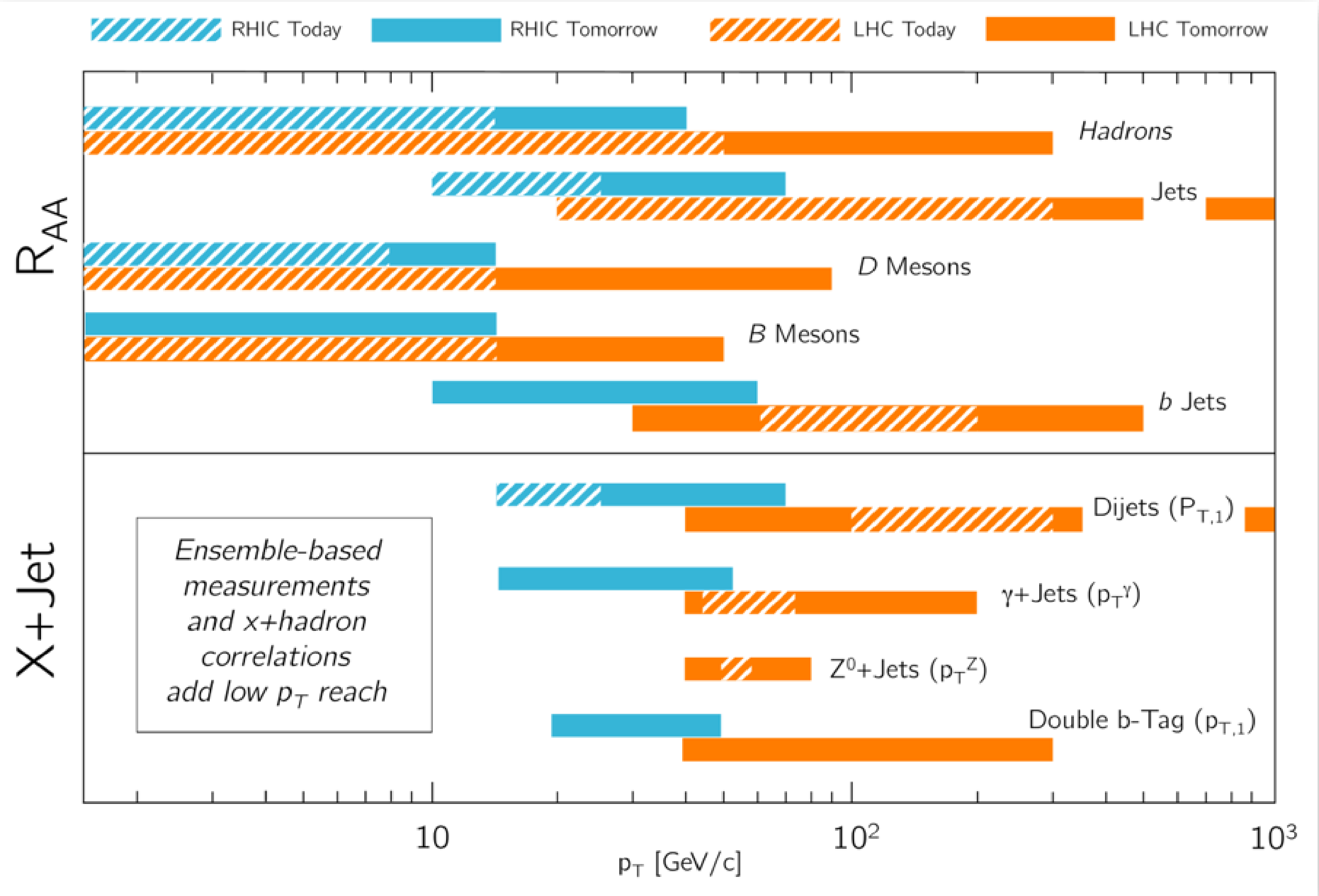
sPHENIX Mission





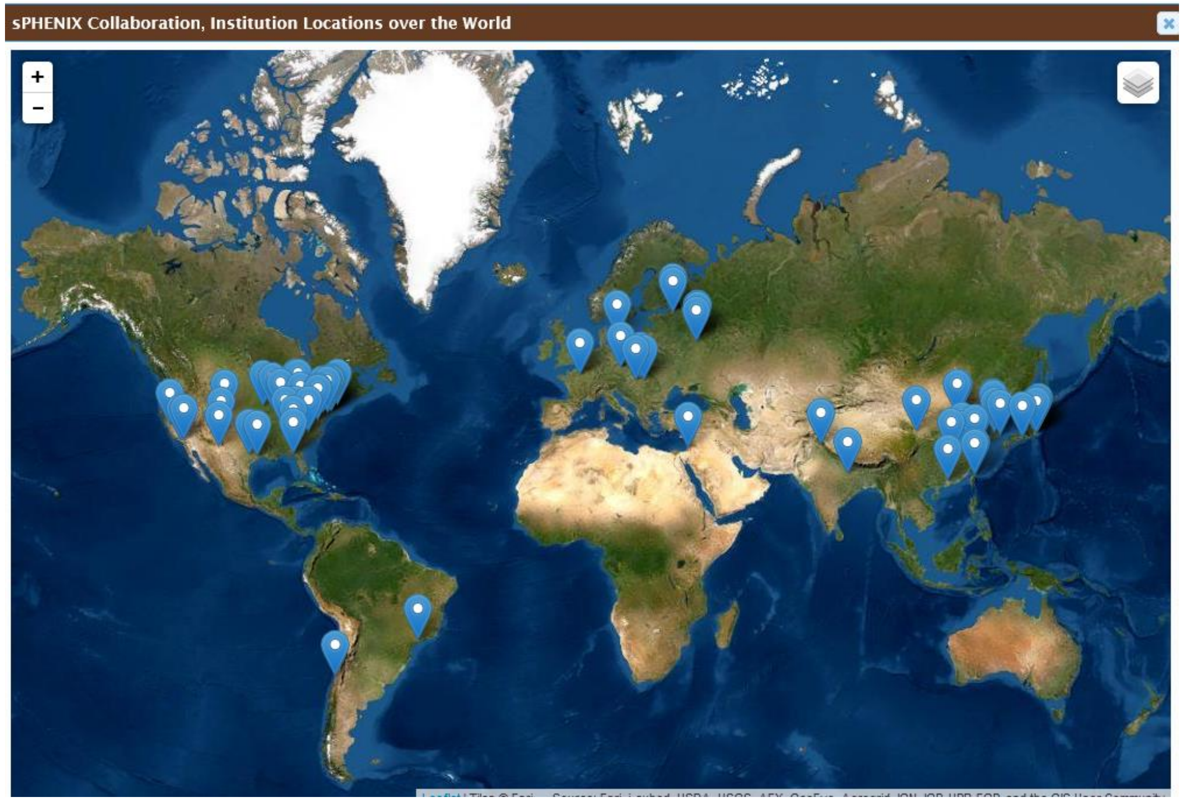
- **A state-of-the-art jet detector**; <u>the first new detector at RHIC in >20 years.</u>
- **Completing the scientific mission of RHIC**, as prioritized in DOE/NSF NSAC 2015 Nuclear Physics Long Range Plan.
- Complementarity in kinematics and medium property to LHC, also confirmed by ECFA WG5 (Heavy Ion group).
- Submitted Beam Use Proposal (BUP) on Aug. 31, 2020.
- sPHENIX as the highest priority for Runs 2023-2025 (PAC Report, Sep. 2020)

Complementarity b/w RHIC & LHC



- **Generally, RHIC has better access to low p_T region.**
- Future RHIC & LHC experiments have larger coverage in p_T & **<u>more overlap</u>** to compare the measurements.

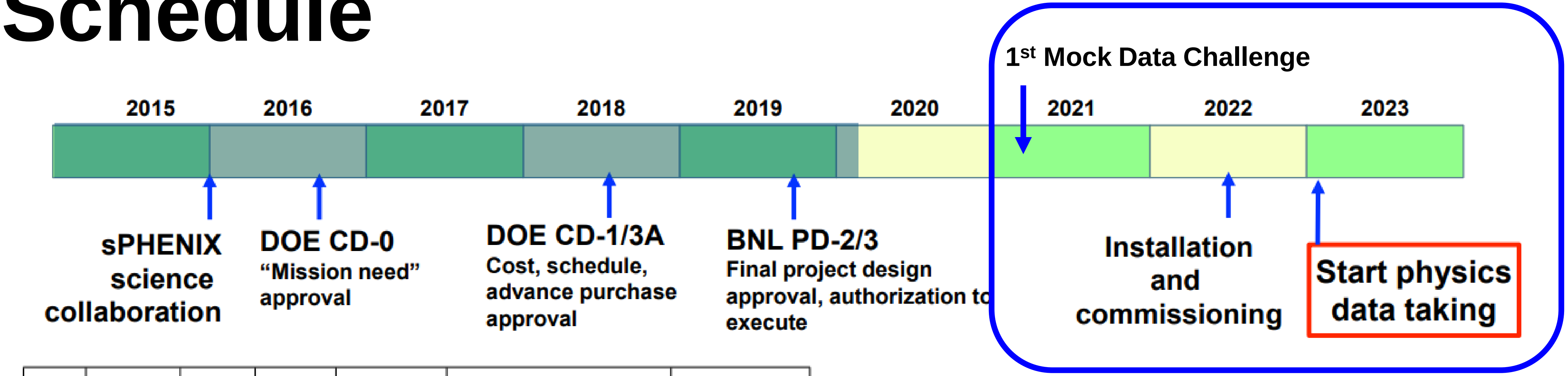
sPHENIX Collaboration



Asian regional meetings were held annually during the pre-pandemic days (at Fudan in 2019)

- More than 320 members from 84 institutions in 14 countries (as of early 2021)
- 9 institutes from China (Fudan, CCNU, CIAE, IMP-CAS, PKU, SINAP, SYSU, THU, USTC)
  - Fudan team: 5 faculties, 2 postdocs and a few PhD students

Schedule



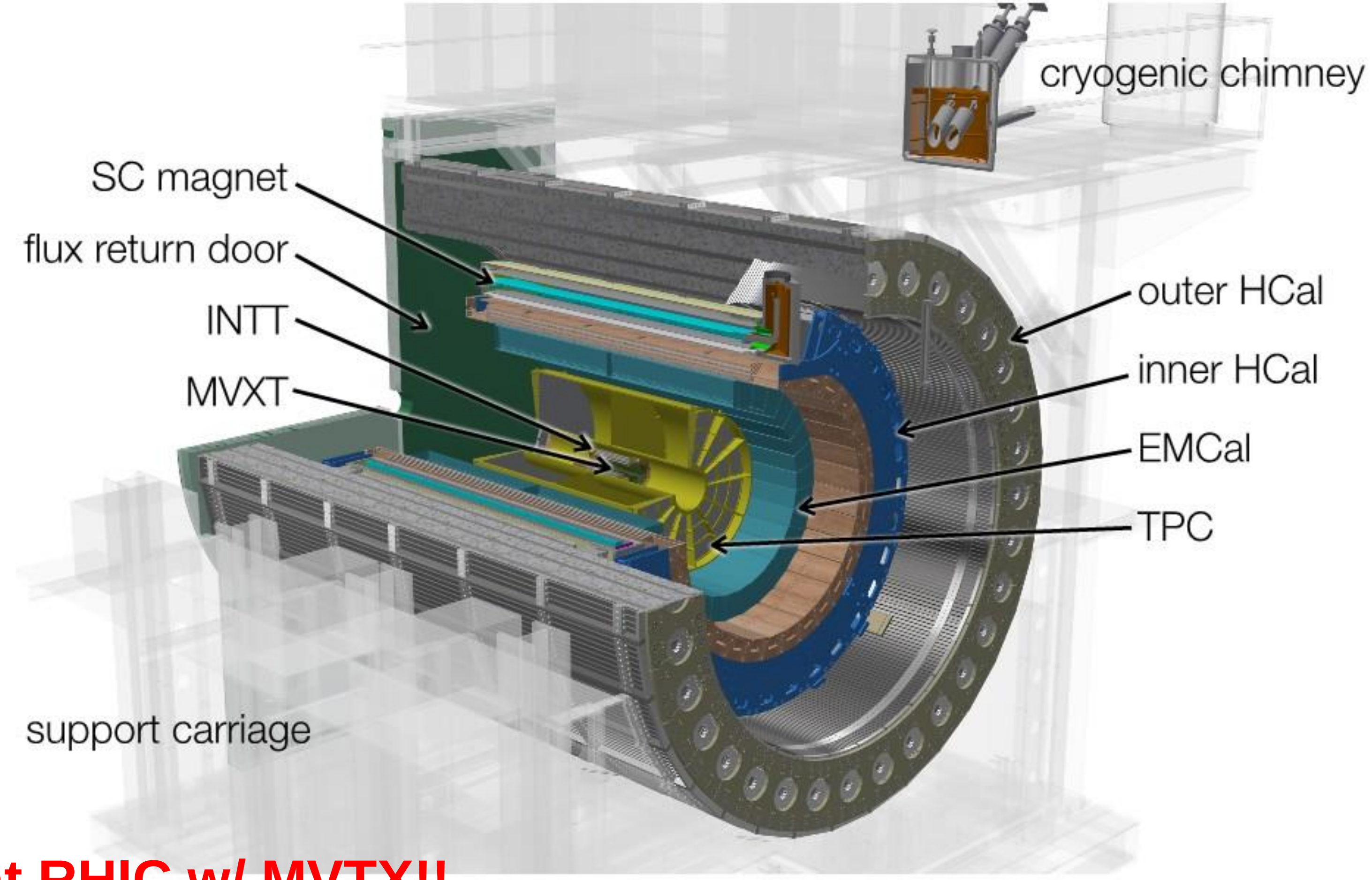
Year	Species	$\sqrt{s_{NN}}$ [GeV]	Cryo Weeks	Physics Weeks	Rec. Lum. $\lvert z \rvert < 10$ cm	Samp. Lum. $\lvert z \rvert < 10$ cm
2023	Au+Au	200	24 (28)	9 (13)	3.7 (5.7) nb^{-1}	4.5 (6.9) nb^{-1}
2024	$p^{\uparrow}p^{\uparrow}$	200	24 (28)	12 (16)	0.3 (0.4) pb^{-1} [5 kHz] 4.5 (6.2) pb^{-1} [10%-str]	45 (62) pb^{-1}
2024	$p^{\uparrow}$+Au	200	–	5	0.003 pb^{-1} [5 kHz] 0.01 pb^{-1} [10%-str]	0.11 pb^{-1}
2025	Au+Au	200	24 (28)	20.5 (24.5)	13 (15) nb^{-1}	21 (25) nb^{-1}

- **Scientific mission of sPHENIX can be achieved with 3 year of running.**
- Consistent with the currently envisioned Electron Ion Collider (EIC) schedule.
- If opportunity arises, additional runs can fully utilize the potential of the detector.

sPHENIX Detector

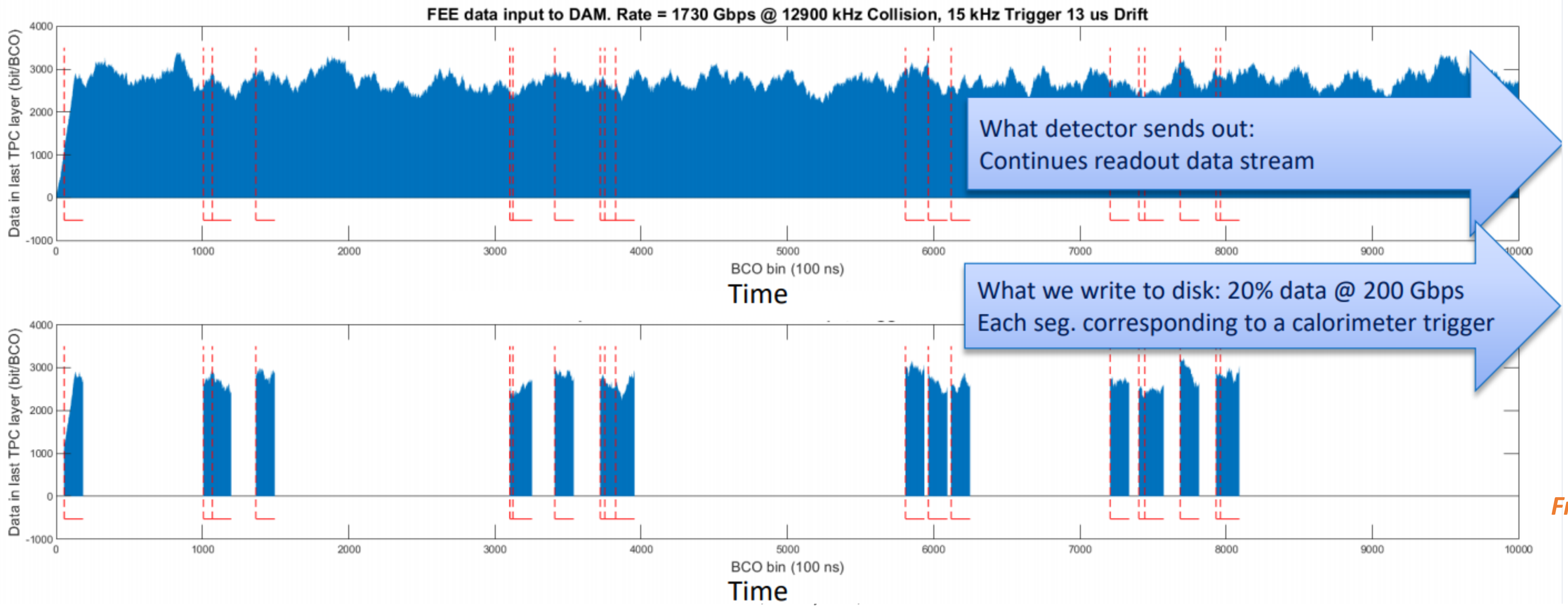
- High data rates: 15 kHz for all subdetectors
- 1.4 T Solenoid from BaBar
- Hermetic coverage: $|\eta|<1.1$
- Trigger capability also with streaming readout
- **High resolution vertexing with MAPS Vertex detector (MVTX)**
- **Large acceptance hadronic calorimetry for jets**

→ brings first b-jet tagging at RHIC w/ MVTX!!



Streaming Readout & pp Program

- **DAQ will be a hybrid of TPC/INTT/MVTX streaming & calorimeter triggers**
- **Streaming readout:** triggerless configuration recording 10% of collisions.
  → increases amount of Run-24 data by orders of magnitude
- **Crucial for open heavy ion programs** as well as some cold QCD measurements



From Jin Huang

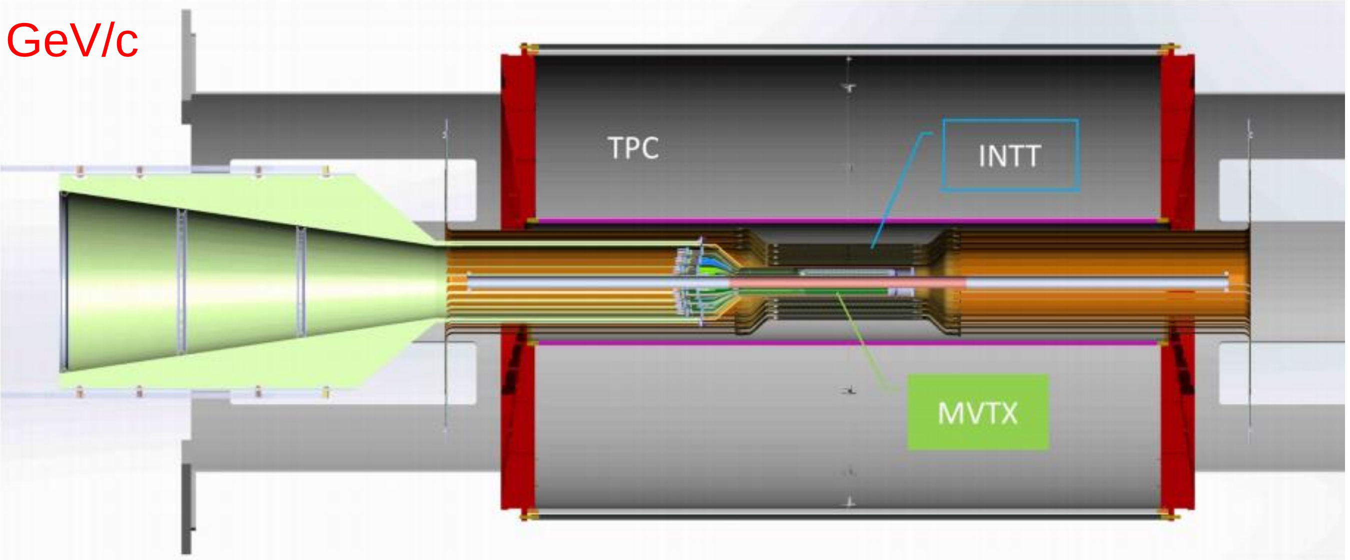
sPHENIX Tracking Detectors

Inner tracker:

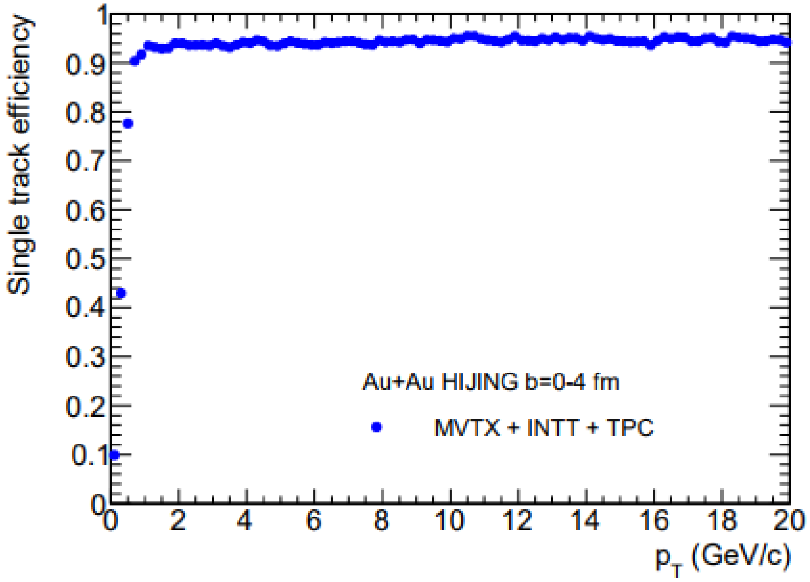
- **MVTX**: Monolithic Active Pixel Sensors (3 layers)
  - Procurement copies of ALICE ITS IB staves integrated into sPHENIX
  - 30μm pitch. Precision vertexing
- **INTT**: 2 layers of silicon strips (86μm pitch)
  - Fast integration time. Can resolve one beam crossing
- DCA(rϕ or z) resolution < 50μm for p_T>1 GeV/c

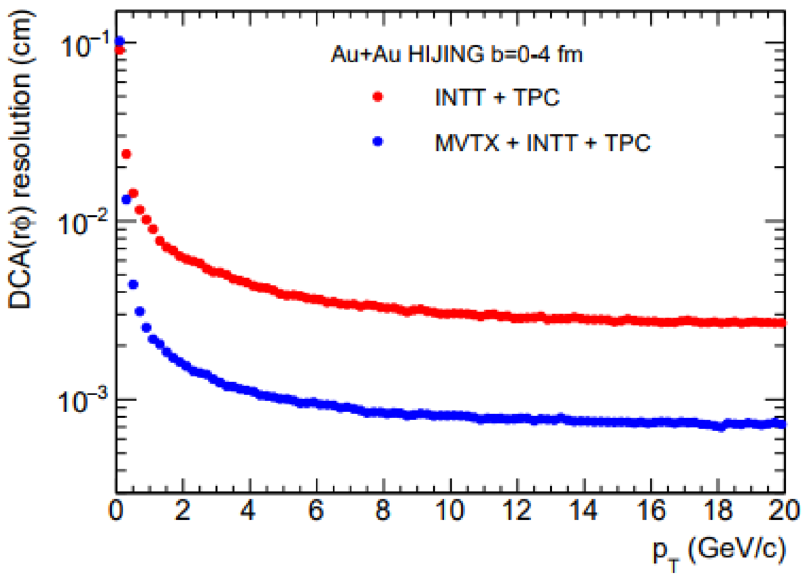
Outer tracker:

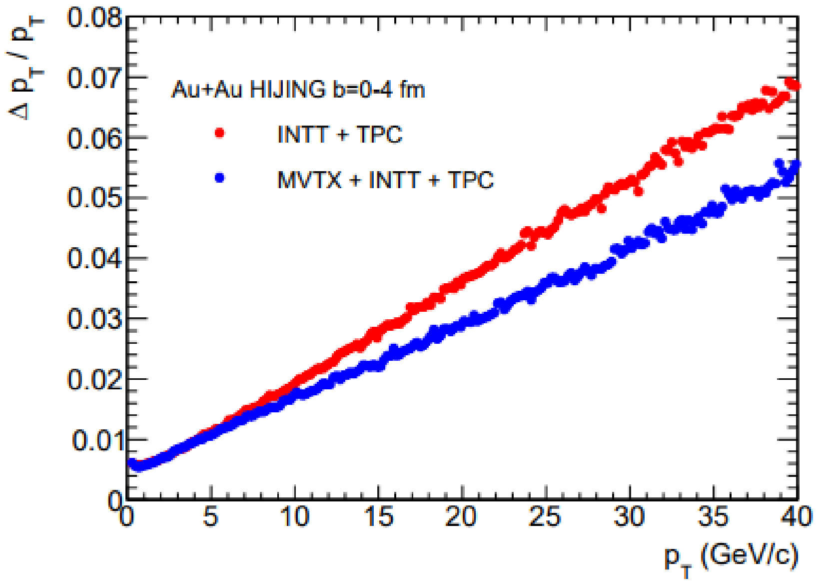
- **Compact GEM-based TPC**: 48 layers with gateless and continuous readout
  - Main tracking device; provide momentum measurement
- δp/p < 2% for p_T<10 GeV/c



Impact of MVTX on Tracking

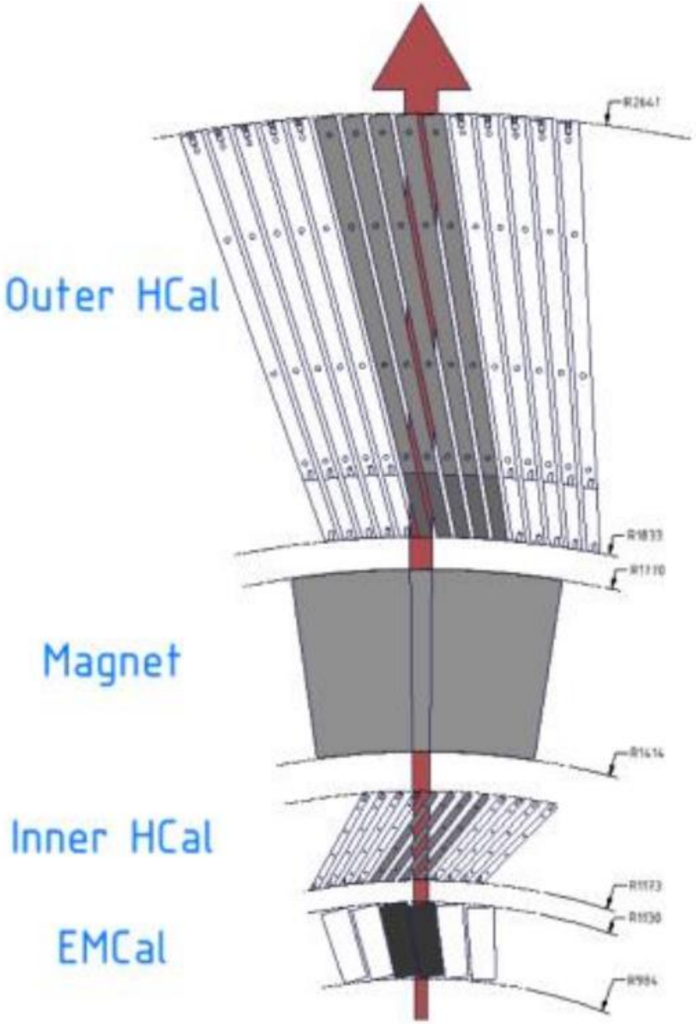






- **Tracking efficiency above 90% at p_T>1 GeV/c. →** promising to measure rare processes such as Υ(nS) production.
- **DCA pointing resolutions in rϕ & z ~ 40μm at p_T=0.5-1 GeV/c. → crucial for open heavy-flavor programs.**
- **Momentum resolution < 2% for p_T < 10 GeV/c. → Important for Υ(nS) separation; δM/M < 125 GeV required.**

sPHENIX Calorimeters



Full Electromagnetic and Hadronic calorimeter system

- Large Acceptance: $1.1 < |\eta|$ and full 2π azimuthal coverage
- SiPM used for light collection & readout

EMCal

- Tungsten-scintillating fiber sampling calorimeter (SPACAL type). 18 X_0, 1 λ.

Inner HCal

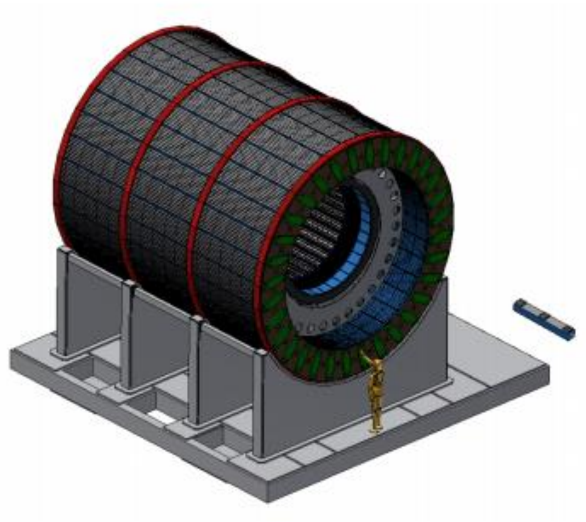
- Aluminum absorber plates and scintillating tiles with embedded WLS fibers

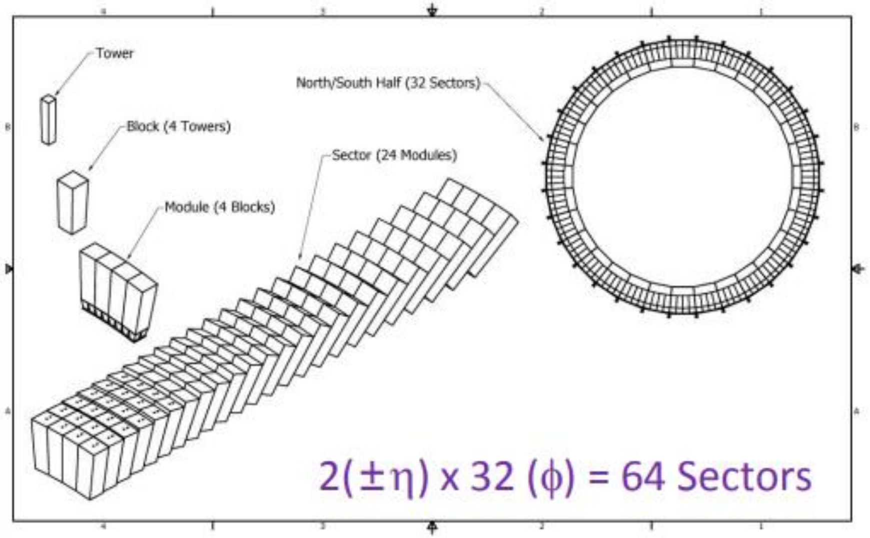
Outer HCal

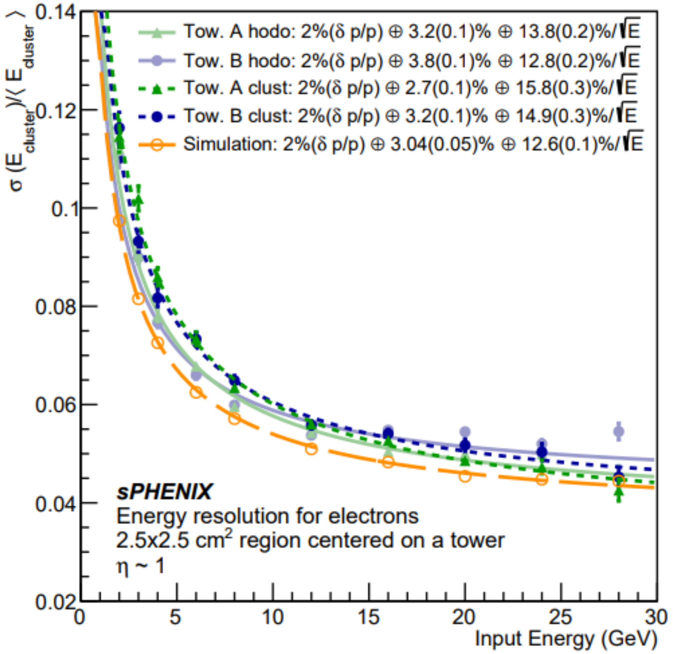
- Steel absorber plates and scintillating tiles with embedded WLS fibers
- $\sigma_E/E < 100\%/\sqrt{E}$ (single particle) for overall HCal.

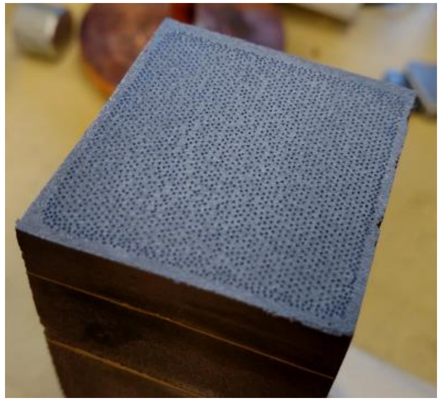
sPHENIX EMCal

EMCal covering $\pm$ 1.1 in η and 2π in ϕ. $\Delta\phi \times \Delta\eta \sim 0.025 \times 0.025$





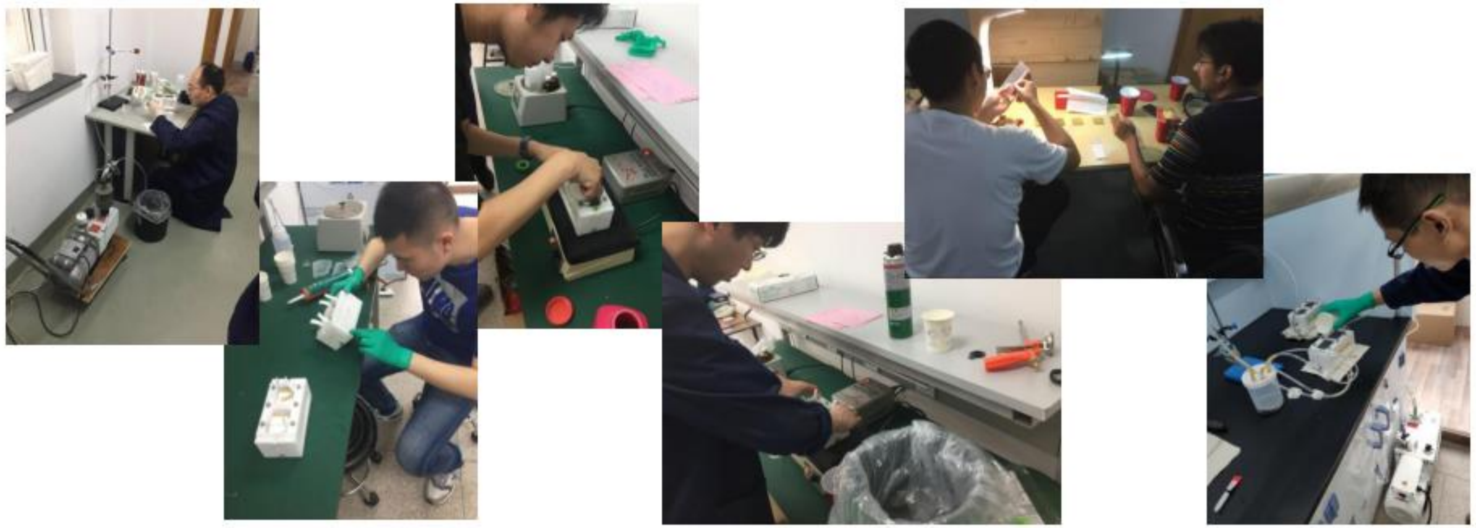




- Total 6144 blocks for EMCal. Consists of scintillating fibers embedded in a matrix of tungsten powder infused with epoxy (W/SciFi).
- Tower size $\Delta\eta \times \Delta\phi = 0.025 \times 0.025$. Resolution ~ $16\%/\sqrt{E} \oplus 5\%$.
- Cooperation with BNL, MIT & UIUC. **Fudan is one of the main block construction site.** 1248 blocks will be made by Fudan/PKU/CIAE.

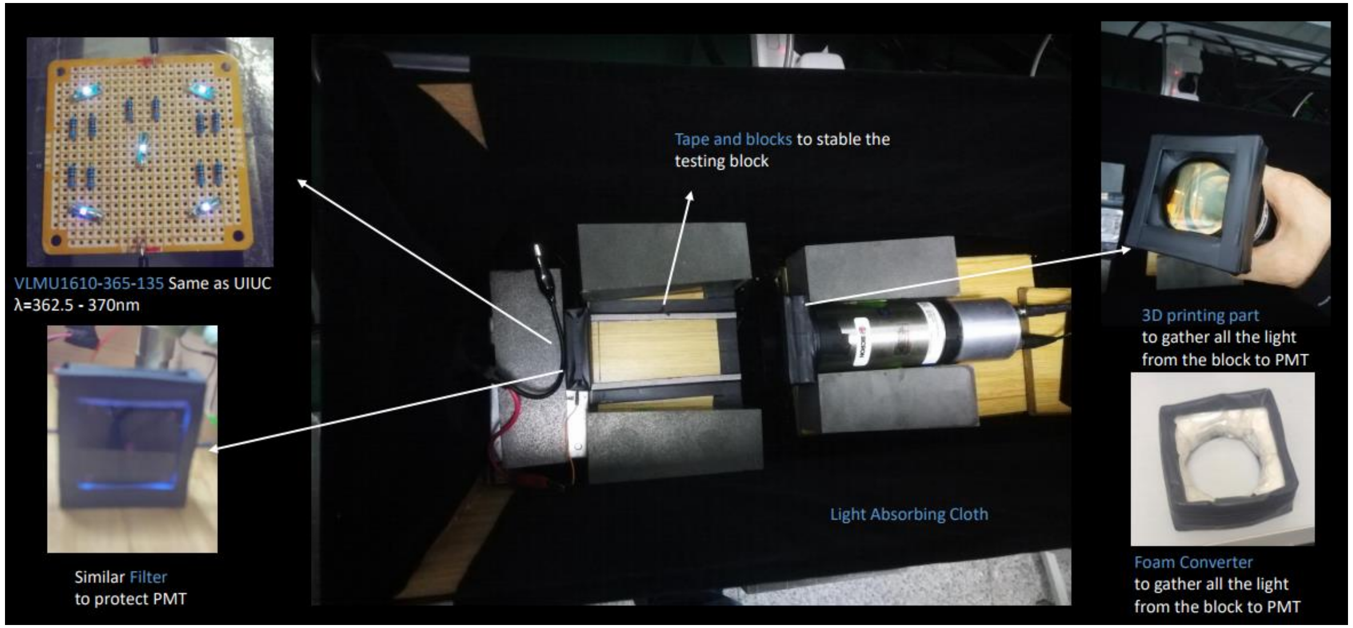
sPHENIX EMCal Production

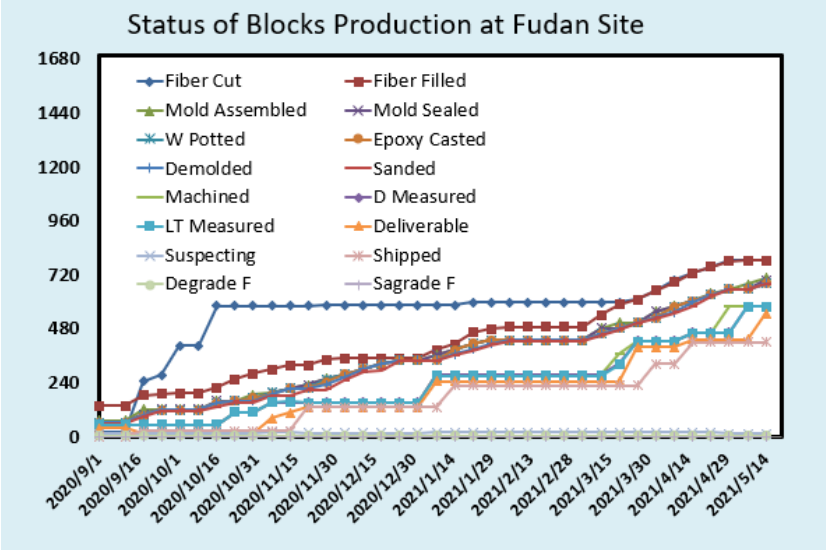
Material from Weihu Ma (Fudan)

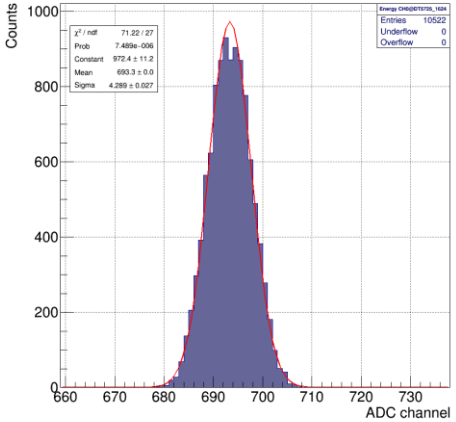


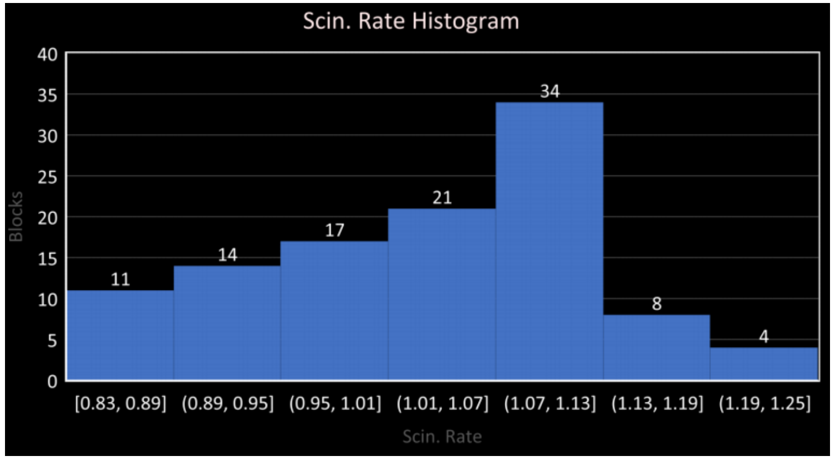
sPHENIX QA & Shipment

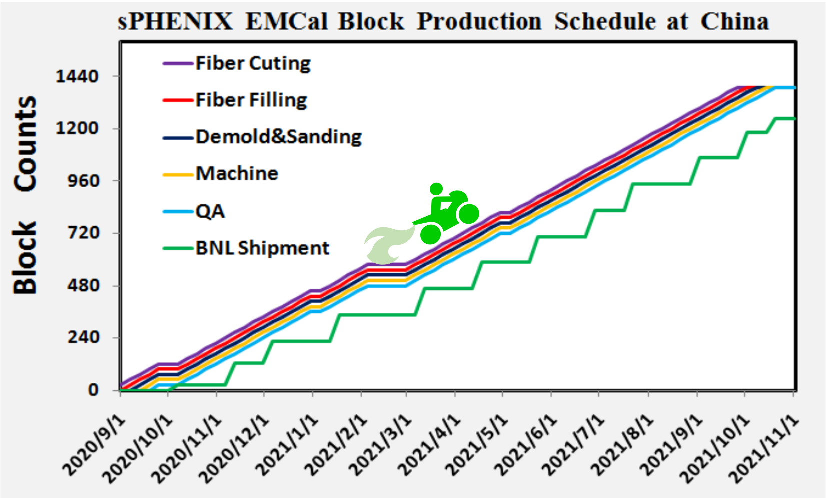
Material from Xiaozhou Yu & Weihu Ma (Fudan)





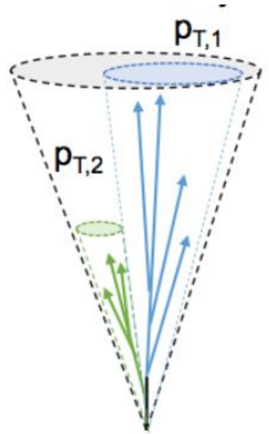






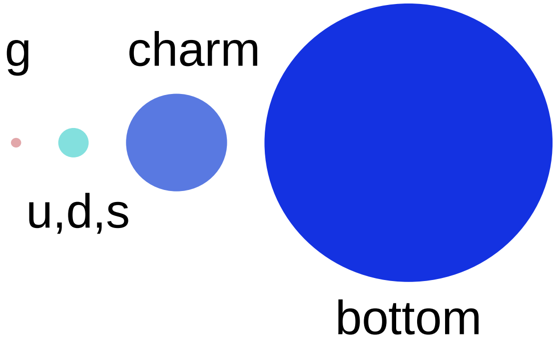
4 Core Physics Programs @ sPHENIX

Jet Structure



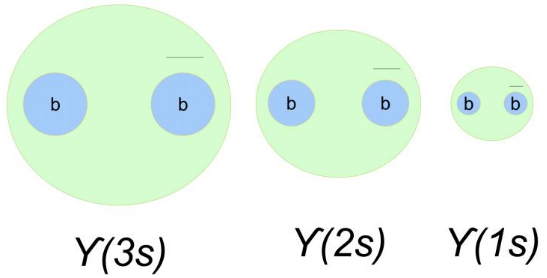
Vary momentum & angular scale of probe

Open Heavy Flavors



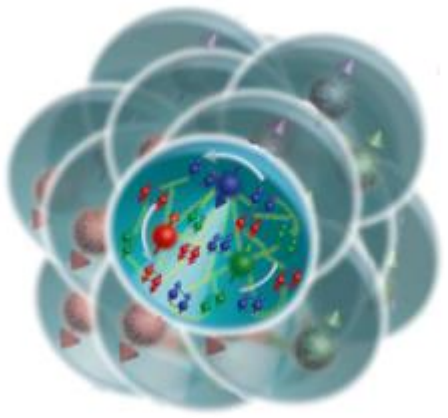
Vary mass & momentum of probe

Upsilon Spetroscopy
"Closed Heavy Flavors"



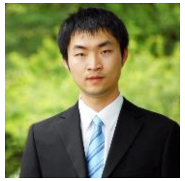
Vary size of probe

Cold QCD



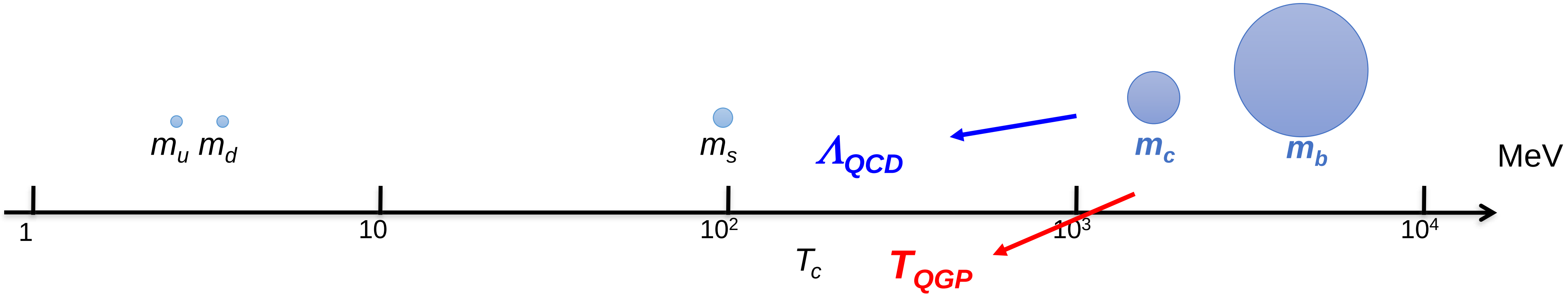
Vary temperature of QCD matter

This Talk



- **Co-convenors of Heavy Flavor Topical Group: Jin Huang (BNL)** & **Hideki Okawa (Fudan)**

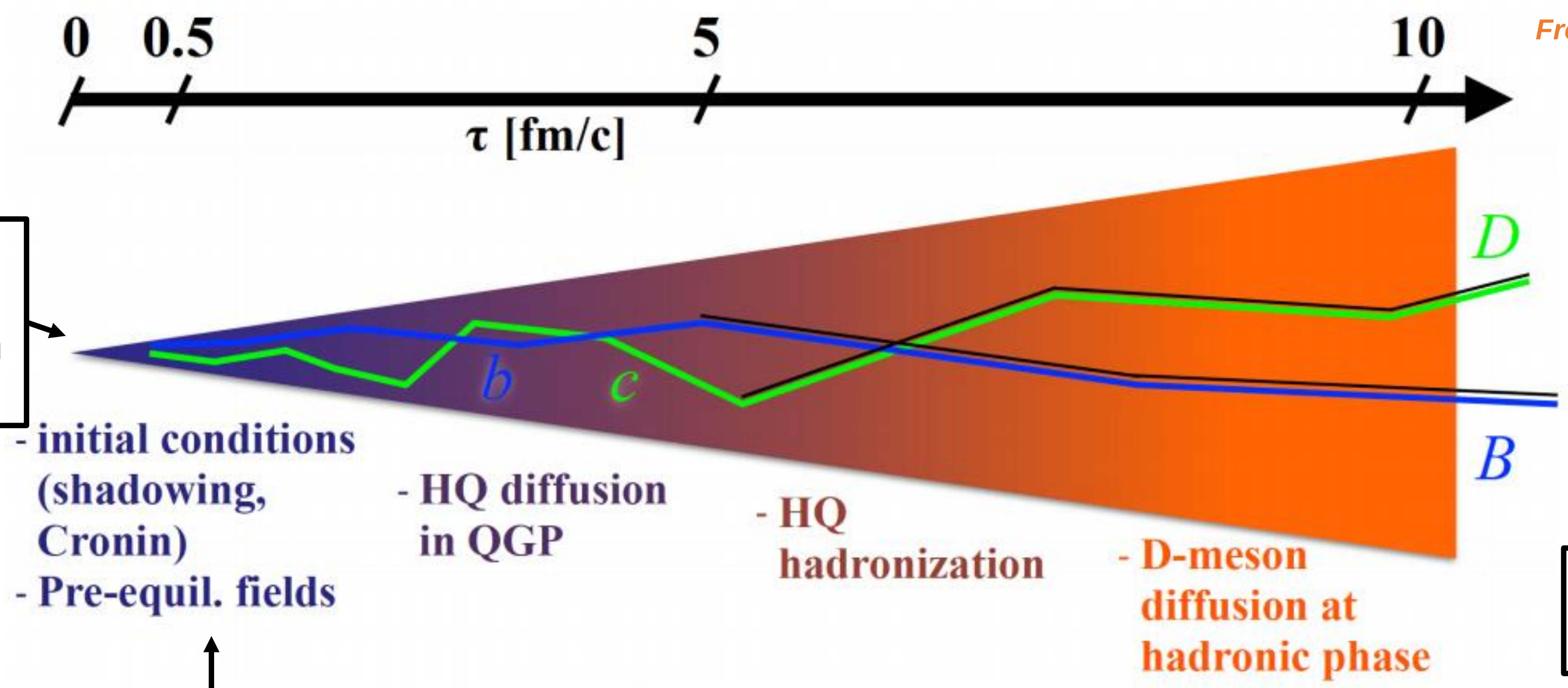
Why Heavy Flavors?



- Unique probes for both perturbative & non-perturbative regimes.
  - $m_{b,c} \gg \Lambda_{QCD}$ → **pQCD prediction of initial production**
  - $m_{b,c} \gg T_{QGP}$ → **No thermal production of HF**; **c/b conserved from the initial hard scatterings** & <u>experience full QGP evolution</u>; able to tag hadronization

Why Heavy Flavors?

From R. Rapp



Reliable calculation of initial production with pQCD

Energy loss in QGP

Sensitivity to initial electromagnetic field

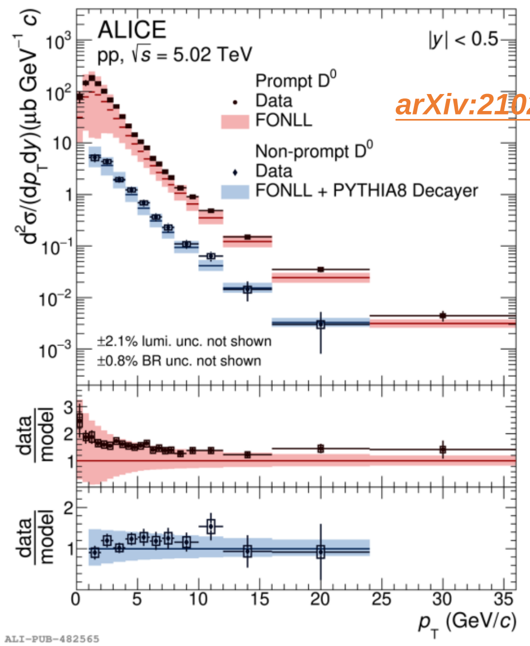
Color screening of quarkonium

Diffusion

Hadronization

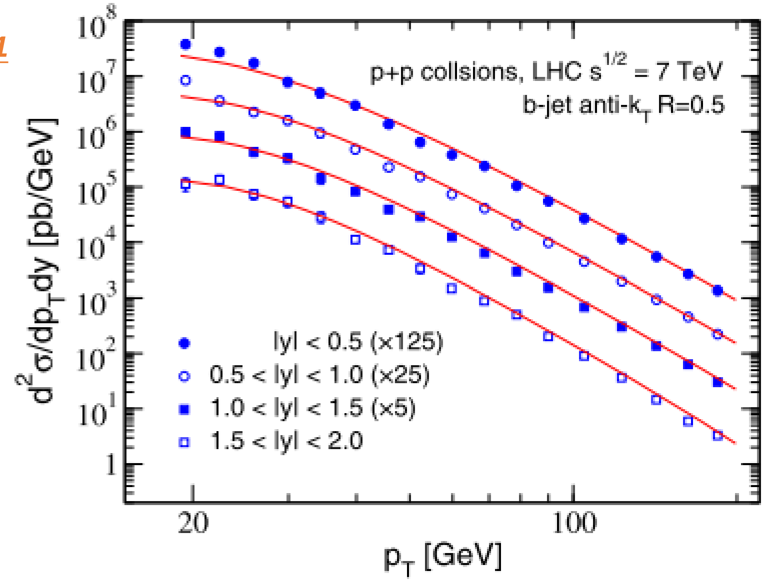
pQCD Predictions

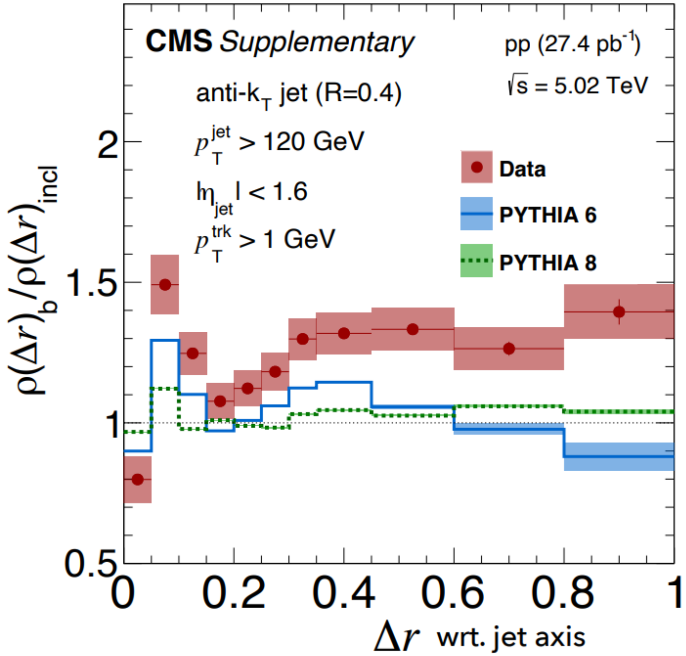
JHEP 05 (2021) 054



arXiv:2102.13601

J. Huang et al. PLB 726 (2013) 251



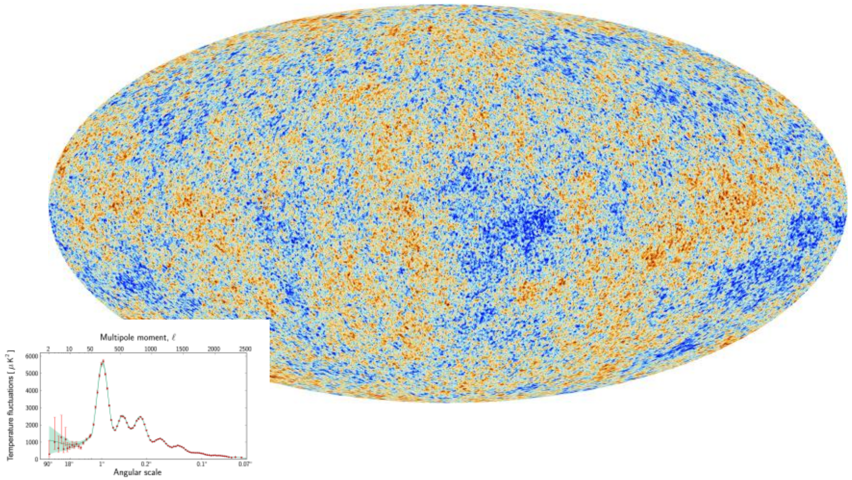


- pQCD provides important foundation to study the properties of the QGP.
- Various c & b-hadron production cross sections as well as b-jet cross section are well described by pQCD calculation (e.g. FONLL) both in LHC & RHIC.
- However, larger uncertainty in model prediction & modeling differential distributions to be improved.

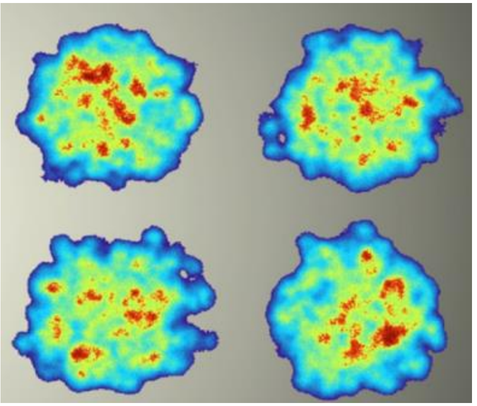
Key Observables

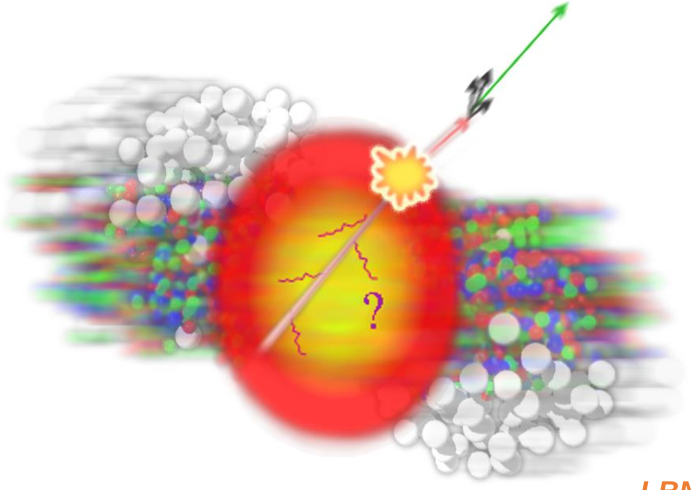
Two popular & crucial observables for QGP studies

1. **Collective flow** → "CMB" of the Heavy Ion "Little Bangs"
2. **Nuclear Modification Factor** → quantitative measure for parton energy loss (i.e. "jet quench")



NSF 2015 Long Range Plan



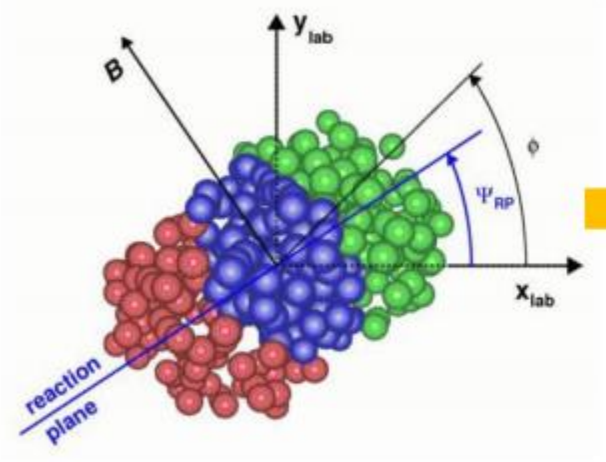


LBNL

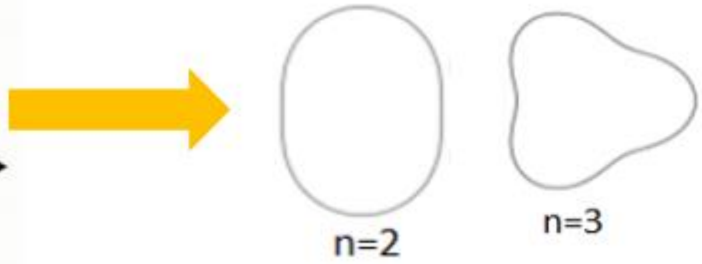
Collective Flow: “CMB” of Little Bang

$$E\frac{d^3N}{dp_T} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}\left\{1 + \sum_{i=1}^{\infty} v_n \cos[n(\varphi - \Psi_n)]\right\}$$

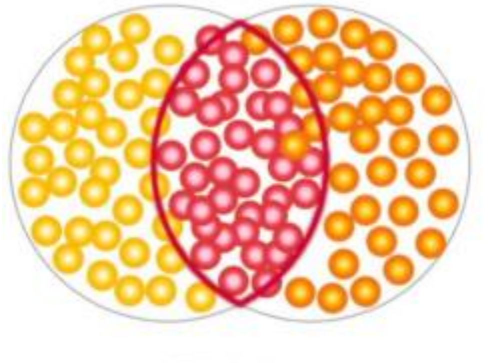
- **Fourier analysis of azimuthal distributions** against the reaction plane.
- **Elliptic flow (v_2)** has been dominantly measured to constrain the QGP properties.



From Maria Lucia Sambataro

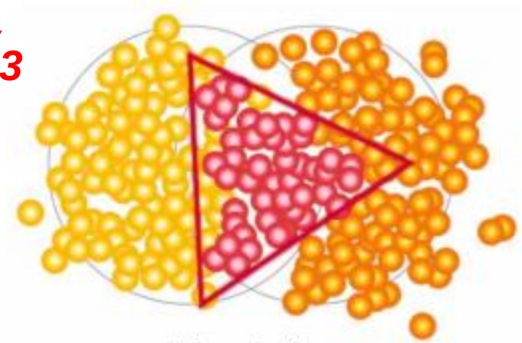


v_2



Elliptic flow

v_3



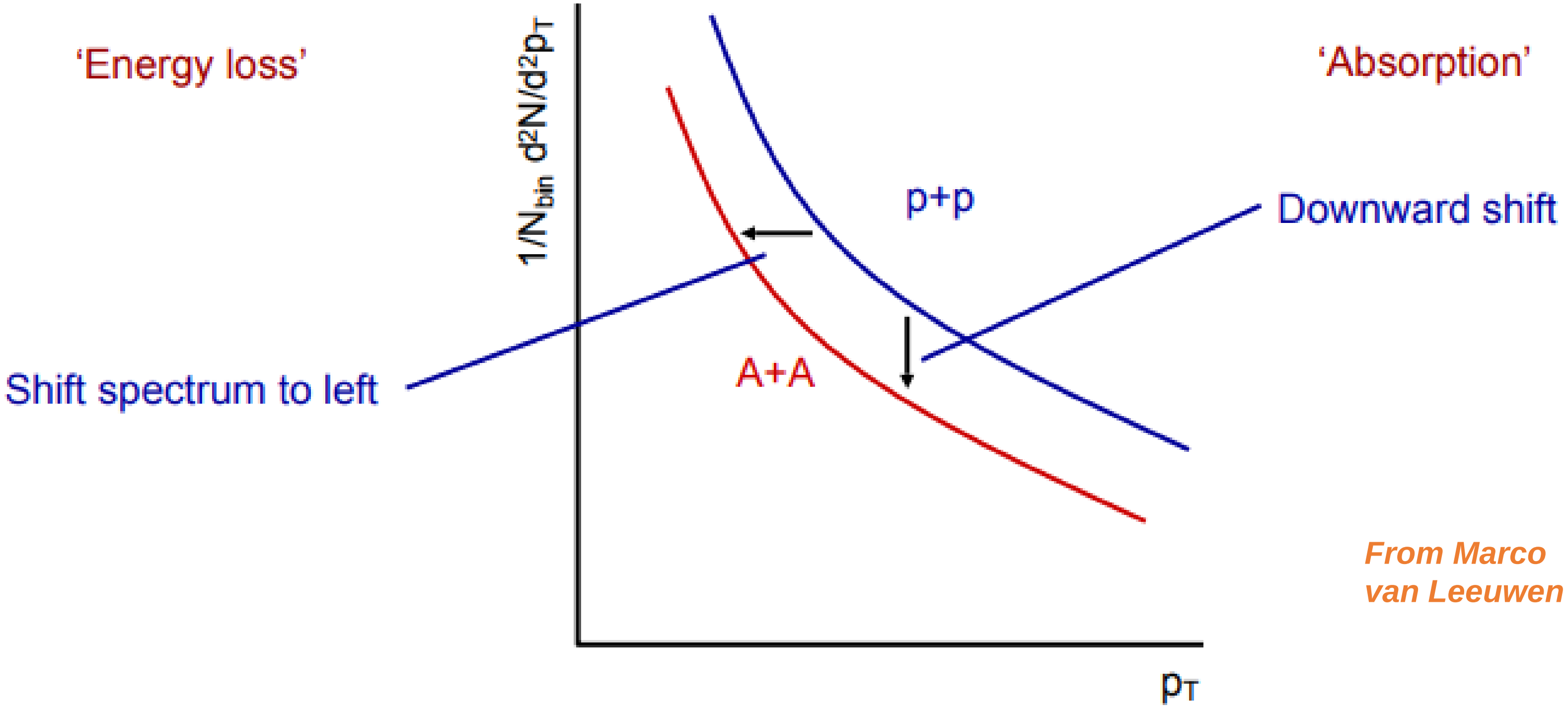
Triangular flow

Nuclear Modification Factor

Nuclear Modification Factor

$$R_{AA} = \frac{1}{T_{AA}} \frac{dN_{AA}}{dp_T} \Big/ \frac{d\sigma_{pp}}{dp_T}$$

T_{AA}: # of nucleon-nucleon scatterings



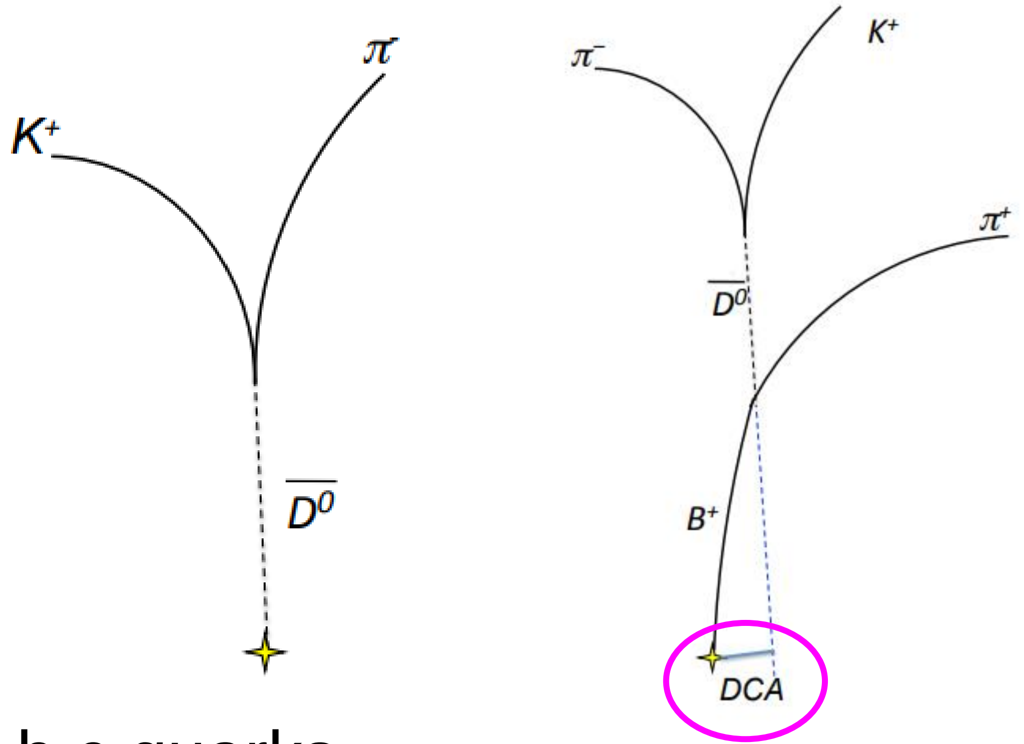
From Marco van Leeuwen

- The most widely used observable to quantify the jet quench. **Compare the differential spectrum in pp & AA collisions.**
- **R_{AA}=1 (no quench); < 1 (jet quench)**

Heavy Flavor Hadron Reconstruction

L. Gladilin, Eur. Phys. J. C (2015) 75:19

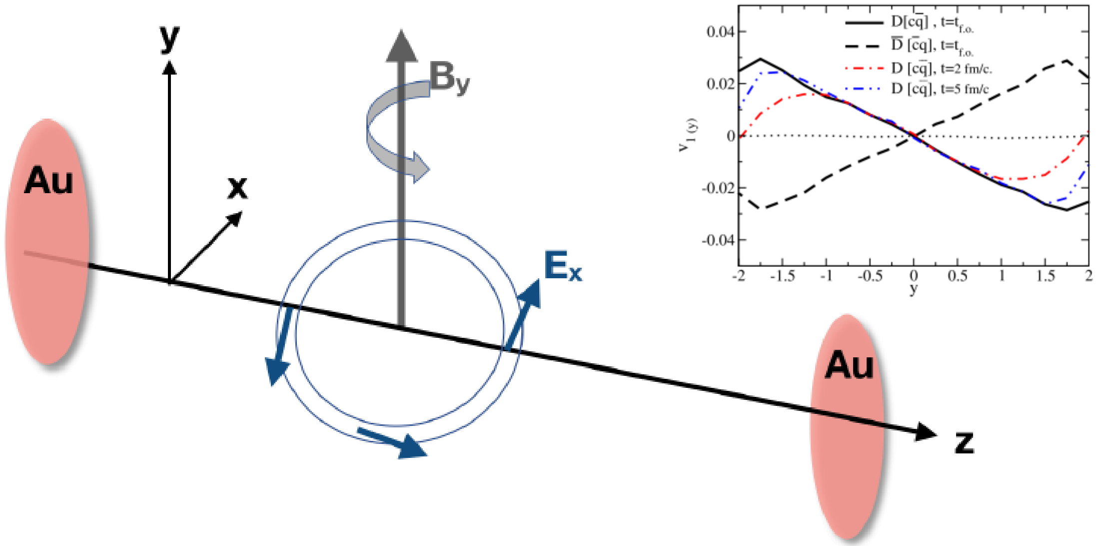
H_c	$f(c \to H_c)$ [%]	$f(b \to H_c)$ [%]
D^0	$54.2 \pm 2.4 \pm 0.7$	$58.7 \pm 2.1 \pm 0.8$
D^+	$22.5 \pm 1.0 \pm 0.5$	$22.3 \pm 1.1 \pm 0.5$
D_s^+	$9.2 \pm 0.8 \pm 0.5$	$13.8 \pm 0.9 \pm 0.6$
Λ_c^+	$5.7 \pm 0.6 \pm 0.3$	$7.3 \pm 0.8 \pm 0.4$
D^{*+}, rate	$23.4 \pm 0.7 \pm 0.3$	$23.3 \pm 1.0 \pm 0.3$
D^{*+}, double-tag	$24.4 \pm 1.3 \pm 0.2$	$17.5 \pm 2.0 \pm 0.1$
D^{*+}, combined	$23.6 \pm 0.6 \pm 0.3$	$22.1 \pm 0.9 \pm 0.3$



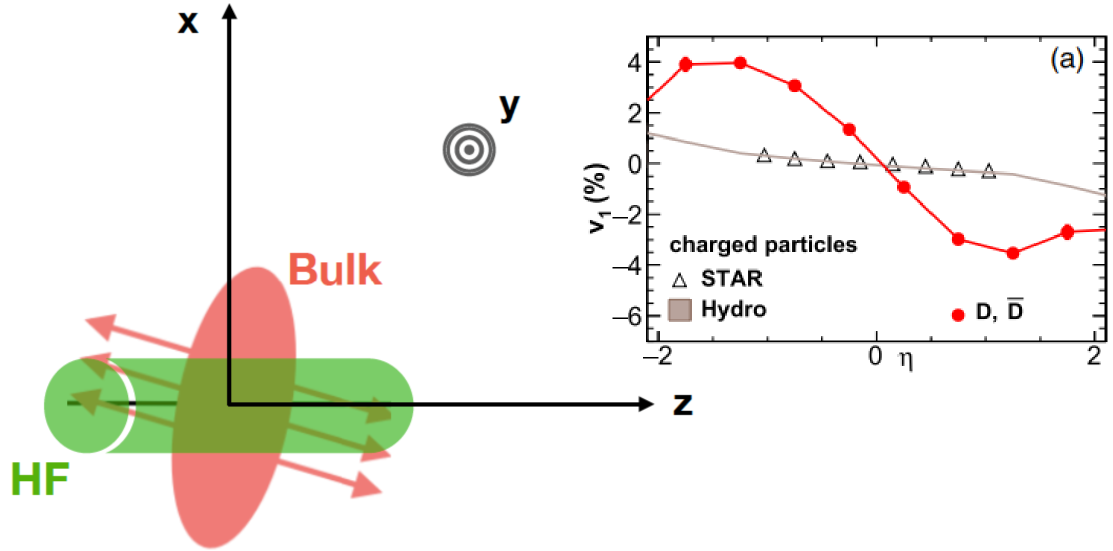
- Decays to **D mesons** are dominant for b,c quarks.
- Hadronic modes: $BR(D^0 \rightarrow K^-\pi^+)=3.89\%$; $BR(D^+ \rightarrow K^-\pi^+\pi^+)=8.98\%$.
- Displacement of D mesons allows us to discriminate b vs c.

Sensitivity to Initial EM Field & Tilt

S. Das et al., PLB 768 (2017) 260

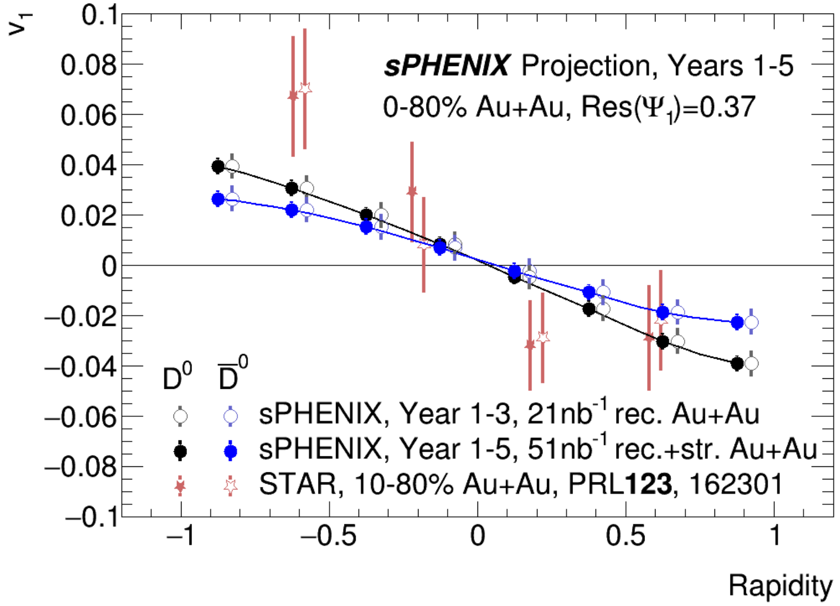


S. Chatterjee, P. Bozek, PRL 120 (2018) 192301

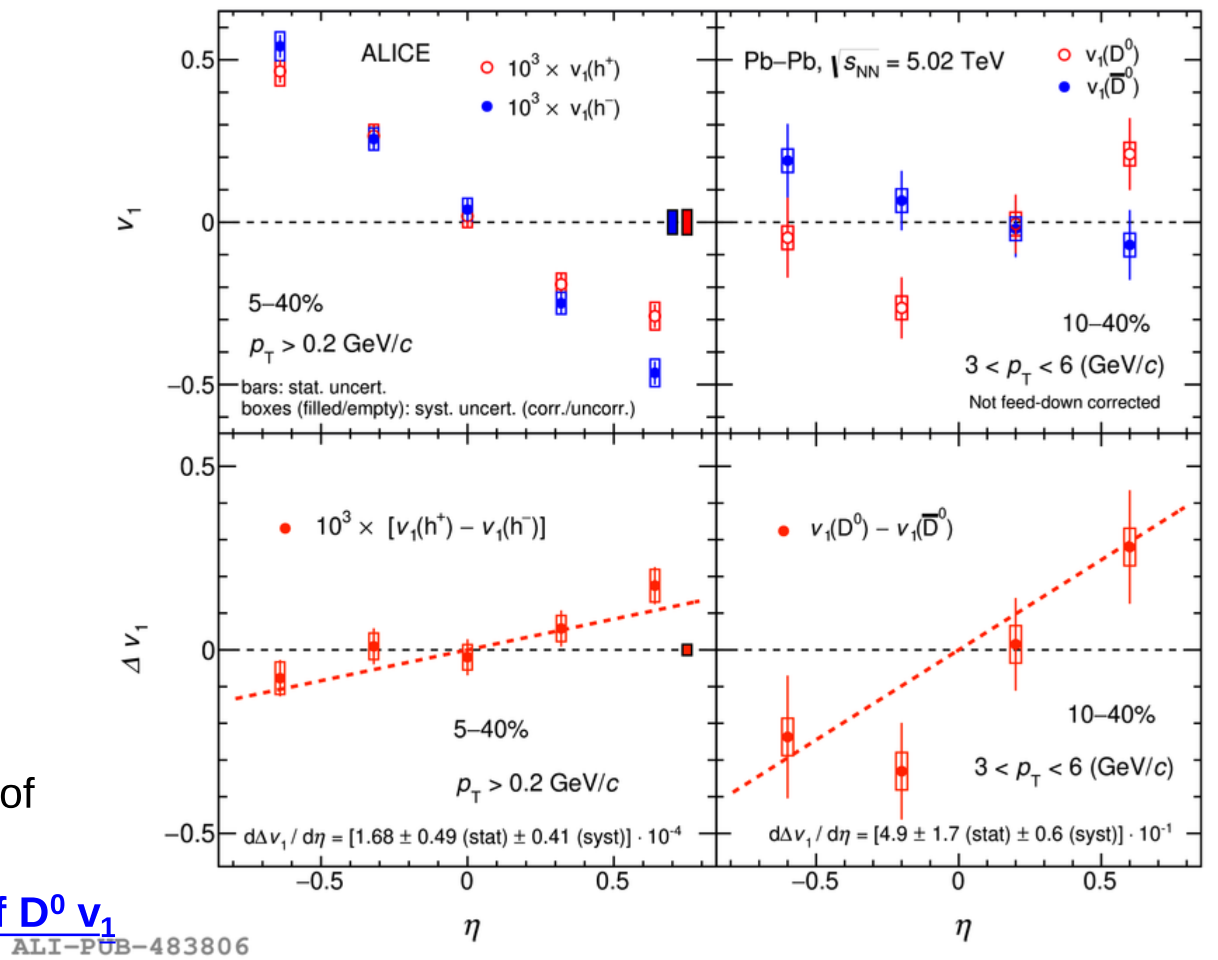


- Strong initial electromagnetic field is generated by the Heavy Ion collisions.
- **Formation of HF quarks limited to primordial stage** of collisions due to large mass ($\tau_f \sim$ 0.1fm/c for charm; when B field reaches its maximum) → **much larger directed flow v_1** than light quarks
- HF quark v_1 has also access to the “tilt” (i.e. longitudinal profile) of the QGP → dragged from the distributed thermalized matter

D^0 v_1 measurement

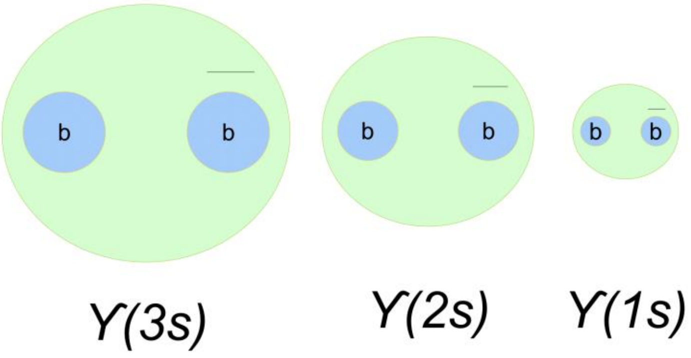


[ALICE, PRL 125 (2020) 022301]



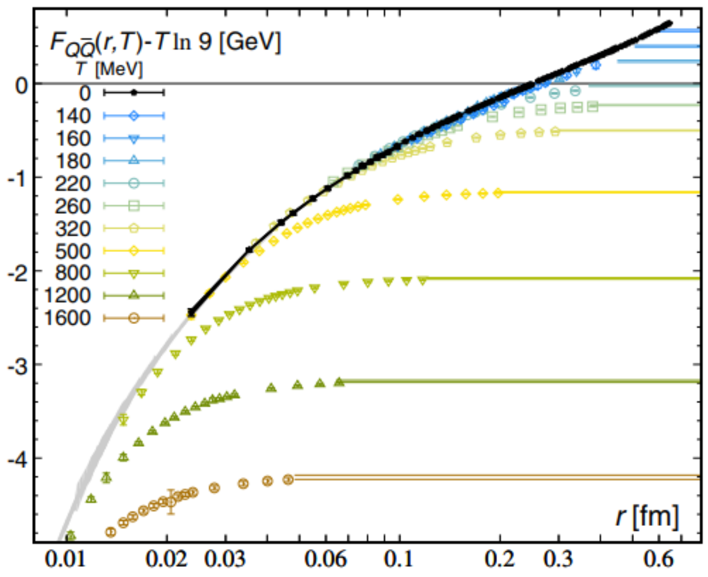
- **First observation of D^0 v_1 at STAR.**
- Different slope between ALICE & STAR. Due to different B & E fields?
- Some tensions with theory calculations (an order of magnitude larger Δv_1 in data).
- **sPHENIX will provide outstanding precision of D^0 v_1 measurements.**

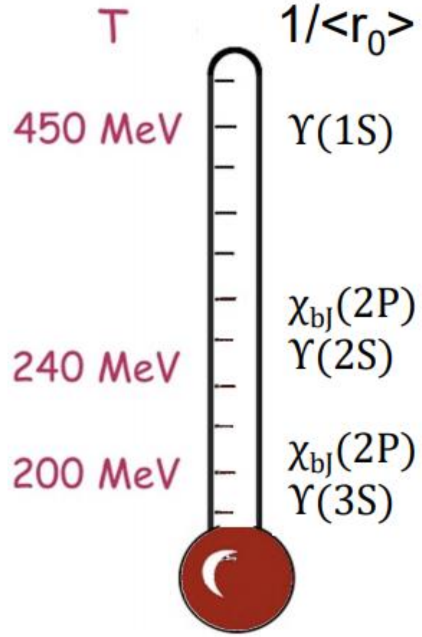
Color Screening of Quarkonium



$$V(r) = -\frac{4}{3}\frac{\alpha_s}{r} + kr$$

A. Bazavov et al., Phys. Rev. D 98 (2018) 054511

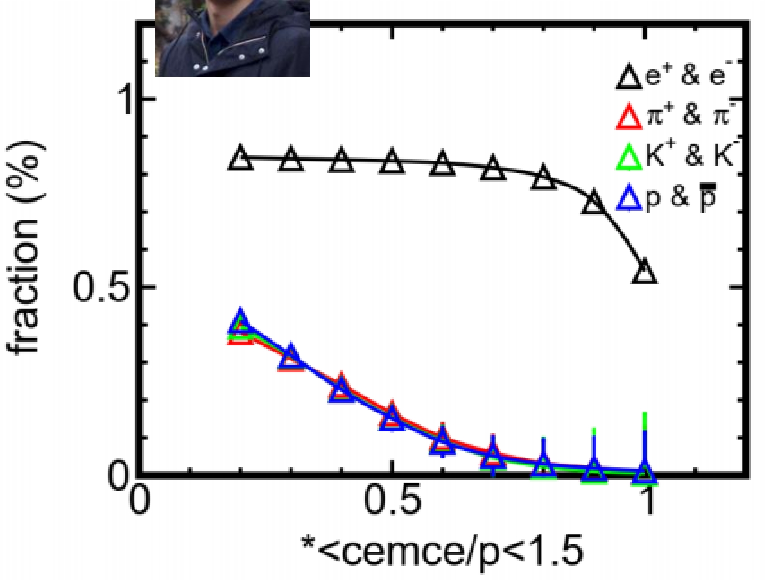


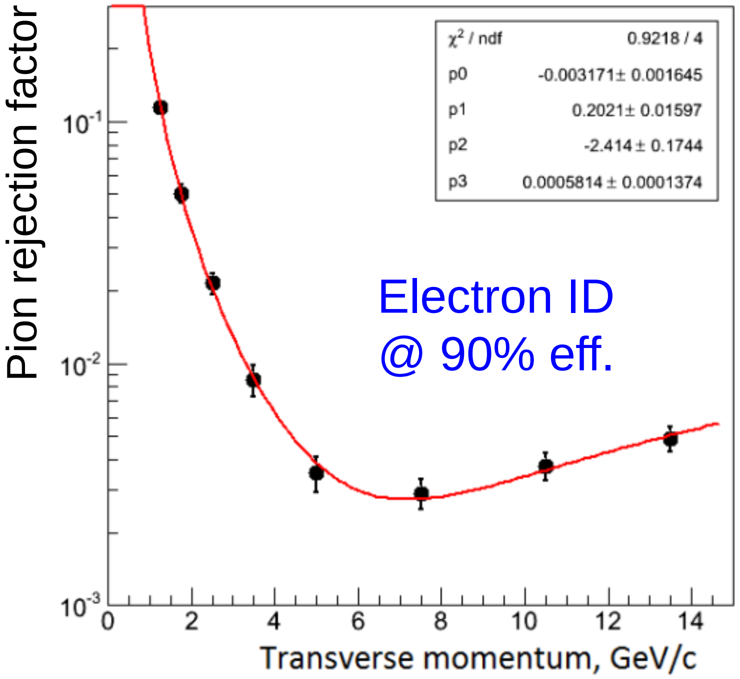


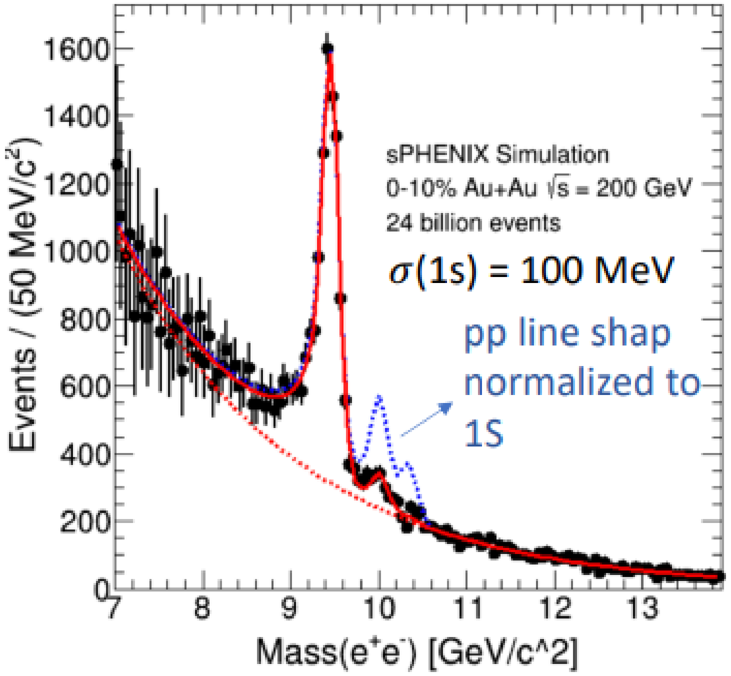
- sPHENIX can reconstruct Upsilons with excellent mass resolution with electrons: δM < 125 MeV
- Excited Upsilon states have larger radius than Υ(1s).

Electron Reconstruction

Weihu Ma (Fudan)



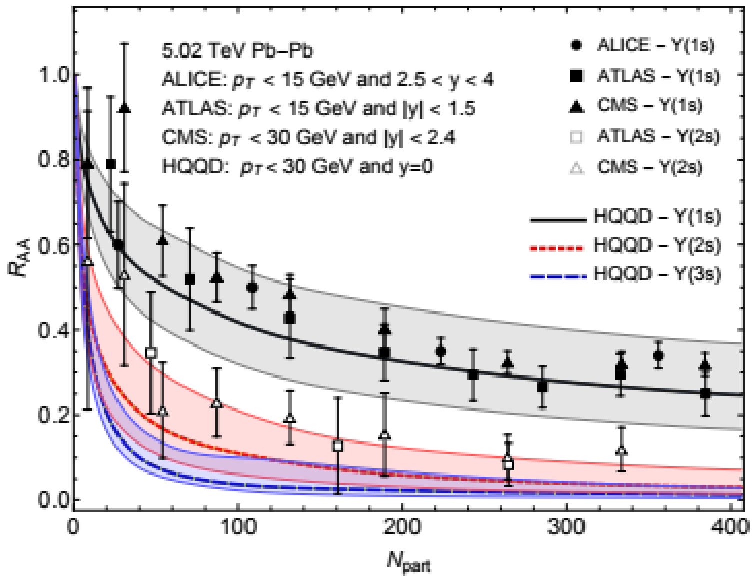


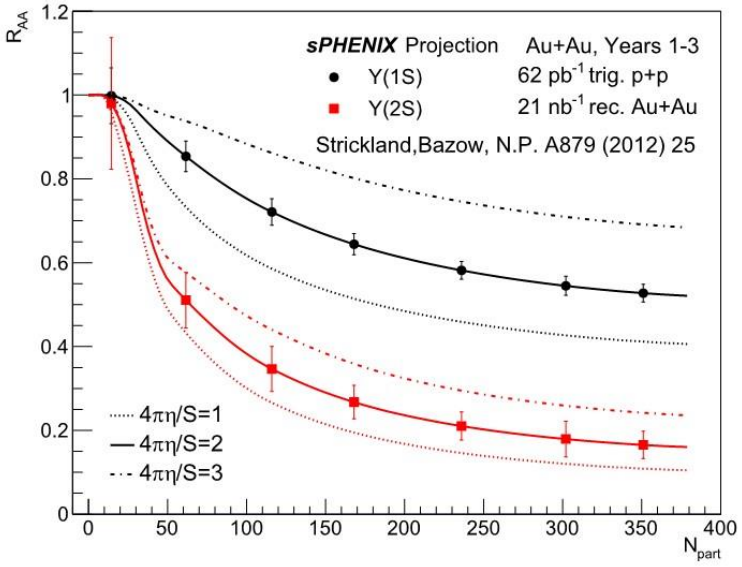


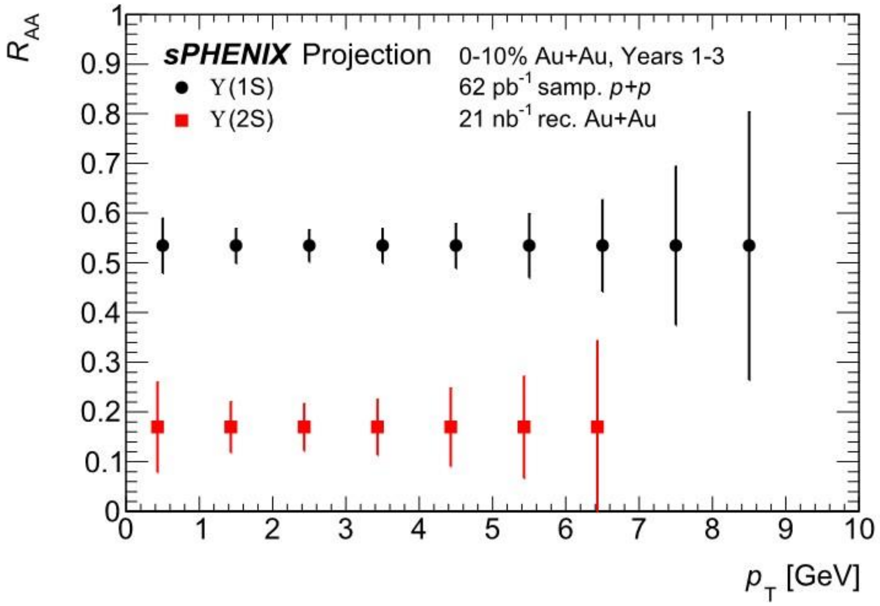
- For Upsilon measurements, we keep the criteria fairly loose to keep high efficiency.
- A simple E/p cut already provides good separation with π, K, p
- Separate working points to be developed for other purposes (e.g. soft-electron b-tag).

Upsilon R_{AA}

LHC *A. Islam, M. Strickland, JHEP 03 (2021) 235*

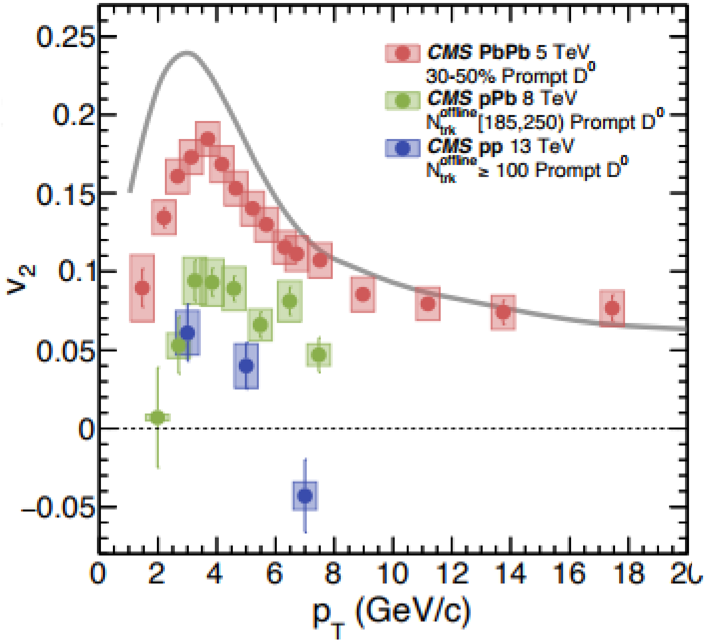




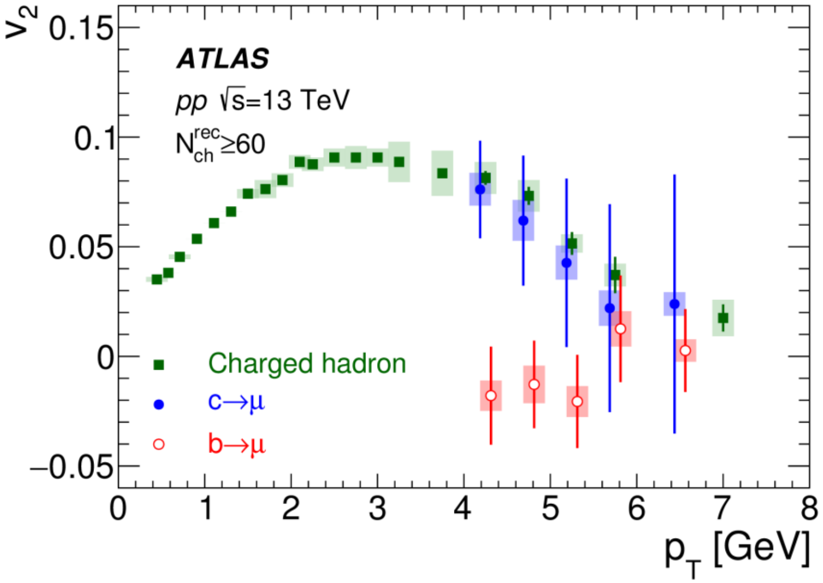


- Measuring centrality & p_T dependence is critical to compare with LHC. sPHENIX will be able provide measurement overlapping with the LHC kinematic regions.
- Measuring Y(3S) modification will be challenging due to the large suppression. Feasibility checks ongoing for Y(3S) modification.

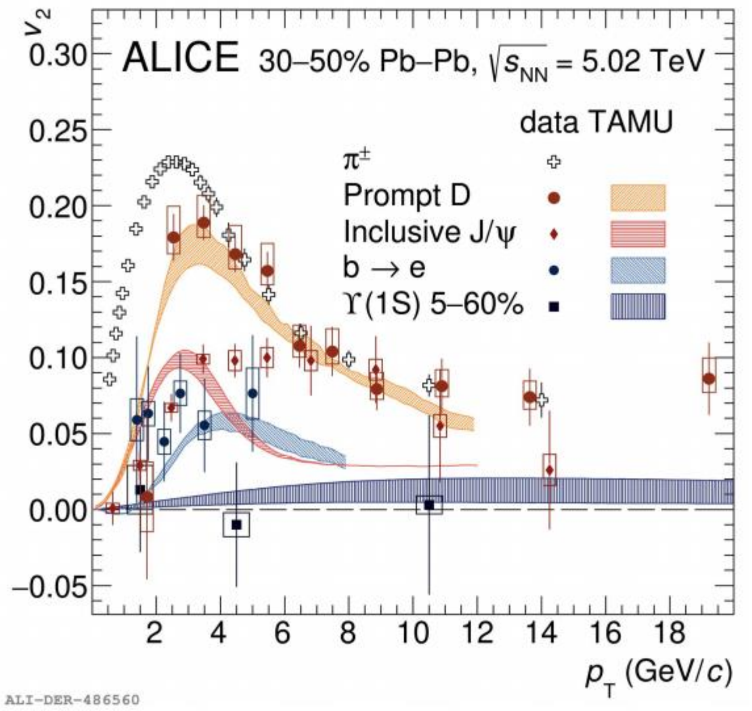
Heavy Flavor Flow



Phys. Rev. Lett. 124 (2020) 082301

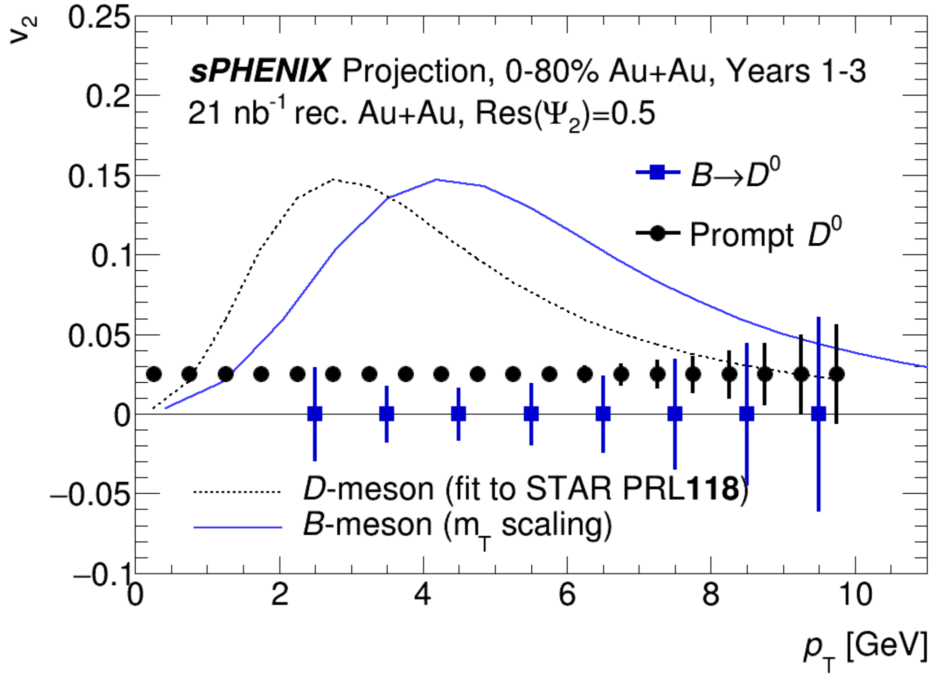


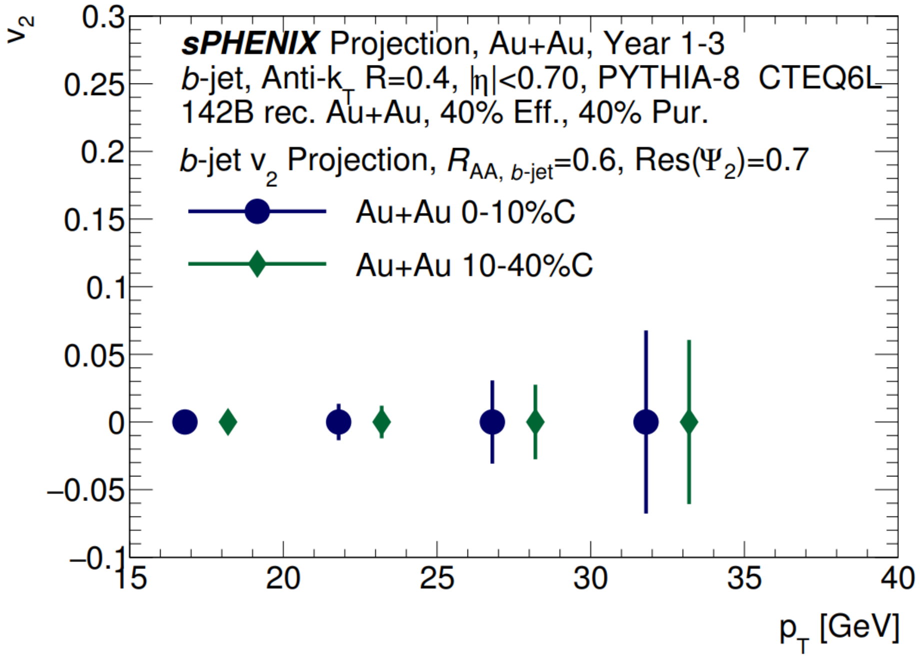
D: PLB 813 (2021) 136054
J/ψ: JHEP 10 (2020) 141
e←b: arXiv:2005.11130 (accepted by PRL)
Υ(1S): PRL 123 (2019)192301
TAMU: PRL 124 (2020) 042301



- **Charm quark flows in all systems!** Bottom quark does not seem to flow in pp.
- Bottom quark also flows in AA, but close to zero. However, Upsilon flow~0??
- In general, phenomenologically challenging to describe flow & R_{AA} at the same time for heavy flavors. More precise measurements from various probes are crucial.

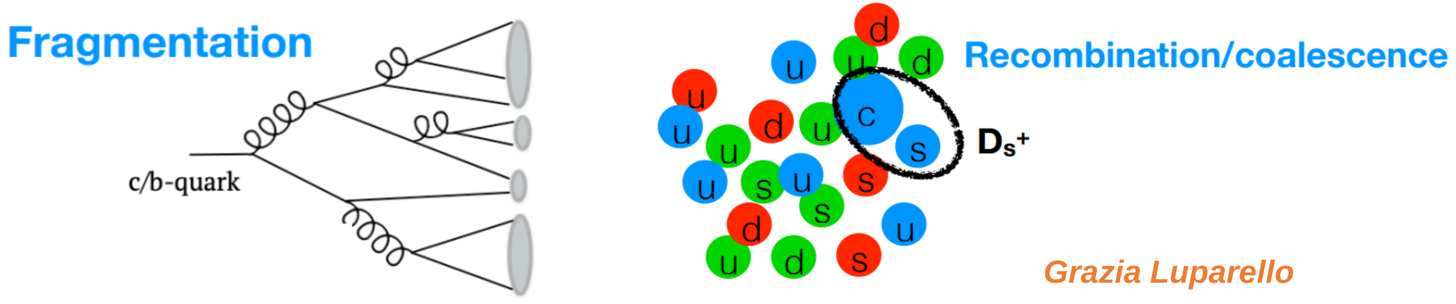
Heavy Flavor Flow in sPHENIX

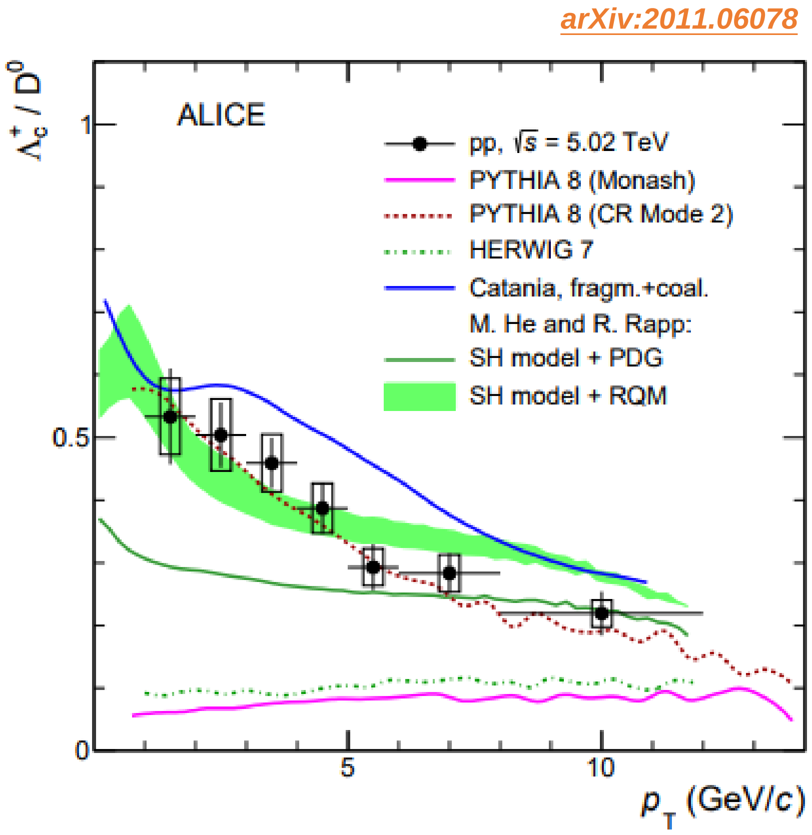




- sPHENIX will provide precise measurements of prompt/non-prompt-D^0 flow.
- High p_T flow can be probed by b-jets.
- Determine b-quark flow → clean access to diffusion at RHIC

Hadronization





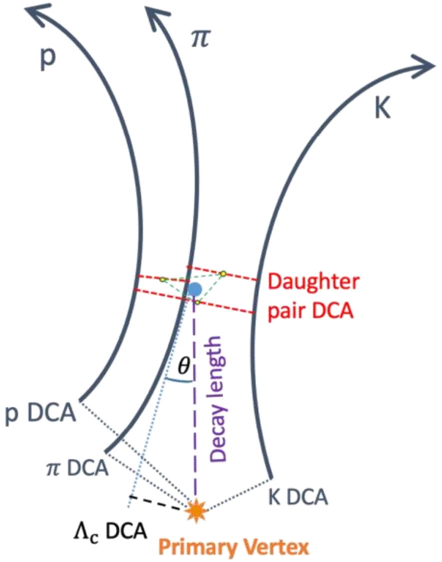
- Hadronization occurs through a complicated interplay between fragmentation & recombination.
- Phase space is filled with partons in pp/AA collisions, leading to modified hadron p_T spectrum.
- Characteristic phenomena:

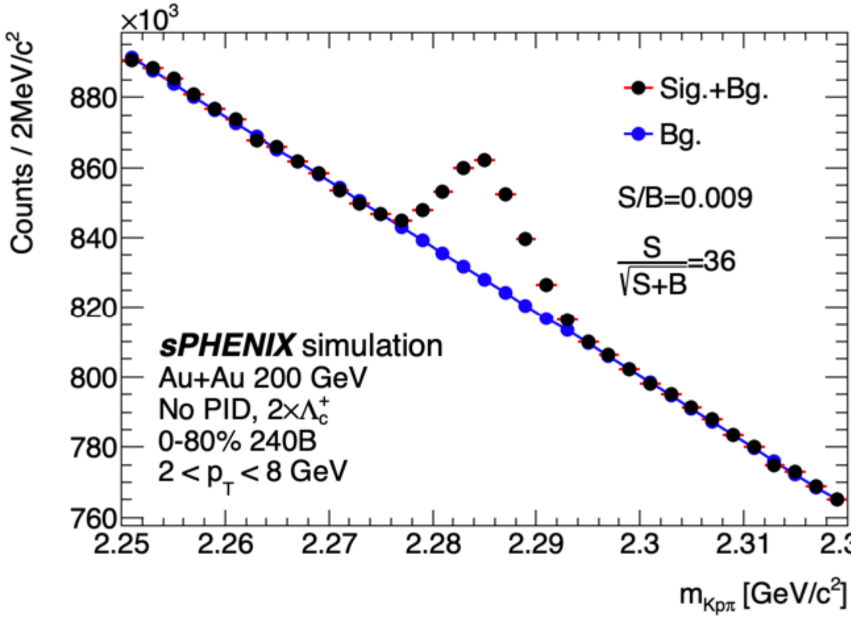
1. Enhancement of baryon/meson ratios at intermediate p_T.
2. Enhancement of heavy-flavor mesons with a strange quark due to the abundance of strange in QGP.

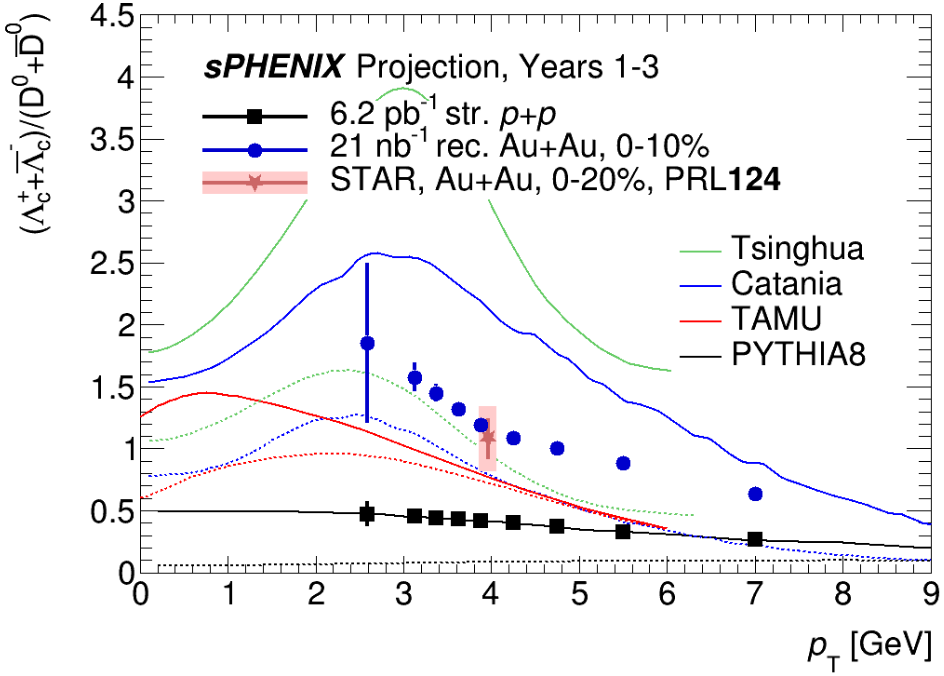
➢ Ratio of production yields between various hadron species will be important probes

Λ_c^+/D^0 ratio is already well above the Pythia8 predictions (e^+e^- conditions) in pp collisions
(recently also new measurements on Ξ_c/D^0)

Λ_c Hadronization



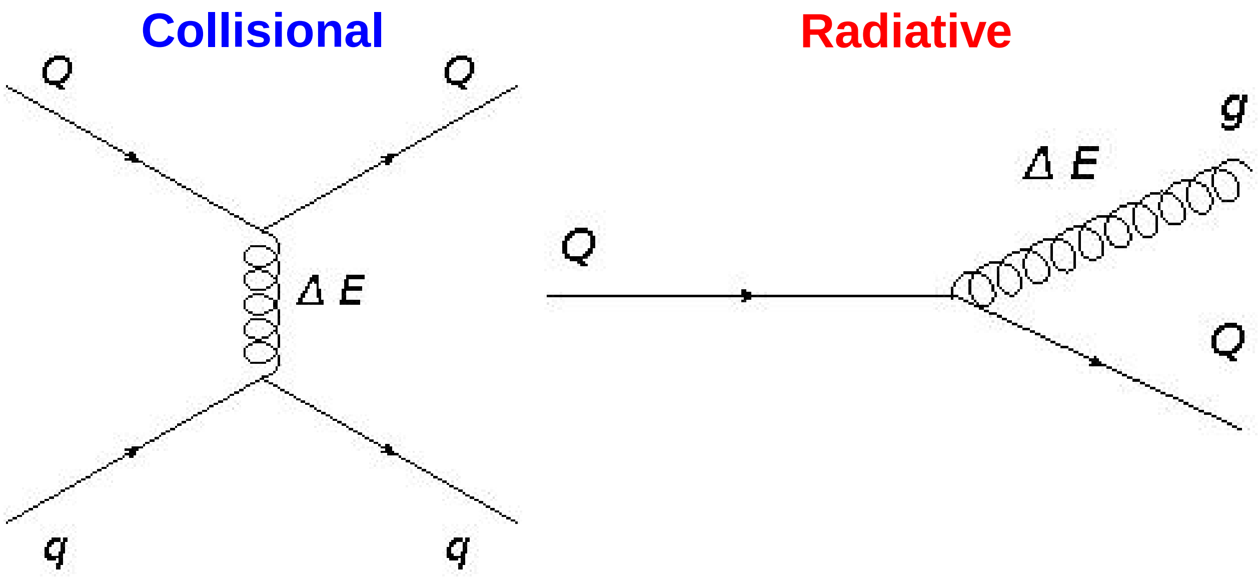


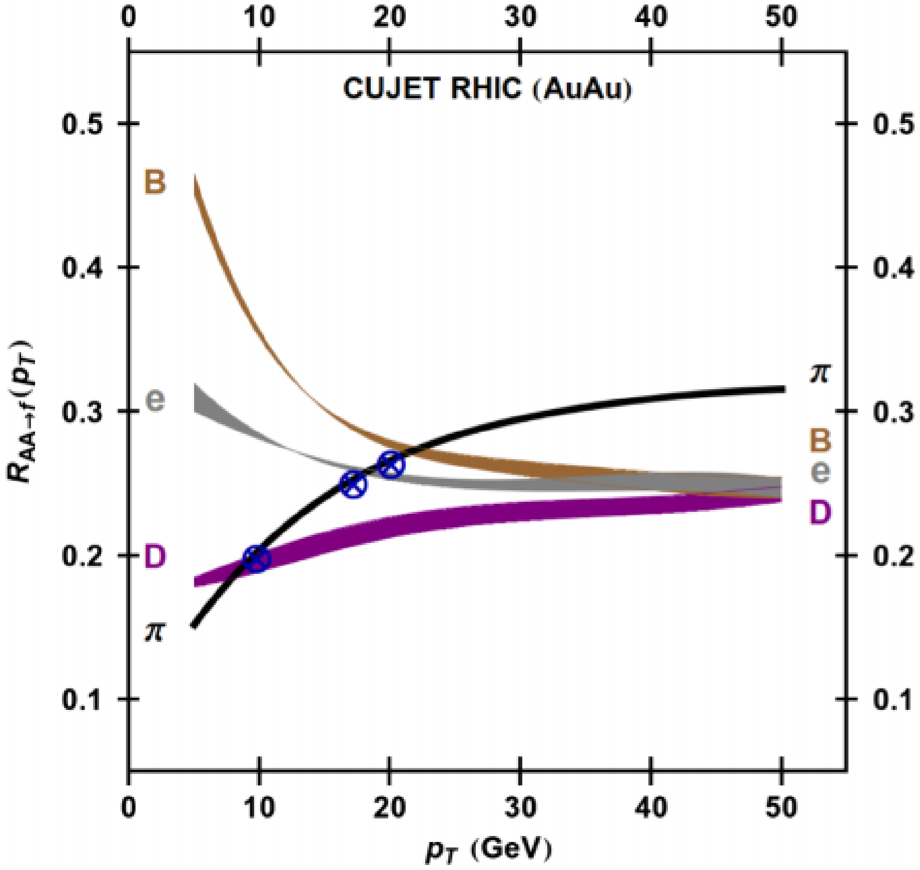


- **Λ_C/D^0 significantly larger than the baseline Pythia calculation in pp, pA, AA.** Important probe to understand the hadronization (effects from coalescence?).
- Also, charm baryons & charm-strange mesons give sizable contributions to the total charm xsec.
- sPHENIX will provide precision measurement at p_T~3-8 GeV.

Parton Energy Loss in QGP

A. Buzzatti and M. Gyulassy
Phys. Rev. Lett. 108, 022301 (2012)



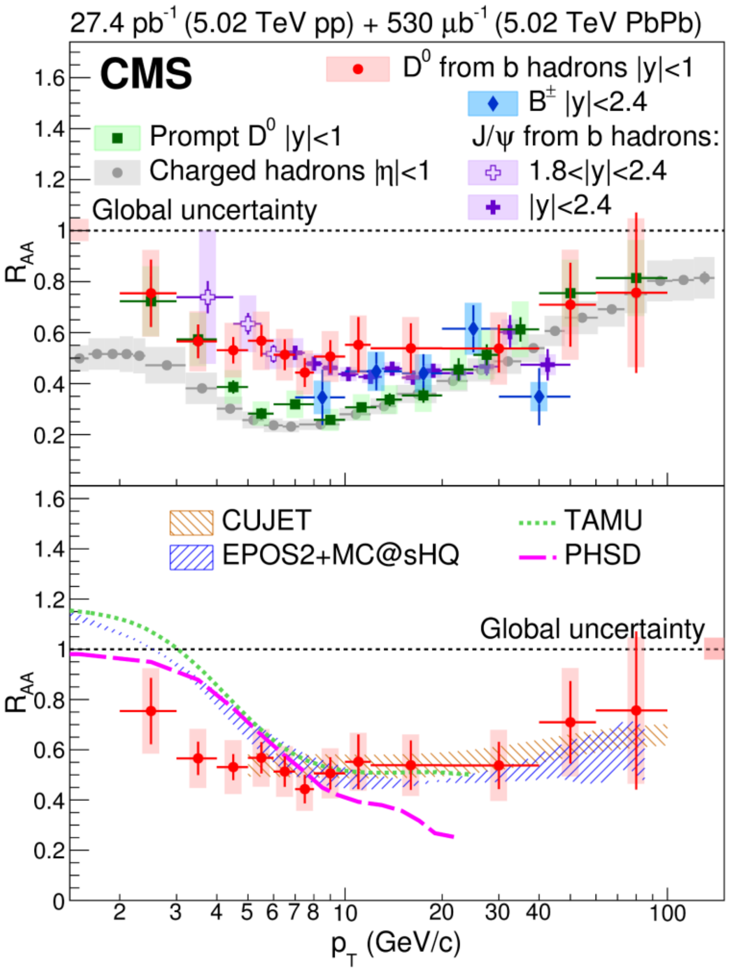


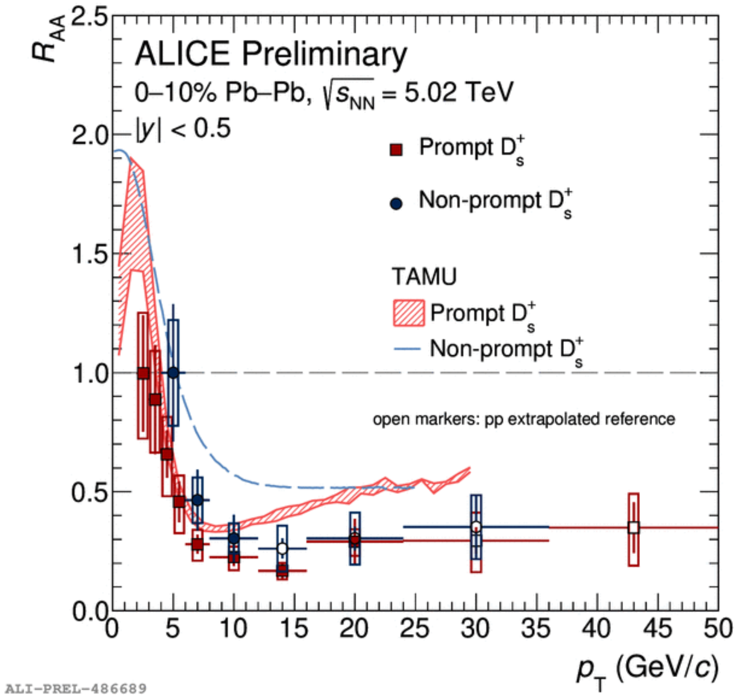
Two categories of energy loss

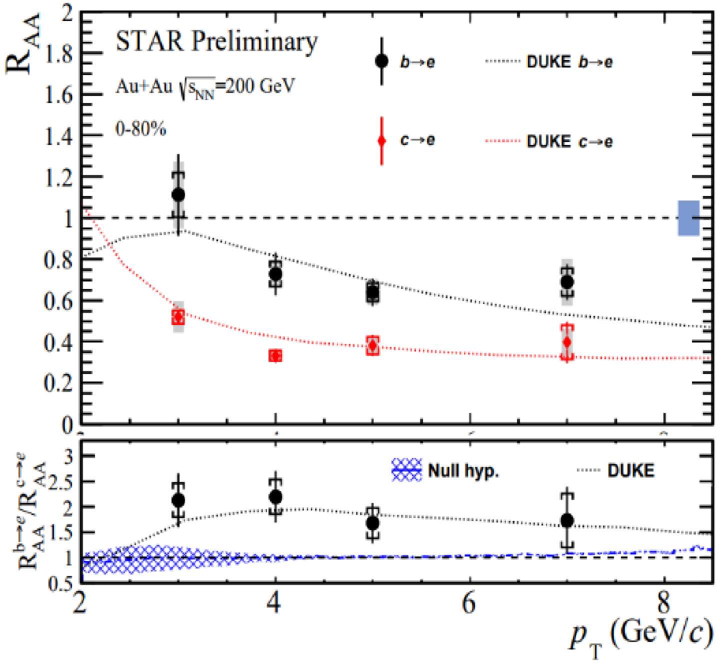
1. **Collisional** (elastic scatterings in QGP)
2. **Radiative** (medium-induced gluon radiation)
   - Dead-cone effect in heavy-flavor jets: suppression of gluon radiation from heavy quarks at small angles.

Prompt/Non-prompt $D^0/D_s/e$ R_{AA}

Phys. Rev. Lett. 123 (2019) 022001

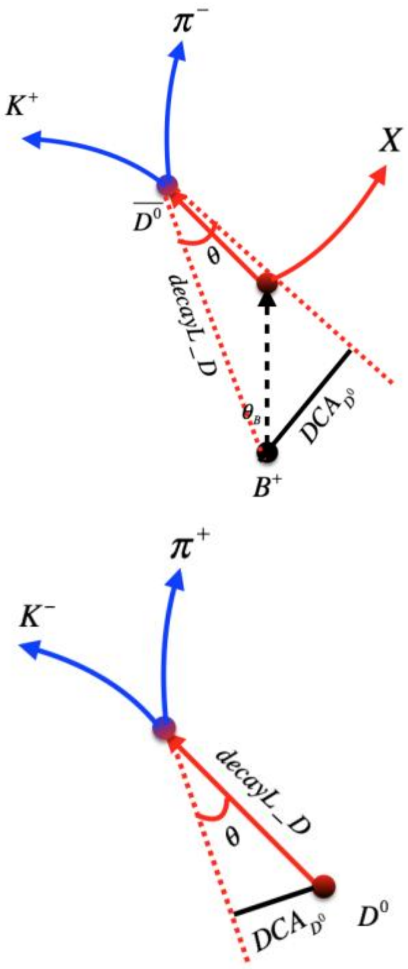


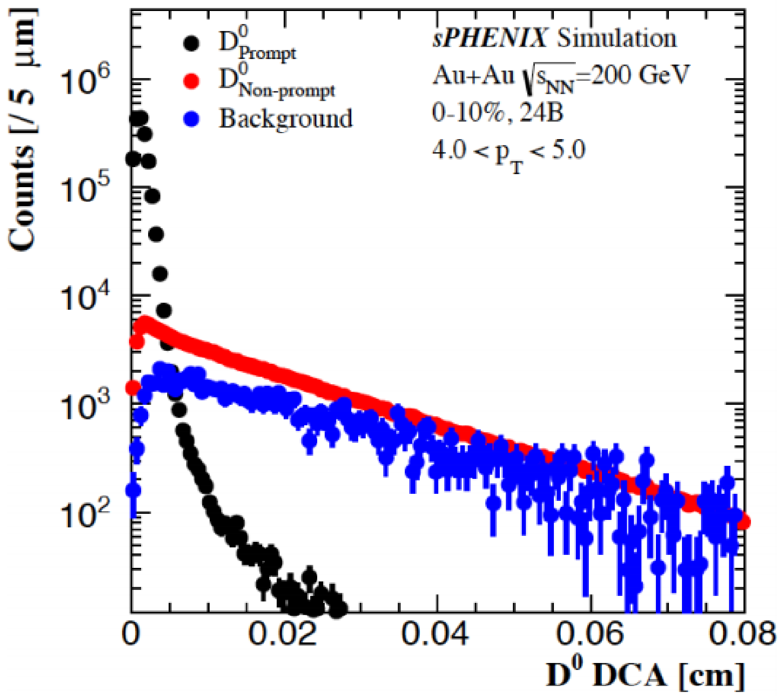


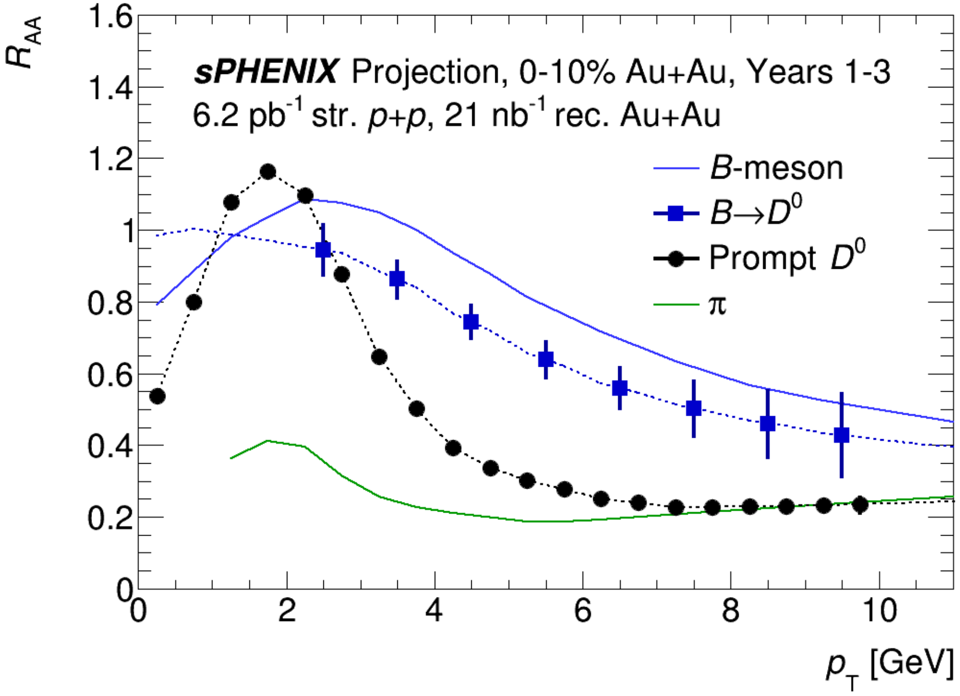


- Observed features still to be understood.
- **Mass dependence disappears in p_T>~20 GeV?**
- Requires precise measurements both from hadrons and jets.

B-meson Projections

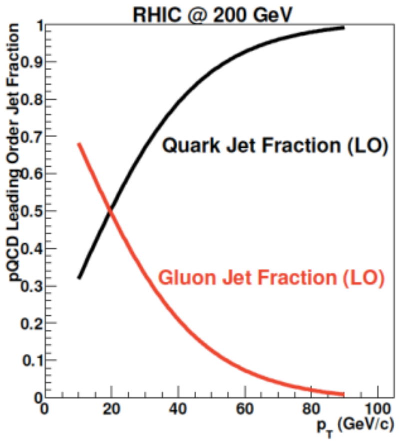


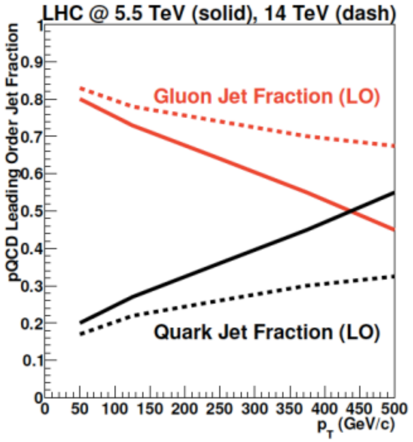




- Streaming readout allows us to measure R_{AA}.
- Precise measurement of non-prompt-D^0 suppression
- Determine b-quark R_{AA} → clean access to diffusion at RHIC

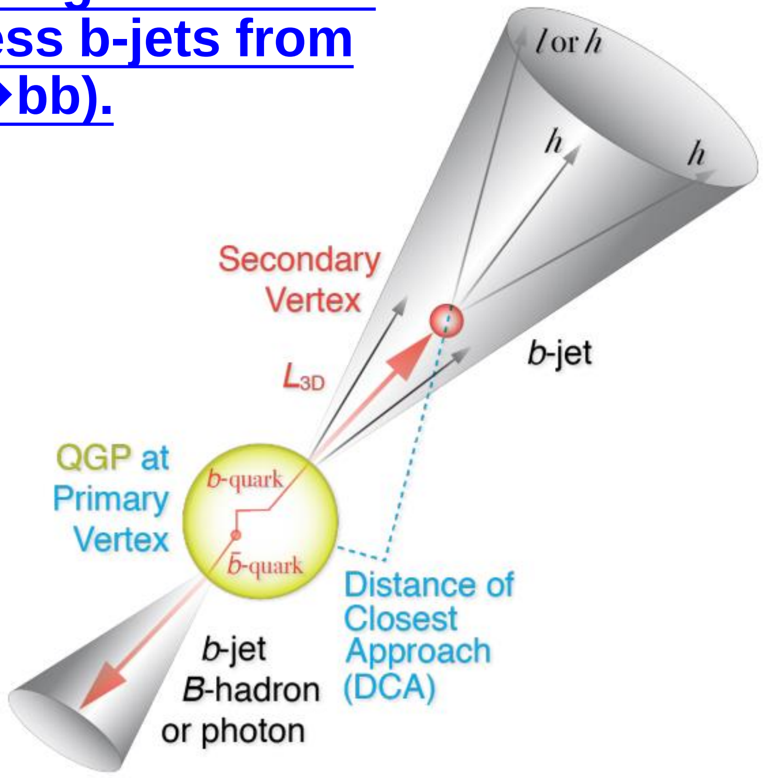
b-jet Identification





- Jets are useful to access the initial parton kinematics.
- **RHIC has an advantage over LHC for having much less b-jets from gluon splitting (g→bb).**

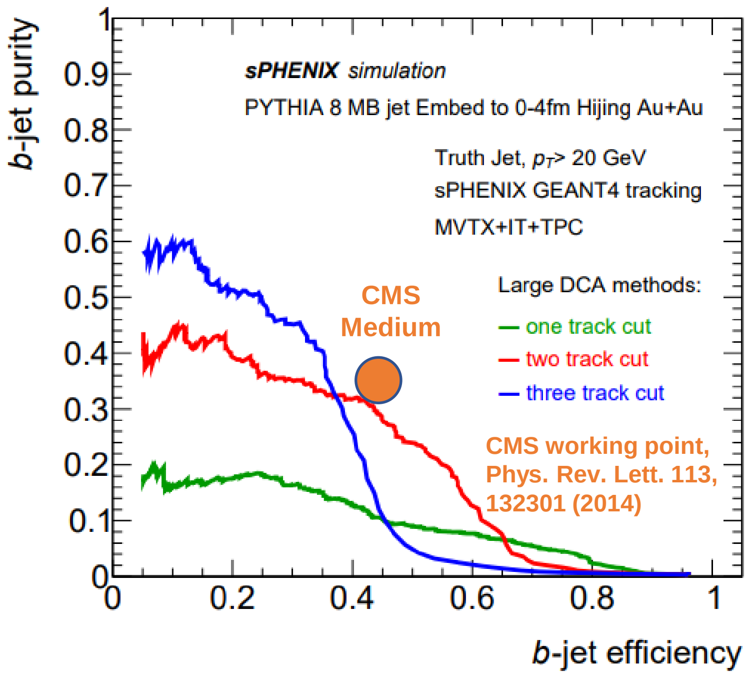
- Heavy flavor jets have distinct signatures with:
  - Tracks with large DCA
  - Presence of secondary vertex
  - Presence of displaced lepton
- Taggers making use of the first two features are investigated so far.

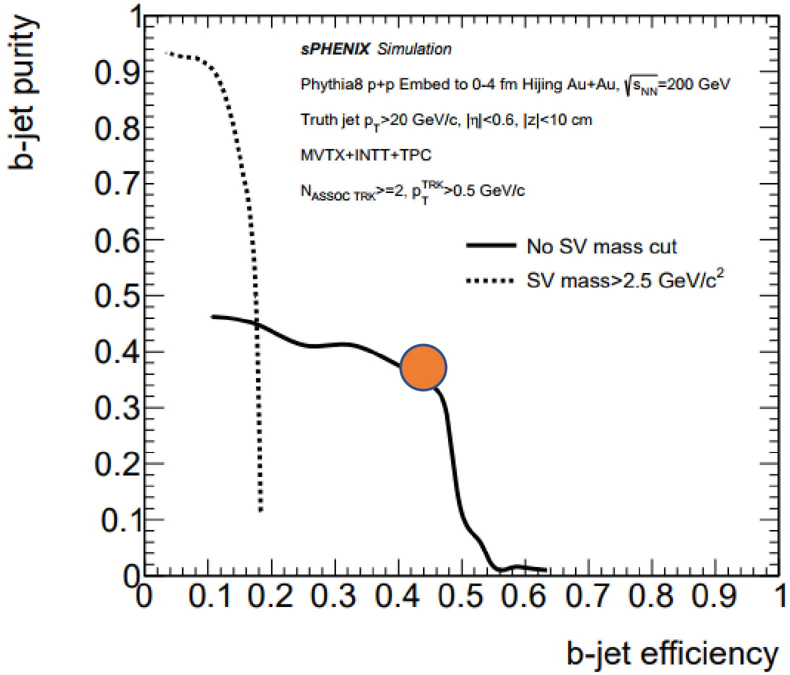


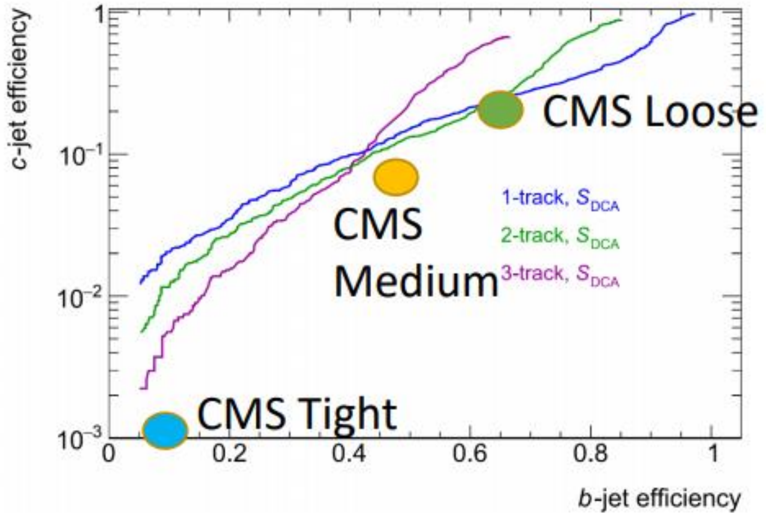
b-jet Identification

sPH-HF-2018-001 - MVTX Proposal

sPH-HF-2017-001





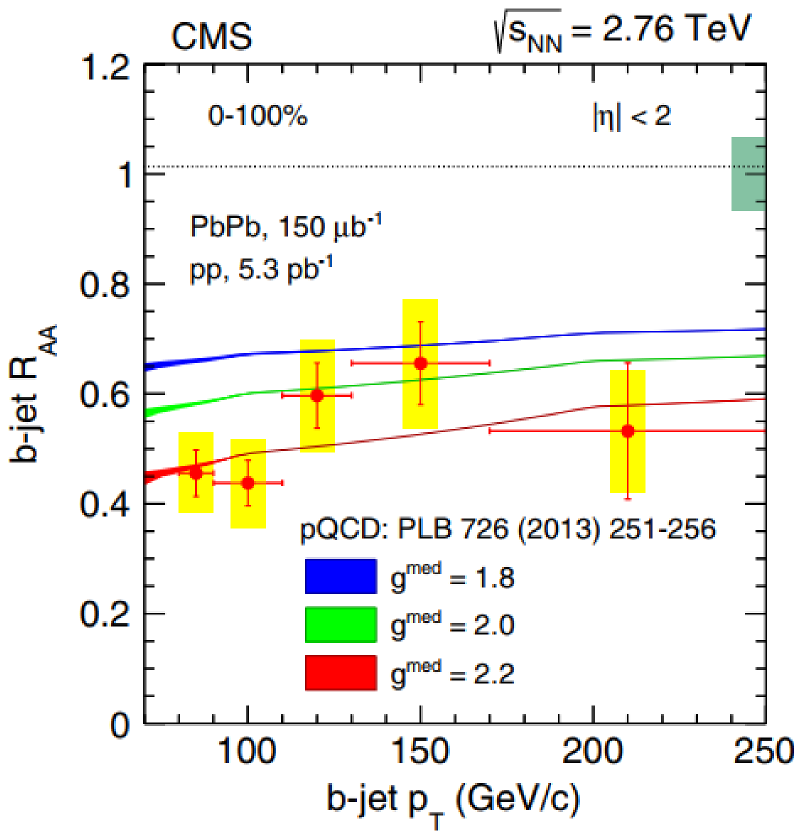


- Already compatible as CMS benchmark performance in Heavy Ion.
- Further studies ongoing to combine the two tagging schemes as well as making use of displaced leptons.
- Machine learning approach is currently under development.

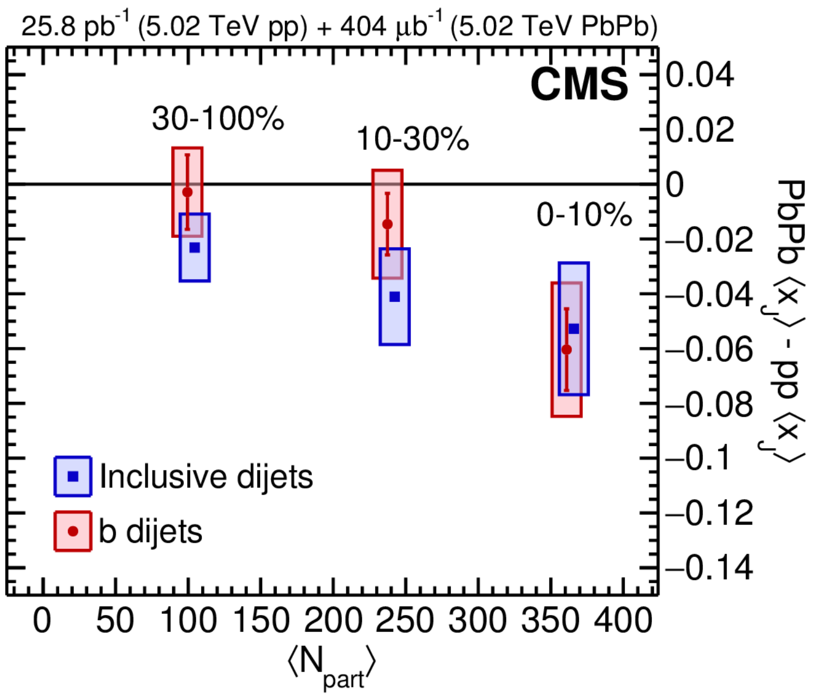
Previous b-jet R_{AA} Measurements

- Evidence of jet quench also in b-jets.
- **Suppression compatible with inclusive jets, which was unexpected.**
- Is this true? Any effect from the gluon-splitting (g→bb)?
- We also like to see the behavior in low p_T region (challenging at LHC).

CMS, Phys. Rev. Lett. 115, 029903 (2015)



JHEP 03 (2018) 181



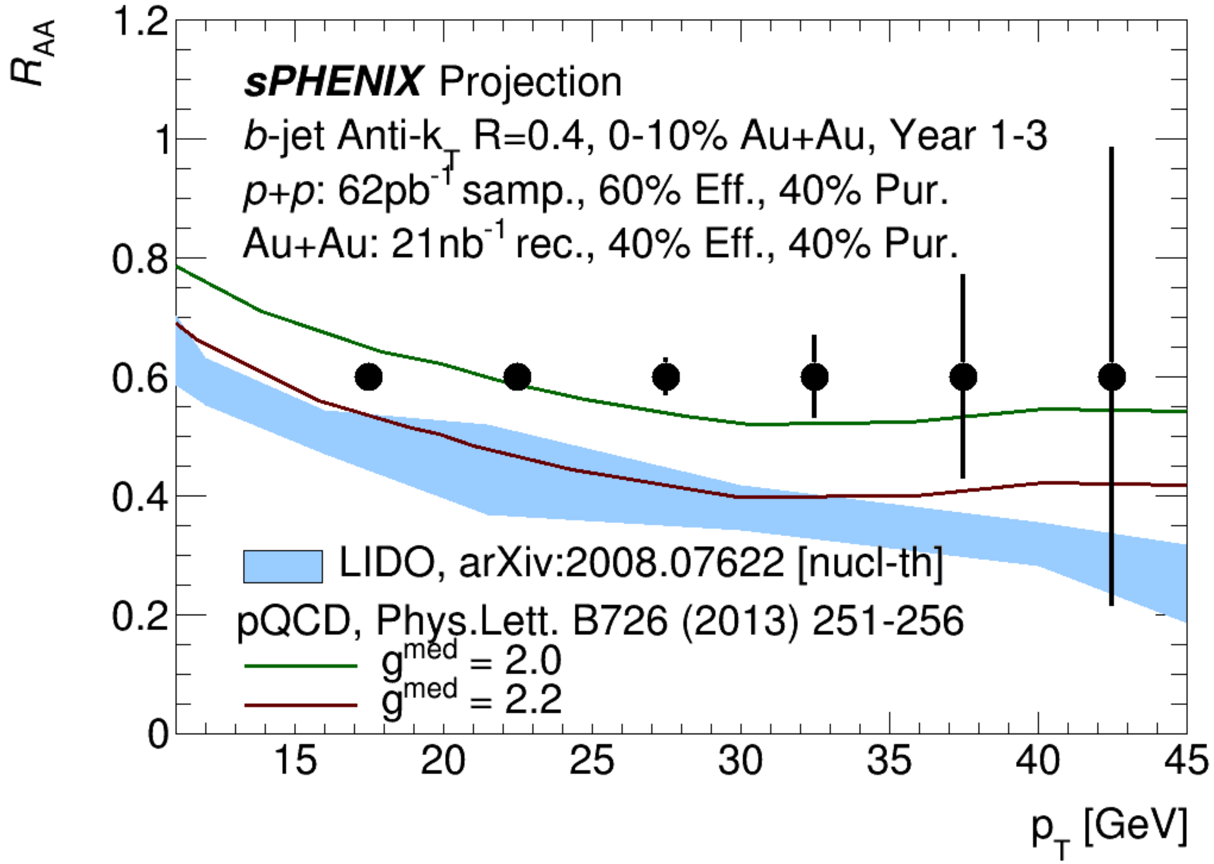
b-jet R_{AA} Projection

- sPHENIX is the only detector at RHIC with full b-tag capability.

Advantage at RHIC

1. Less contributions from the gluon splitting.
2. Access to the low jet p_T region.

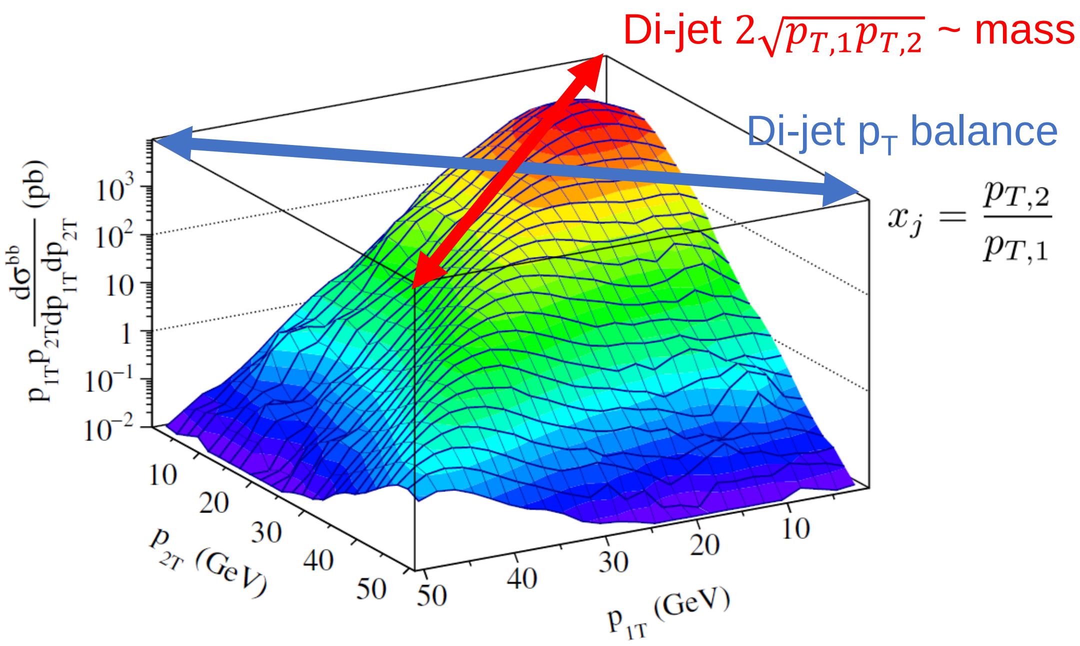
- sPHENIX will provide outstanding precision in low b-jet p_T region. (but this is not the full story)



Even more with b-jet Pairs

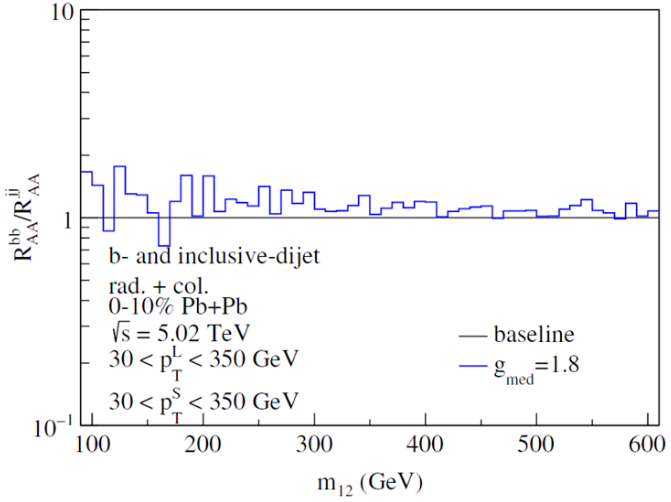
Kang, Reiten, Vitev, Yoon, Phys. Rev. D 99, 034006.

- Considering the correlation between two b-jets will further suppress gluon splitting.
- Two ways to produce 1D integral of 2D di-jet distribution
  - Di-b-jet p_T balance: sensitive to geometry fluctuation (our previous studies in the backup)
  - **<u>Di-b-jet mass: enhance sensitivity to transport property</u>**

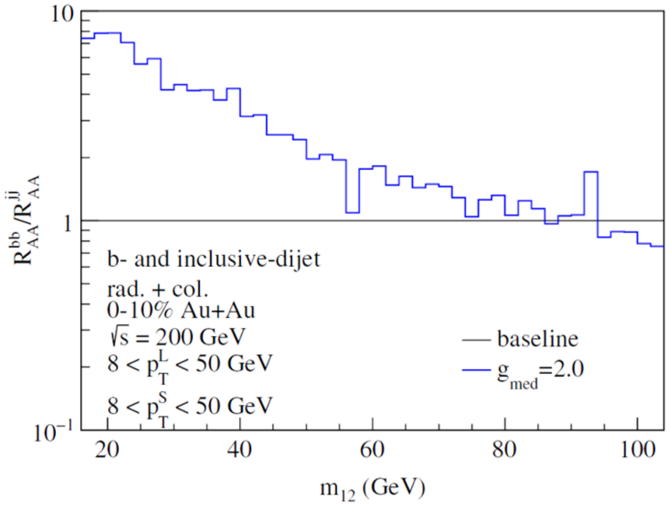


<u>Sensitivity is enhanced at RHIC!</u>

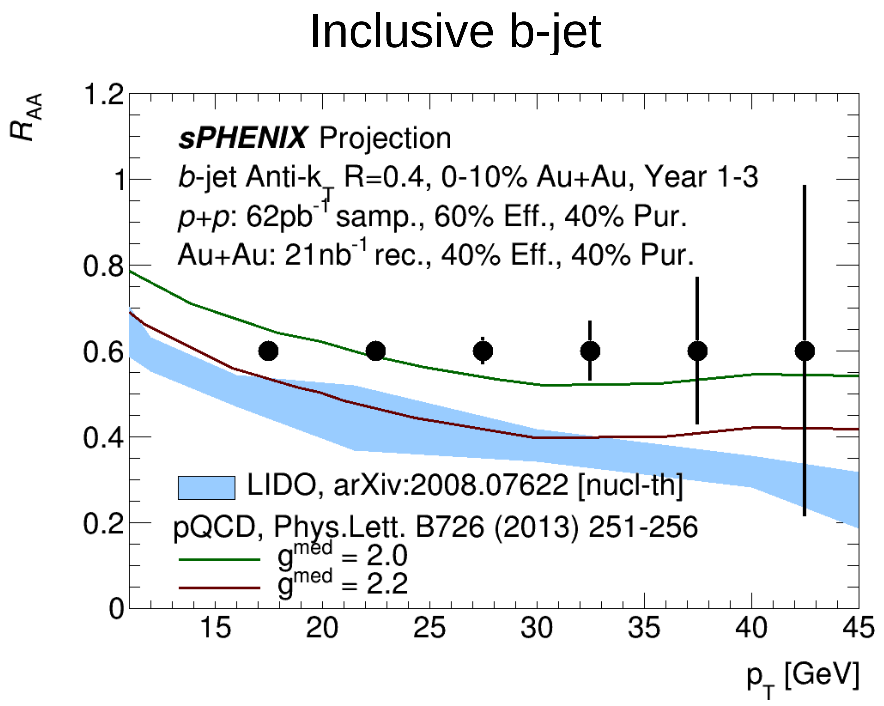
di-b/light-jet R_{AA} ratio: LHC

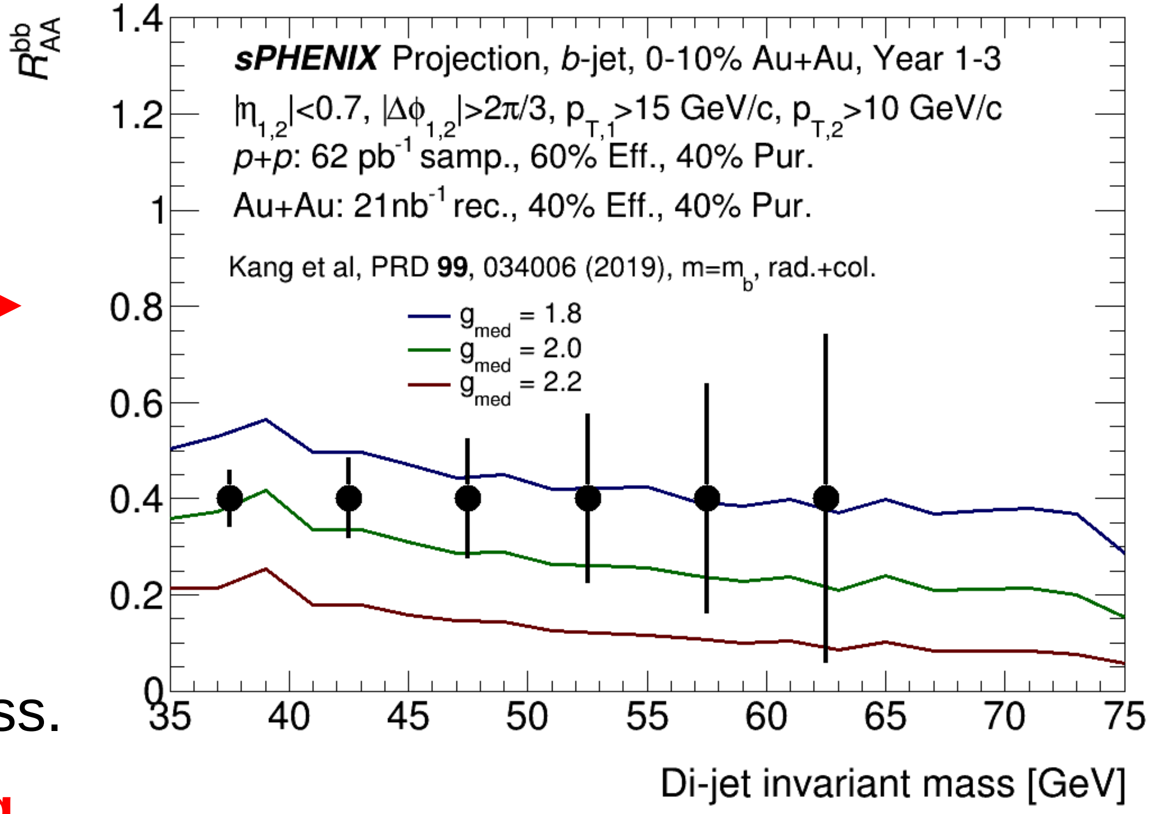


sPHENIX



b-jet Pair Mass



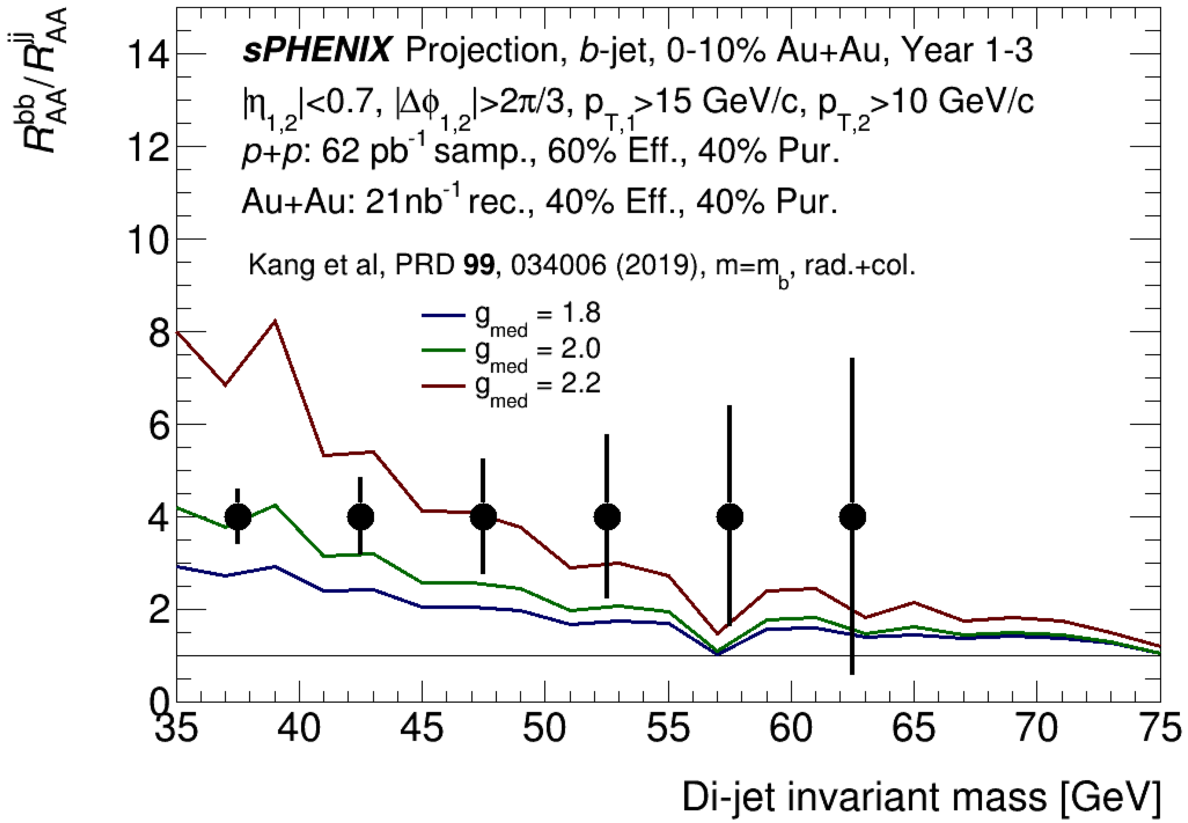


- Covers 35-70 GeV/c^2 in di-b-jet invariant mass.
- **Strong sensitivity to parton-QGP coupling.**
- **x2 effect against 10% variation on g_{med}!**

b-jet Pair vs Light-jet Pair

- b-jet vs light-jet pair mass ratio has **strong sensitivity to parton mass effect**.
- Partial cancellation of experimental systematic uncertainties.
- **1-8 times enhancement on the mass effect against g_{med} variations by taking this ratio.**
- **An excellent example of fruitful collaboration between the experimental/theory communities.**

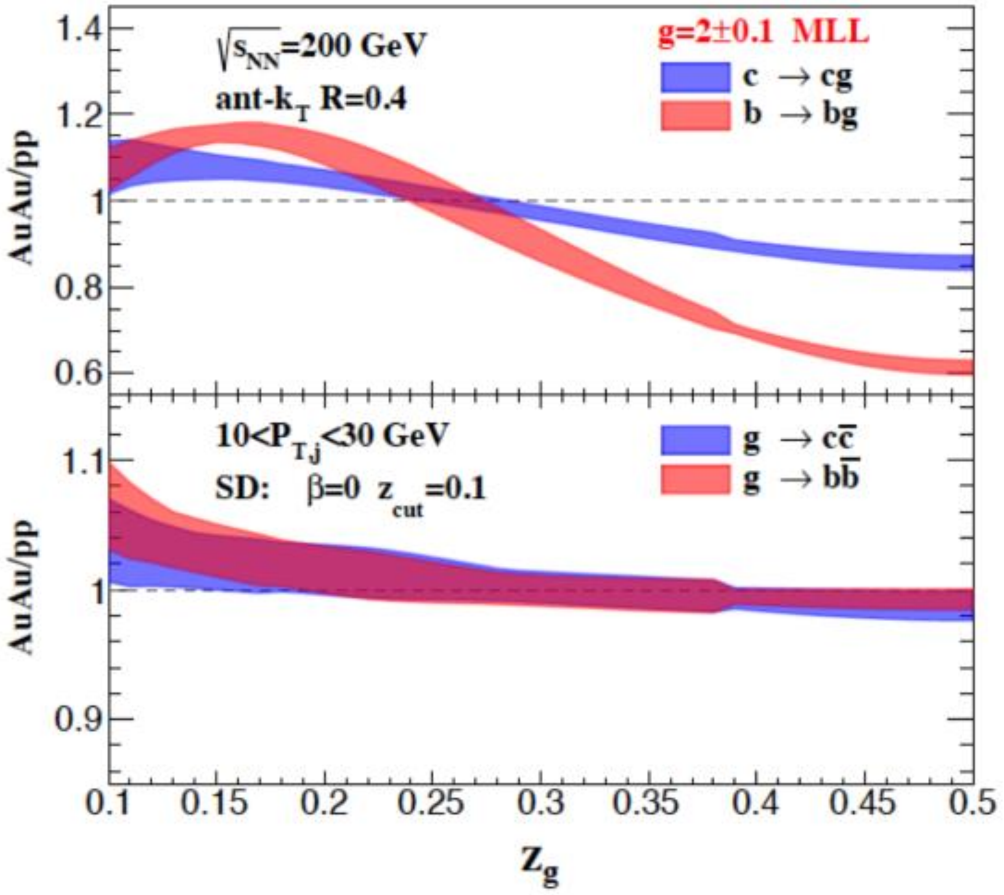
b-jet vs light-jet



More studies under way

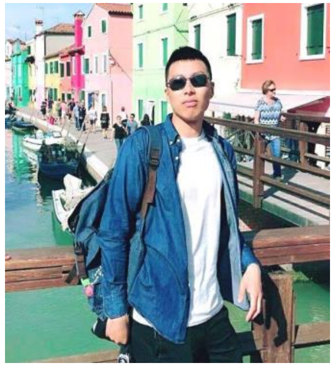
- D-D correlation
- Diffusion of D inside HF jets
- b-jet substructure

H. Li and I. Vitev

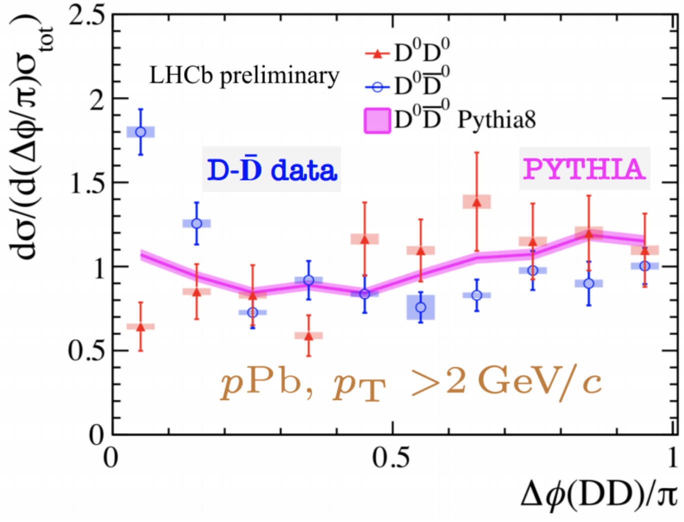


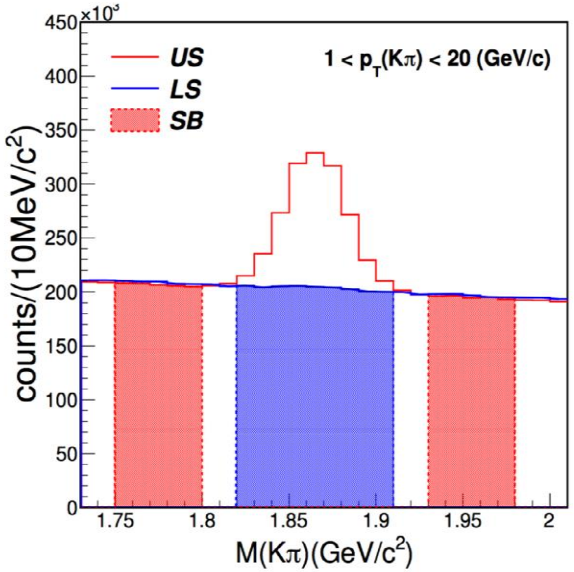
D-$\bar{D}$ Correlation

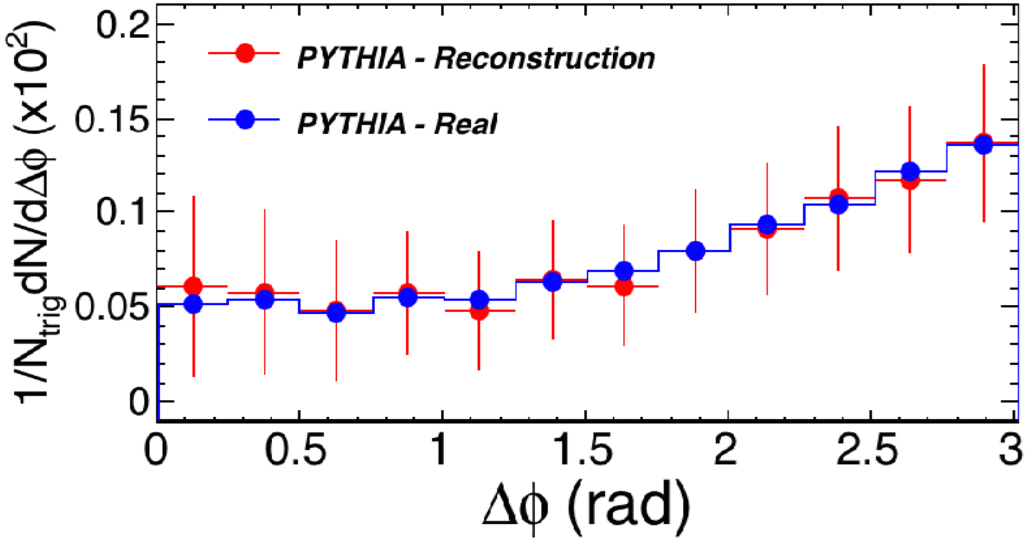
Long Ma (Fudan)



- ***D*-$\bar{D}$ correlation is a more sensitive observable** than R_{AA} & v_2 to constrain the diffusion properties of the charm quark.
- Need high statistics at the LHC (full Run 2 or even Run 3)
- Feasibility studies ongoing at sPHENIX







Toward the First Data Taking

From Yasser Morales

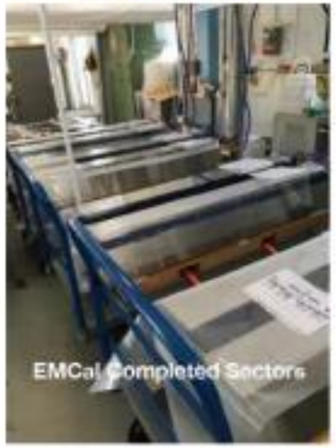
track reinforcement work in Bldg 1008

carriage/cradle @ vendor

SC magnet (former BaBar magnet)

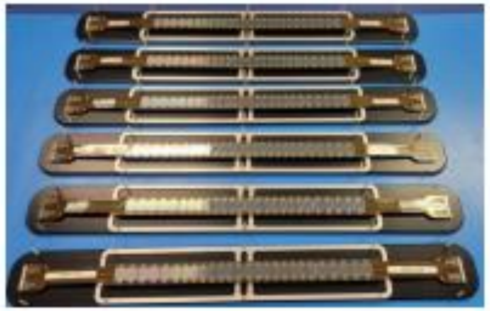
OHCal All sectors completed!!

EMCal Sectors



MVTX stave production complete!!!

INTT ladder production in progress

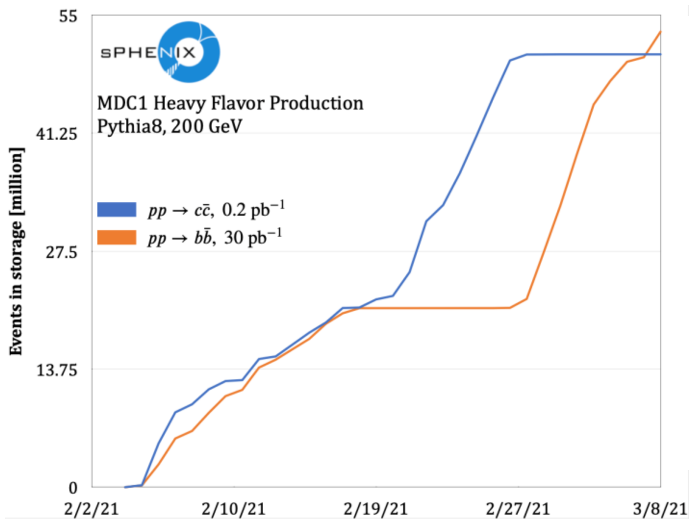


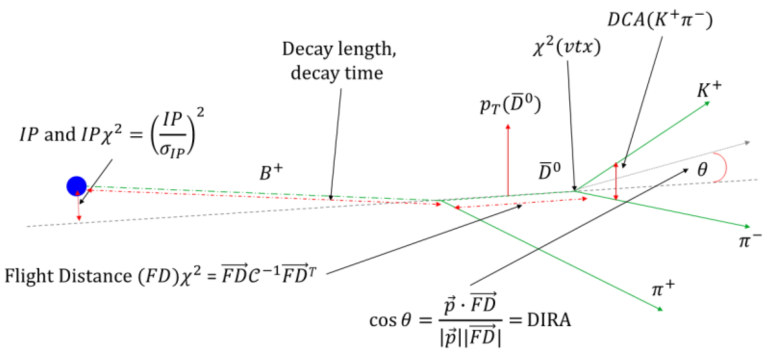
TPC Inner field cage test

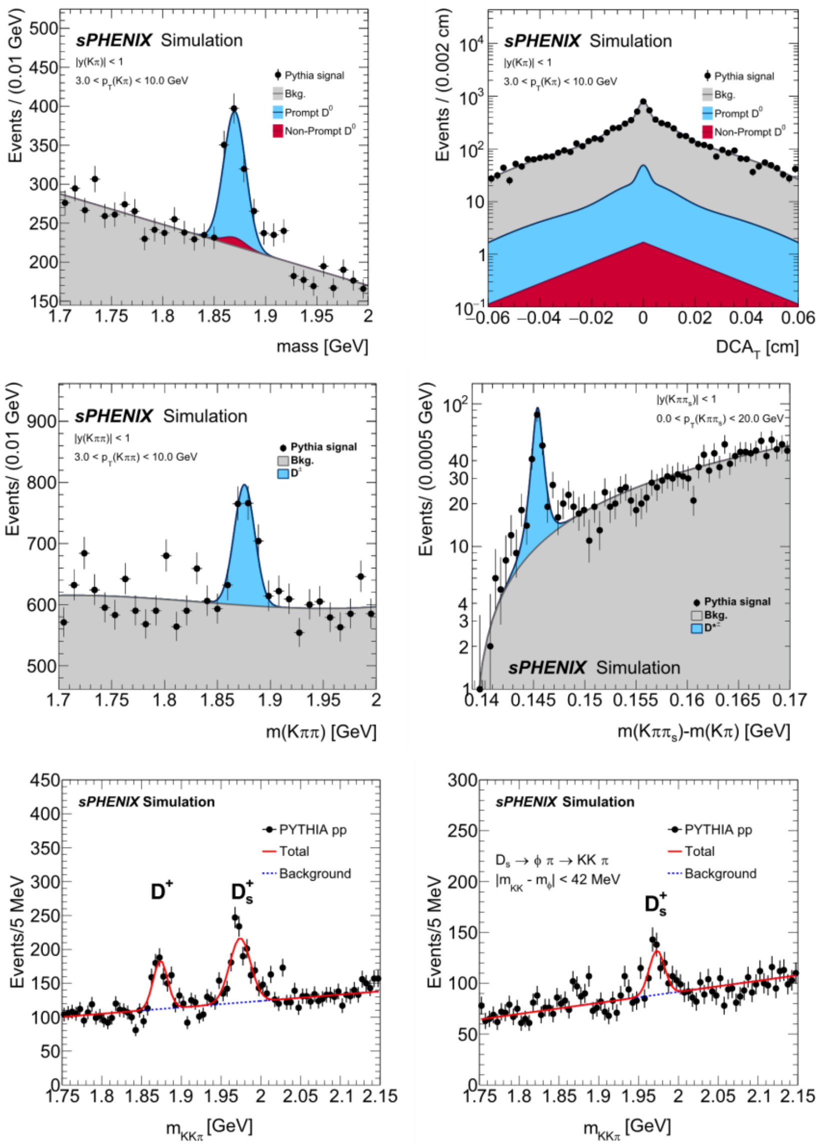
Construction will be completed by the end of this year

Toward the First Data Taking

sPHENIX Note sPH-HF-2021-001







- Currently going through **1st Mock Data Challenge (MDC1)** to test the full chain of generation→ G4 simulation → reconstruction → analysis
  - 50 million full simulation samples produced for ccbar & bbar signals (as well as samples for other analyses)
- KFParticle successfully implemented in sPHENIX.
- Will have another set of production later this year for HF jet studies.

Summary

- Still many mysteries in QGP measurements, especially in the heavy flavor sector.
- sPHENIX brings precision measurements to the b-quark sector at RHIC.
  - Upsilons to probe QGP with different size.
  - Comprehensively covers wide p_T range for open heavy flavor
    - ➢ initial electromagnetic field, diffusion properties, hadronization, parton energy loss
- Despite the challenges from COVID-19, the construction is progressing, targeting the first data in 2023.
- Currently going through the 1st Mock Data Challenge to validate the full analysis framework.
- Preparation under way for the first data taking in 2023! Stay tuned!

Thank you for your attention! 谢谢大家！