

sPHENIX MVTX Upgrade

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Los Alamos National Lab
for the sPHENIX Collaboration

Heavy Flavor Workshop @LBNL
10/30-11/1, 2017

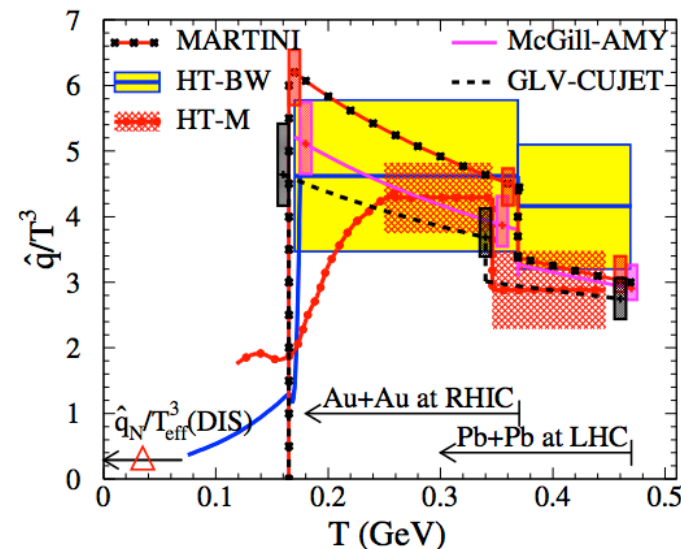
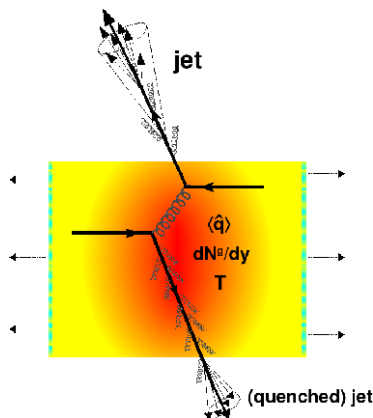
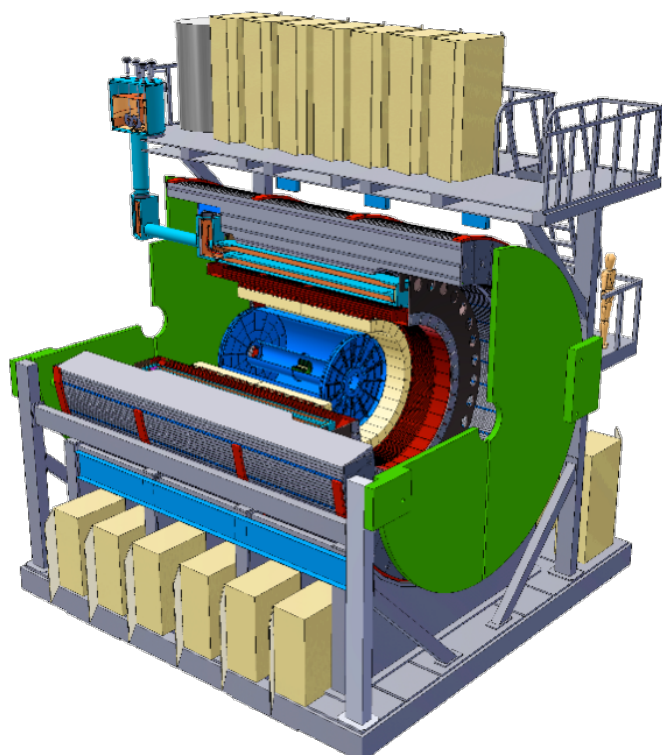
Outline

- Science of sPHENIX
- MVTX upgrade proposal
- Physics prospects

sPHENIX – the Next Generation HI Experiment @RHIC

- To study the inner workings of QGP

- Jets
- Upsilon
- Heavy flavors

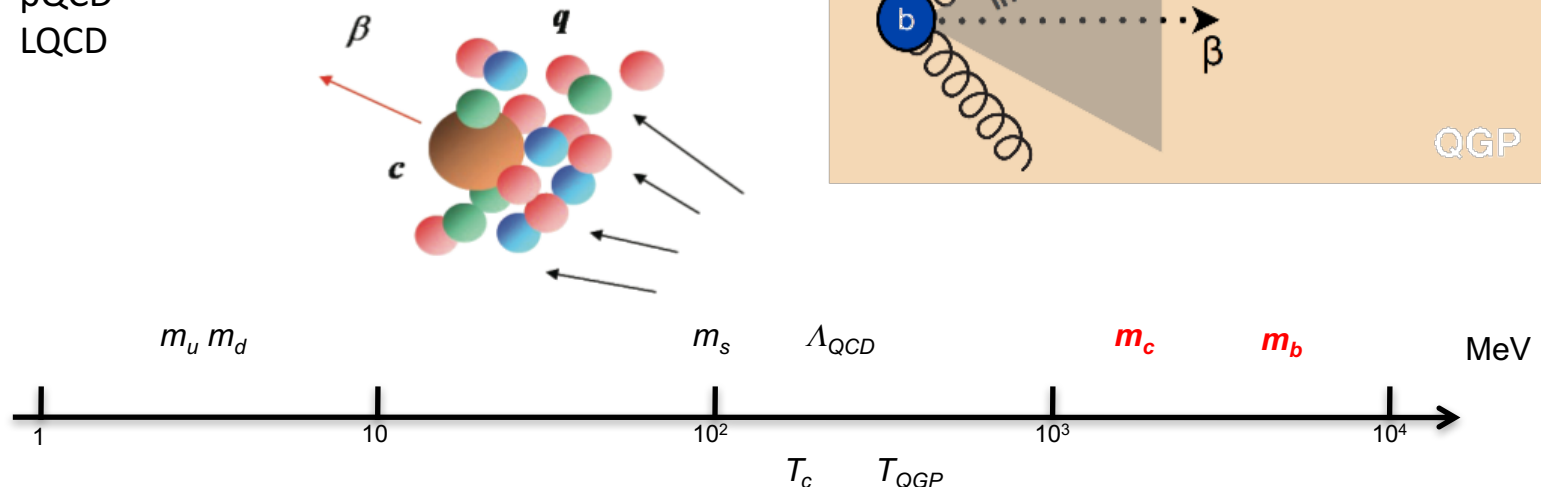
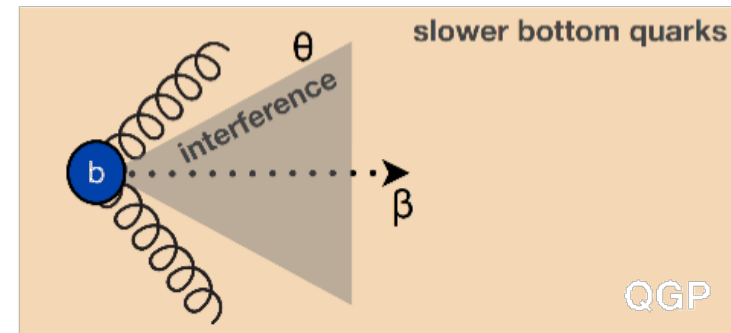
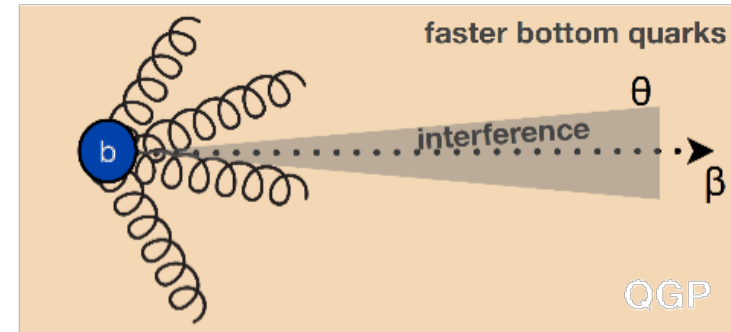


US DOE NSAC LRP 2015

There are two central goals of measurements planned at RHIC, as it completes its scientific mission, and at the LHC: (1) 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. (2) Map the phase diagram of QCD with experiments planned at RHIC.

Heavy Quarks - Unique Probe of QGP

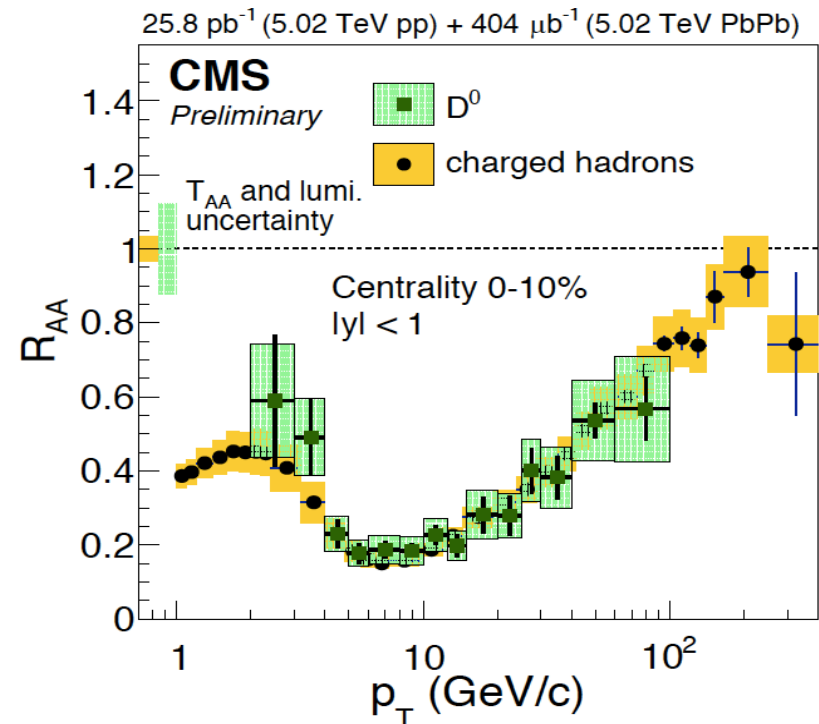
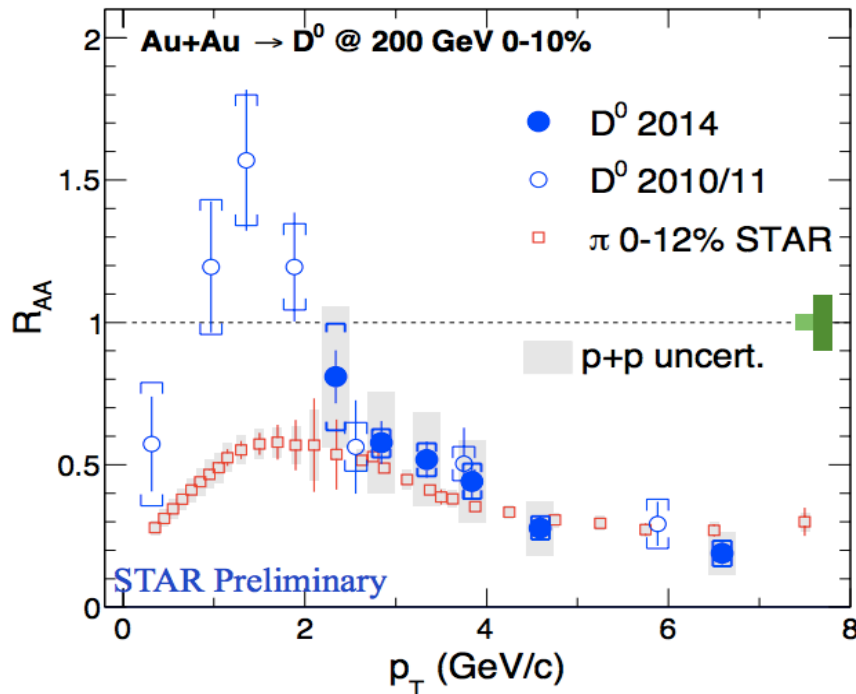
- Study mass dependence
 - Jet quenching, hadronization
 - Collectivity –interaction with medium
- Access QGP properties
 - Diffusions, transport coefficients etc.
- Distinct experimental signatures
 - Displaced 2nd vtx
 - Heavy mass, $\gg \Lambda_{\text{QCD}}$
- Theoretical controls
 - pQCD
 - LQCD



Charm R_{AA}

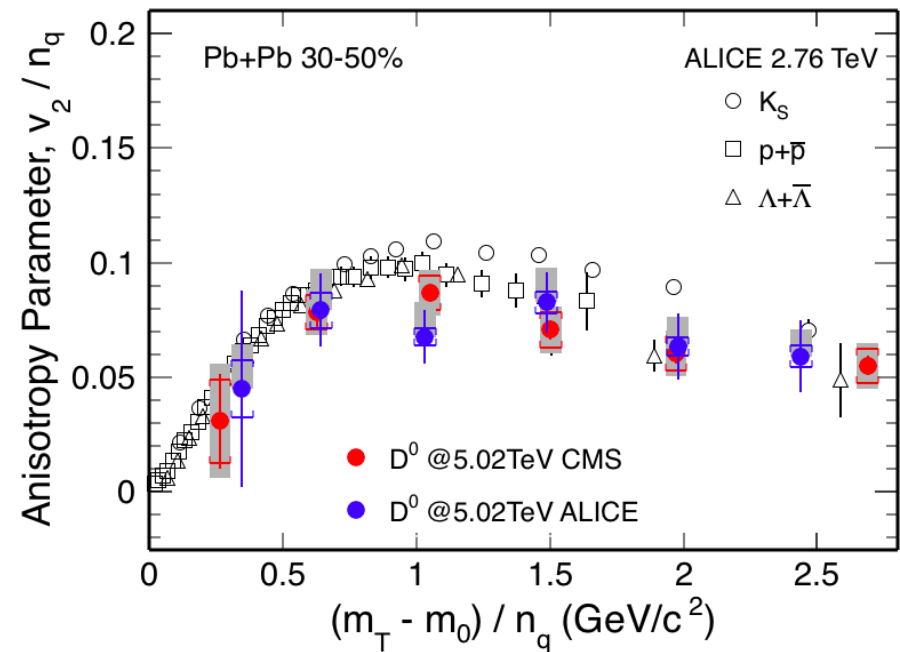
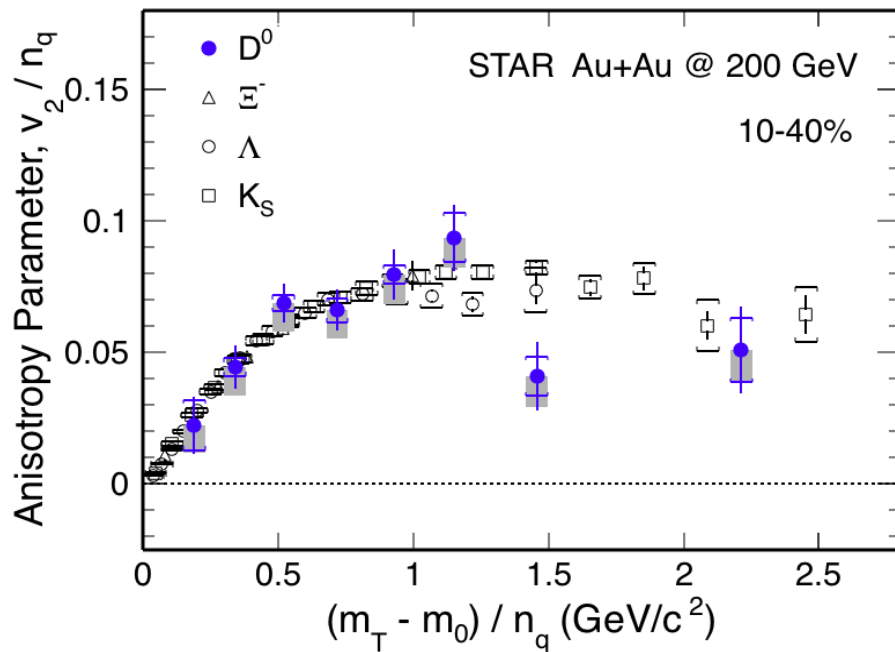
R_{AA} (D-meson) $\sim R_{AA}$ (h) at high $p_T \sim > 4$ GeV/c

- significant suppression of charmed hadron R_{AA} in central A+A collisions
- strong charm-medium interactions
- mass effect expected important at low p_T , dead-cone effects etc.



Charm V_2

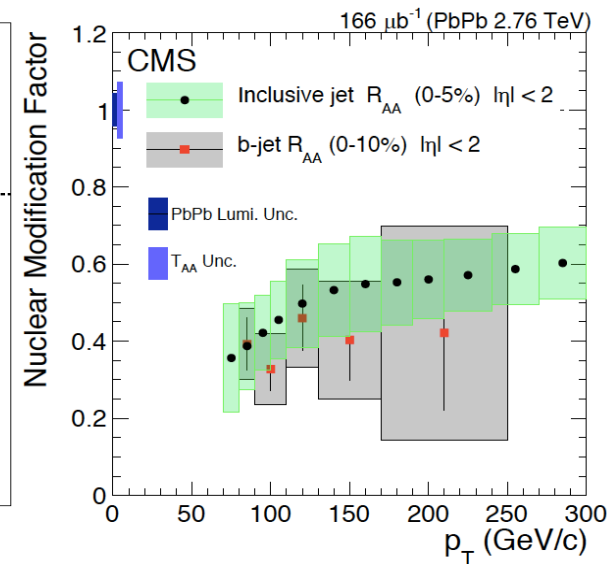
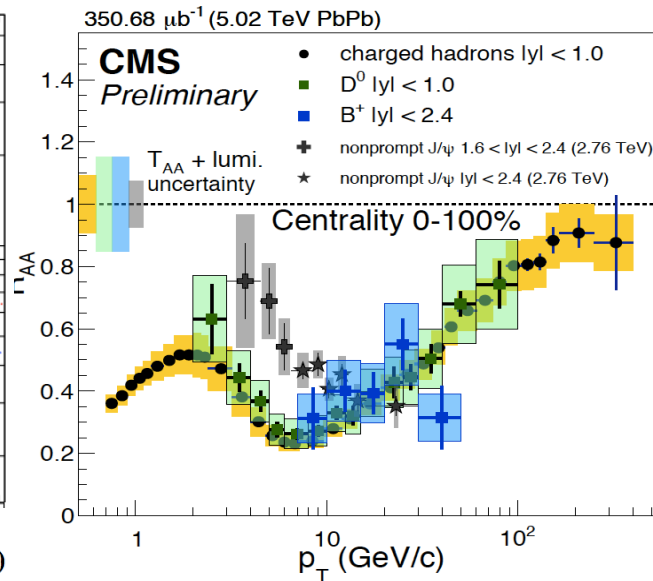
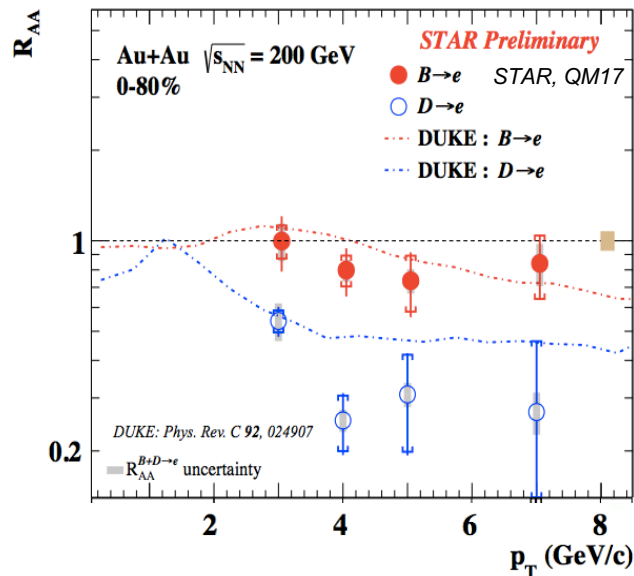
- v_2 of D^0 follows the same trend as light hadrons
- Strong coupling with medium at low p_T ?



Beauty?

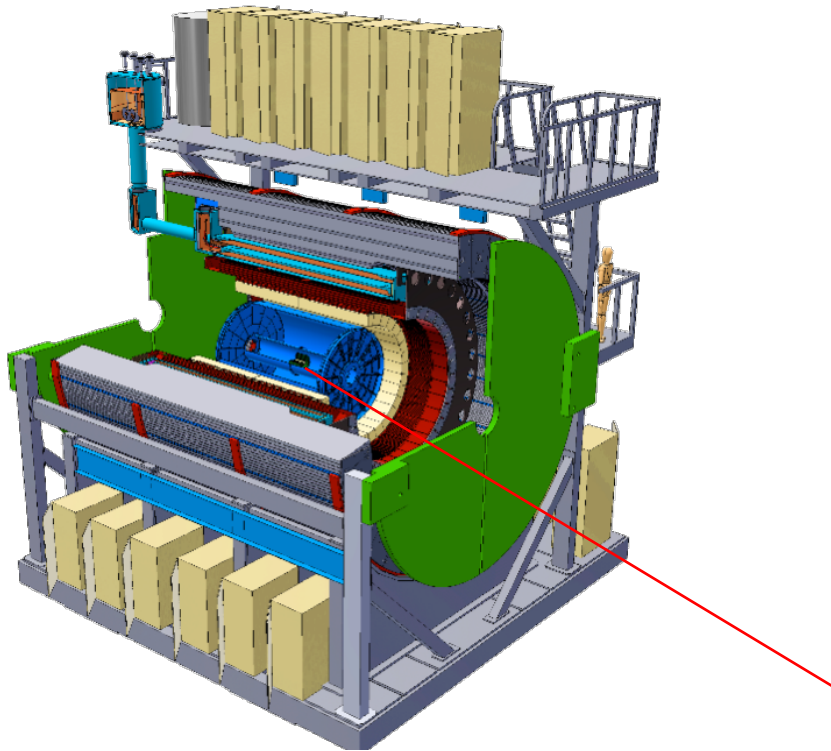
- $R_{AA}(B \rightarrow e) > R_{AA}(D \rightarrow e, h)$ @low p_T
- B^+ & b-jet ~ light hadrons & charm @high p_T

Highly desired:
precision measurements
of B @ $p_T \sim O(m_b)$



MVTX:MAPS-based Vertex Detector

A separate upgrade project for the baseline sPHENIX: **Jet + B-tagging**



Baseline

WBS sPHENIX MIE Project Elements

- | | |
|-----|-------------------------------|
| 1.1 | Project Management |
| 1.2 | Time Projection Chamber |
| 1.3 | Electromagnetic Calorimeter |
| 1.4 | Hadron Calorimeter |
| 1.5 | Calorimeter Electronics |
| 1.6 | DAQ-Trigger |
| 1.7 | Minimum Bias Trigger Detector |

WBS Infrastructure & Facility Upgrade

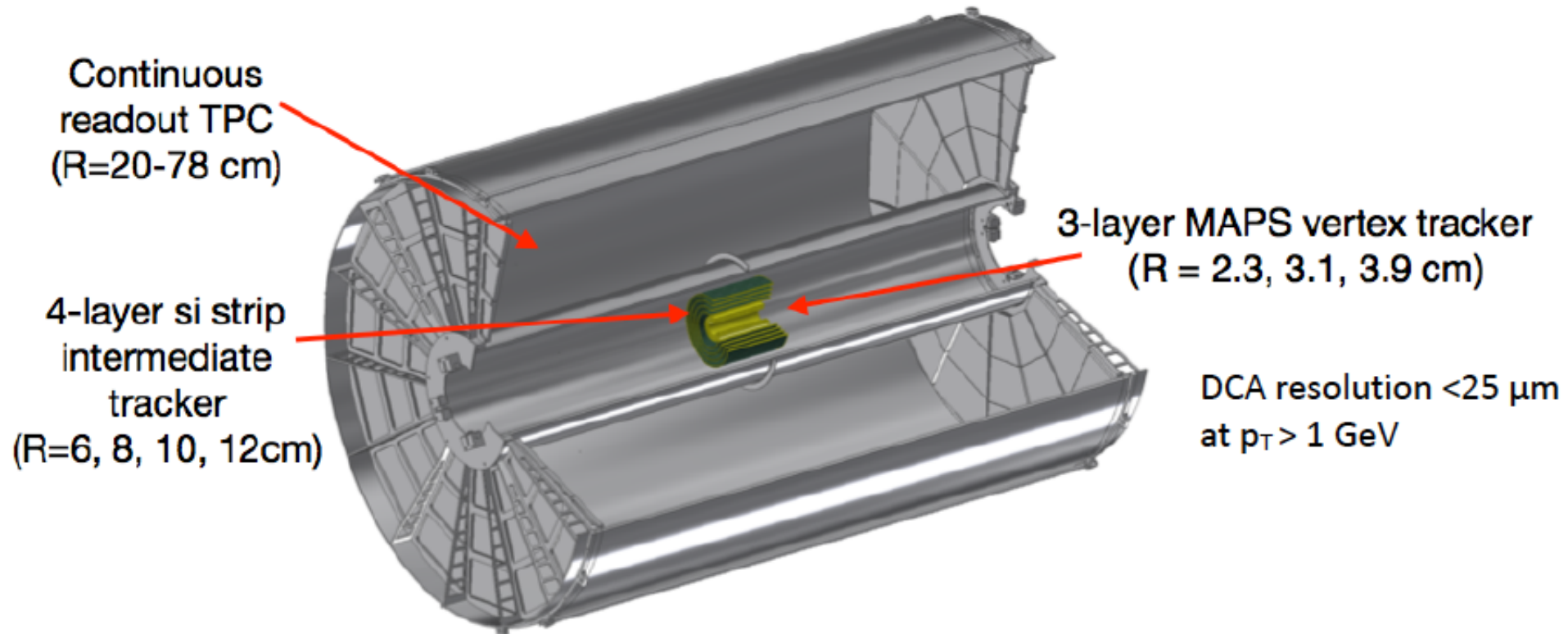
- | | |
|------|--------------------------|
| 1.8 | SC-Magnet |
| 1.9 | Infrastructure |
| 1.10 | Installation-Integration |

Parallel Activities

- MAPS-based Vertex Detector (MVTX)
- Intermediate Silicon Strip Tracker (INTT)

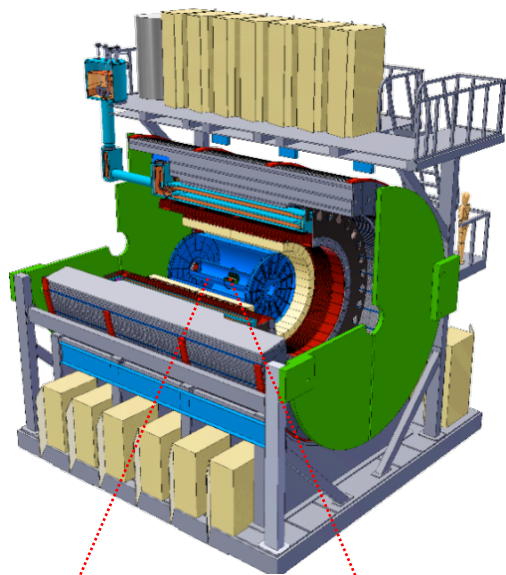
Inner tracking system upgrades

Central Tracking Systems



Good momentum resolution
from $p_T=0.2$ to 40 GeV

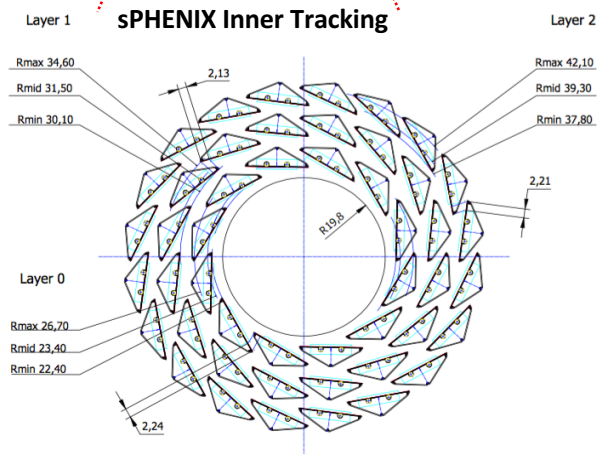
MVTX Proposal



Major challenges:

- Readout
- Mechanics

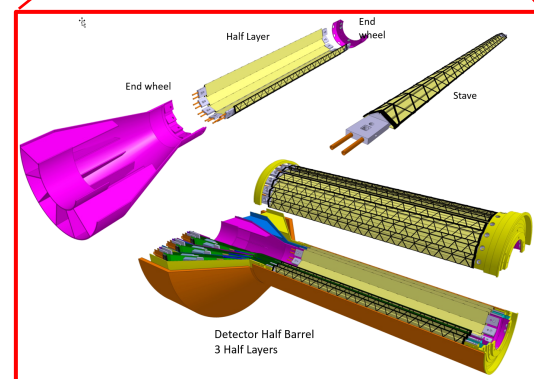
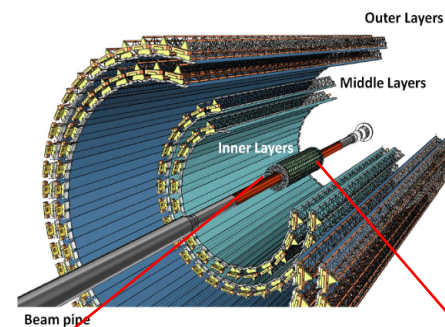
R = 23/31/39 mm
Z = 271 mm



Adapt ITS/IB

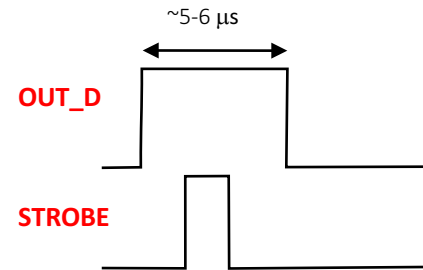
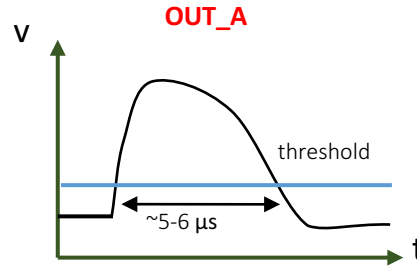
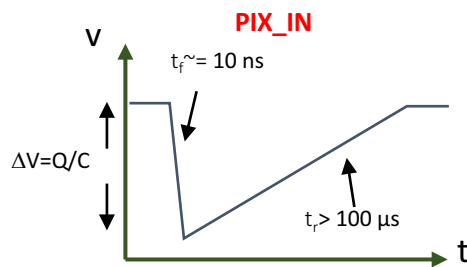
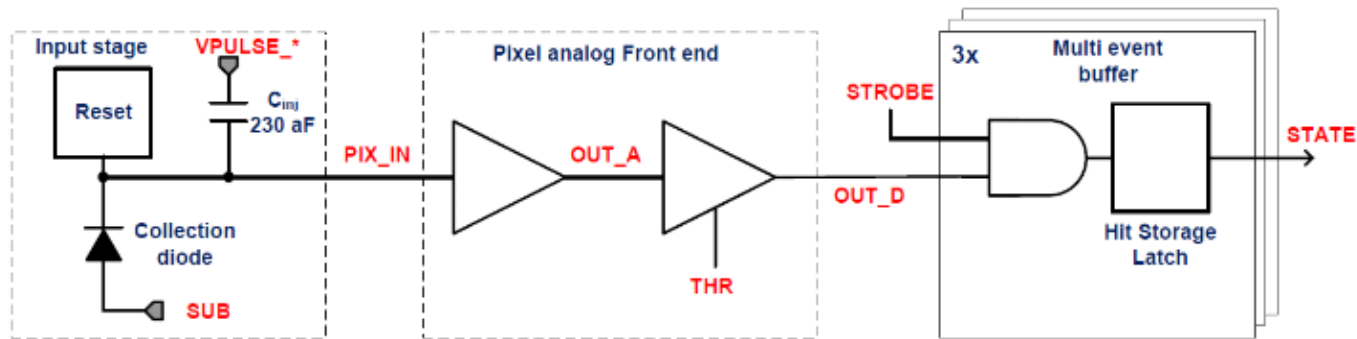
- Min. Risks
- Max. Phys.

ALICE ITS Upgrade:
Inner Barrel Tracker



ALPIDE/MAPS Timing & Trigger

Well fit sPHENIX/RHIC environment, 10MHz Clock (LHC 40MHz)



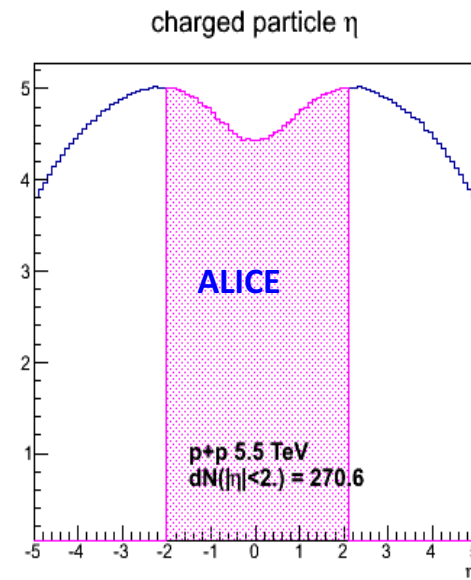
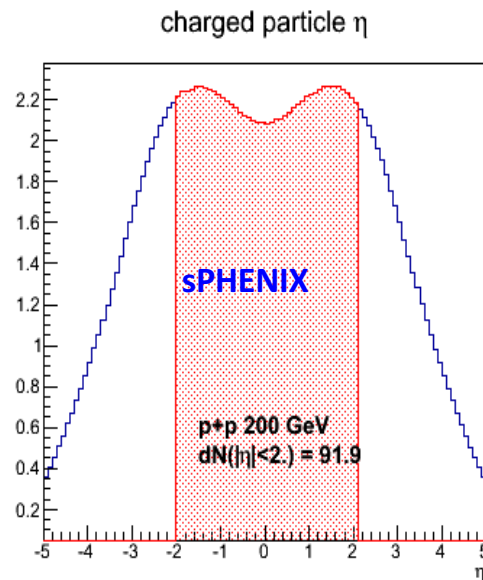
sPHENIX trigger latency: $\sim 4 \mu\text{s}$

sPHENIX vs ALICE Specifications



	ALICE (Run3)	sPHENIX
Pb+Pb / Au+Au	100 kHz (50kHz)	200 kHz
p+p	400 kHz (200kHz)	13 MHz
Trigger	50 kHz	15 kHz

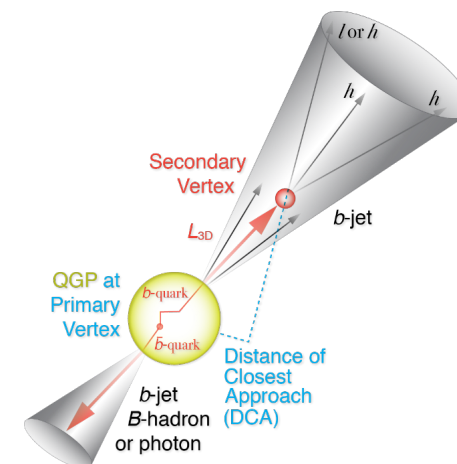
Event size, $dN/d\eta$: sPHENIX = 1/3 ALICE (pp), 1/5 ALICE(AA)



Year	Species	Energy [GeV]	Phys. Wks	Rec. Lum.	Samp. Lum.	Samp. Lum. All-Z
2022	Au+Au	200	16.0	7 nb ⁻¹	8.7 nb ⁻¹	34 nb ⁻¹
2023	p+p	200	11.5	—	48 pb ⁻¹	267 pb ⁻¹
2023	p+Au	200	11.5	—	0.33 pb ⁻¹	1.46 pb ⁻¹
2024	Au+Au	200	23.5	14 nb ⁻¹	26 nb ⁻¹	88 nb ⁻¹
2025	p+p	200	23.5	—	149 pb ⁻¹	783 pb ⁻¹
2026	Au+Au	200	23.5	14 nb ⁻¹	48 nb ⁻¹	92 nb ⁻¹

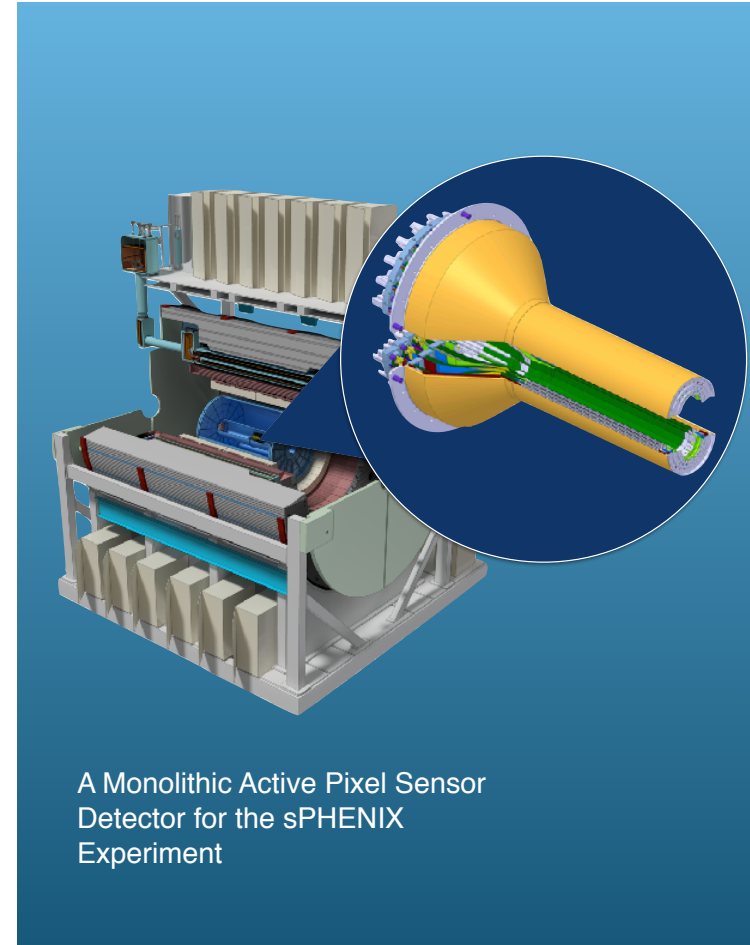
- Precision 2nd vertexing for B-tagging:
 - Tracking resolution better than 30μm @pT=1GeV
 - High multiplicity HI collisions
 - Low multiplicity but high rate p+p collisions
 - High efficiency and high purity

B hadrons/pT<15GeV: O(1M)
 b-jets/pT>15GeV: O(100K)

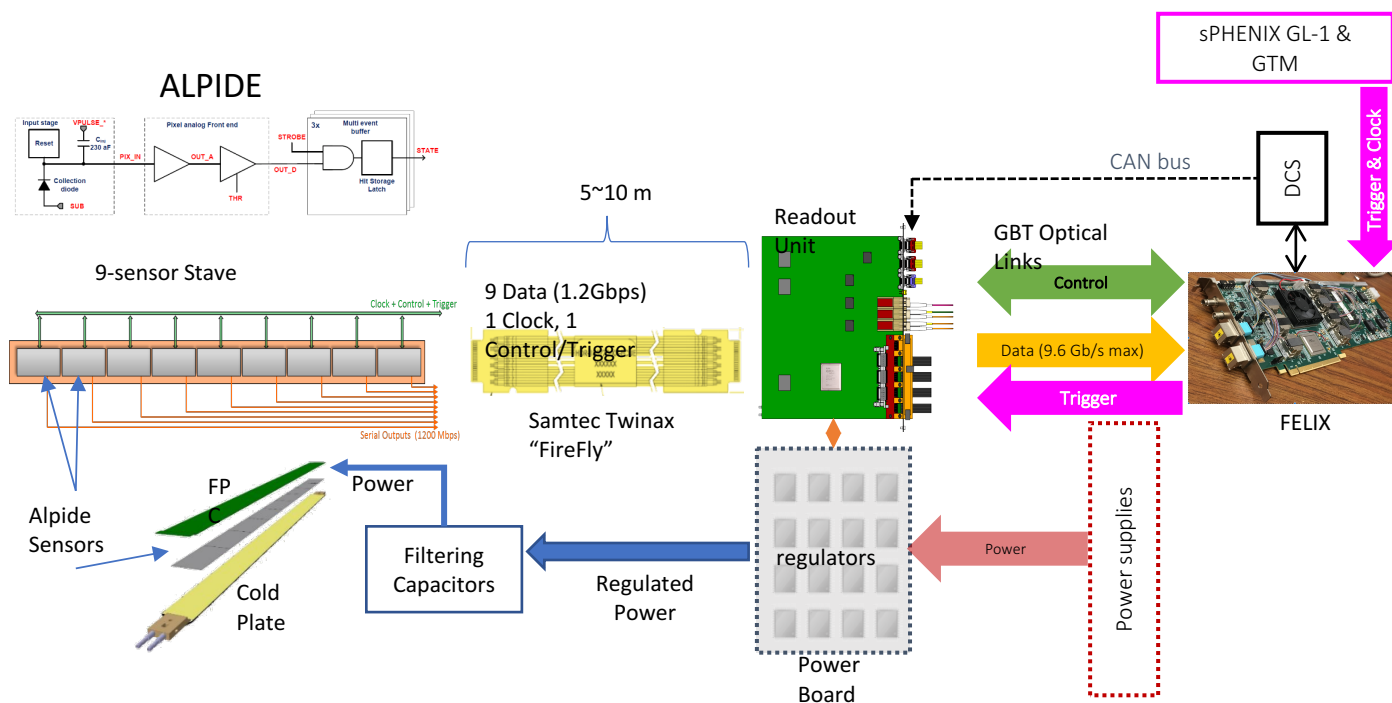


MVTX Proposal Status

- Pre-proposal submitted to DOE, 2/2017
 - Follow-up discussions with DOE and BNL managers
- Update proposal to DOE, early 2018
 - Expanded science + Cost & Schedule
 - Assumed funding starts ~FY19
 - **Ready for sPHENIX day-1, ~Jan. 2023**
- A growing collaboration
 - 15+ institutions from US and abroad
- Early R&D by LANL internal fund
 - FY17-19, \$5M
 - Readout and mechanical design



MVTX Readout and Control R&D at LANL



LANL, UT-Austin, LBNL, BNL, ALICE/ITS ...

- 1) Established the readout chain test: ALPIDE + KC705(RU) + FELIX + RCDAQ/sPHENIX
- 2) RUv1.0 arrived last week, 10/21/2017
- 3) ALPIDE/MAPS and Power Unit being tested

R&D at LANL



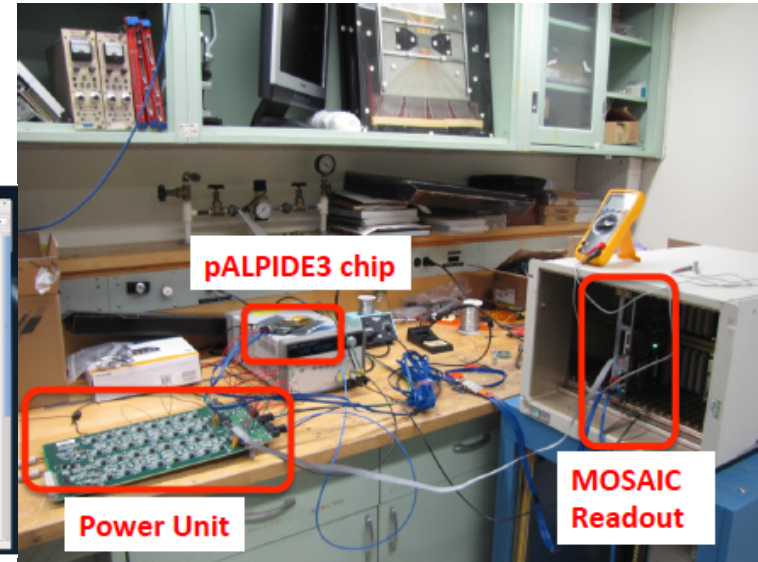
ALPIDE/MAPS sensor evaluation



LV/HV controls

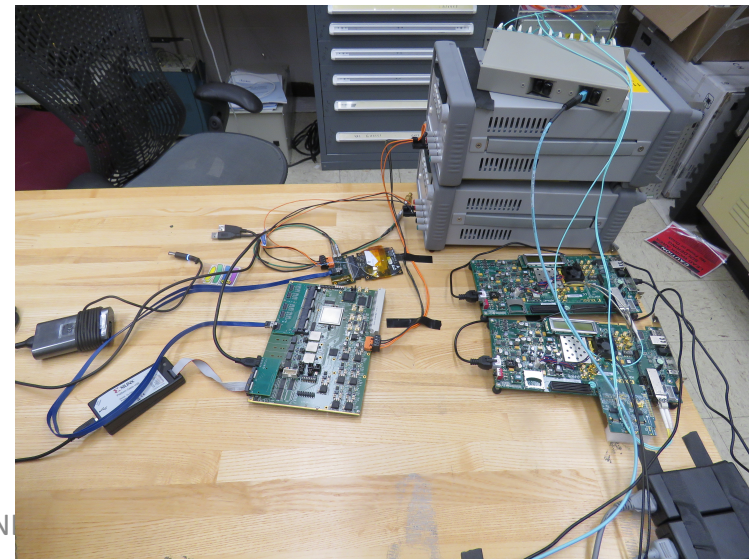
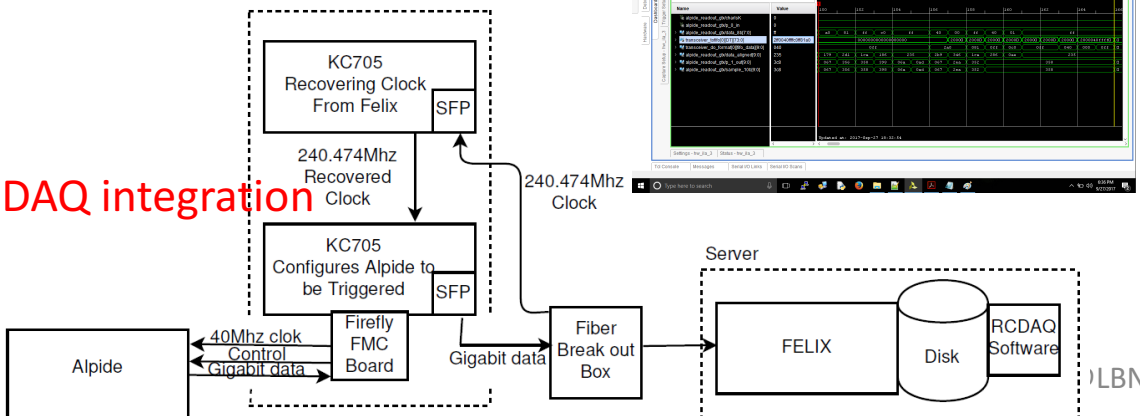


Power unit test

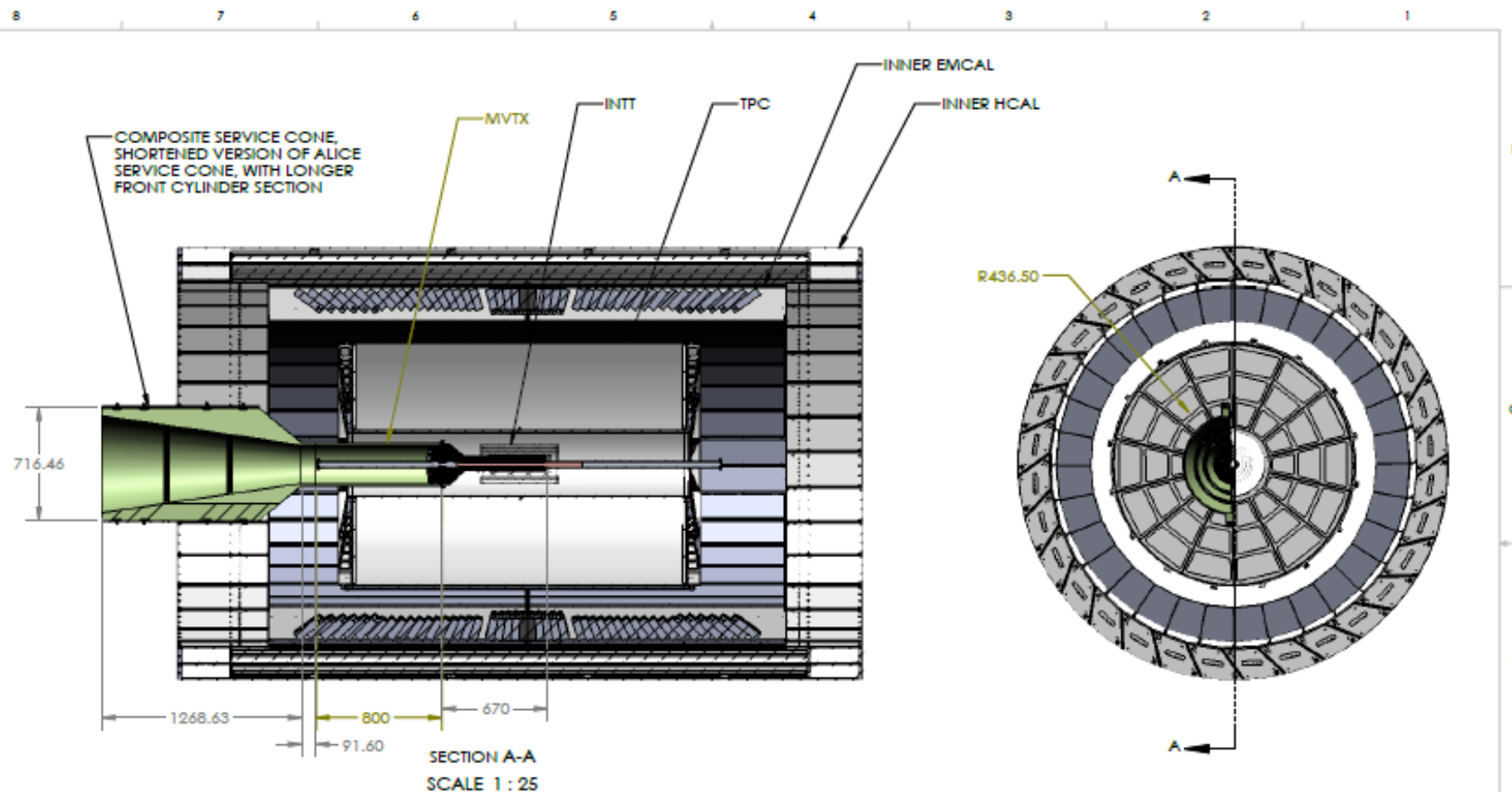


RU Mock UP

DAQ integration



Section view of sPHENIX inner detector assembly the ALICE service barrel has been modified – shortened



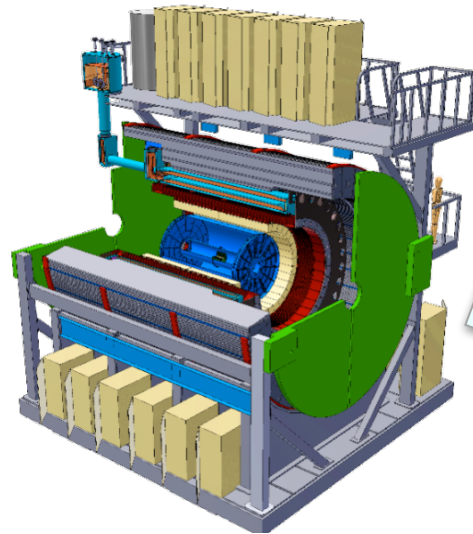
PRELIMINARY

ALL DIMENSIONS IN MILLIMETERS

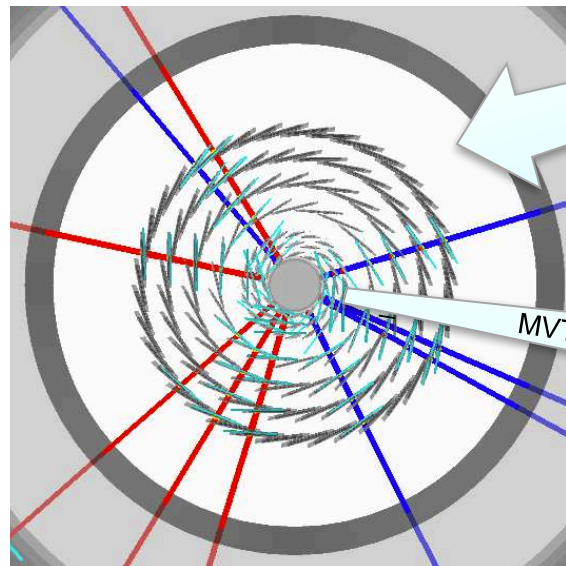
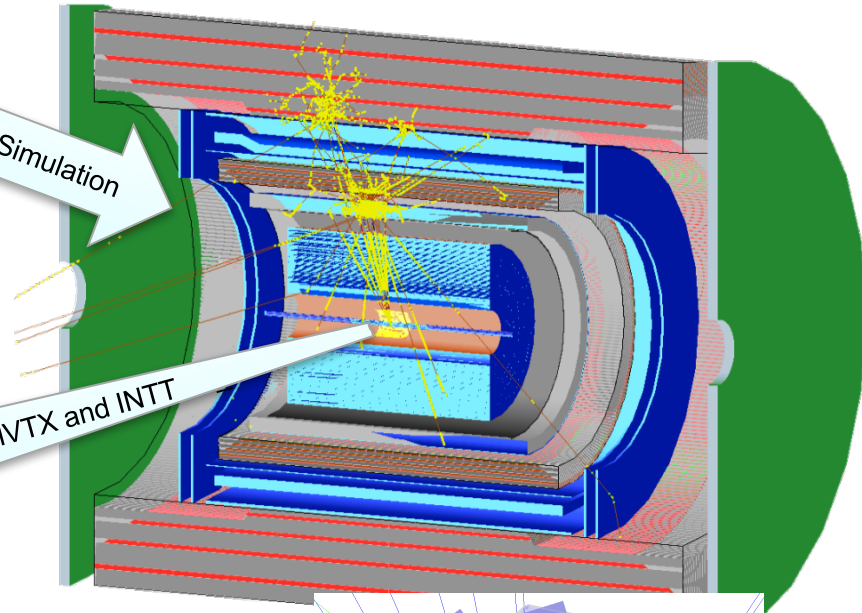
P-25 SUBATOMIC PHYSICS 		DIVISIONS ARE IN INCHES TOLERANCES UNLESS SPECIFIED FINISHES ANGULAR: MAX ± .001 TWO PLACE DECIMAL THREE PLACE DECIMAL .001 .003	NAME DATE 9/22/2017
DESIGNED CHECKED ENG. APP. MFG. APP. Q.A. COMMENTS	DESIGNED CHECKED ENG. APP. MFG. APP. Q.A. COMMENTS	MATERIAL METHOD QUANTITY REQUIRED	Updated sPHENIX assembly-2, MVTX w service cone, INTT, TPC, EMCAL, inner HCAL
REV 1 10/29/17	REV 2 10/29/17	REV 3 10/29/17	REV 4 10/29/17

10/29/17

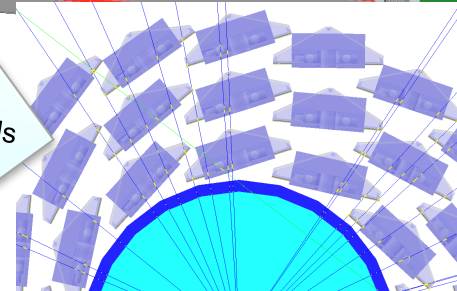
Simulation for b -jet and B -meson



sPHENIX Geant4 display of $p_T=30$ GeV/c B^+ -hadron



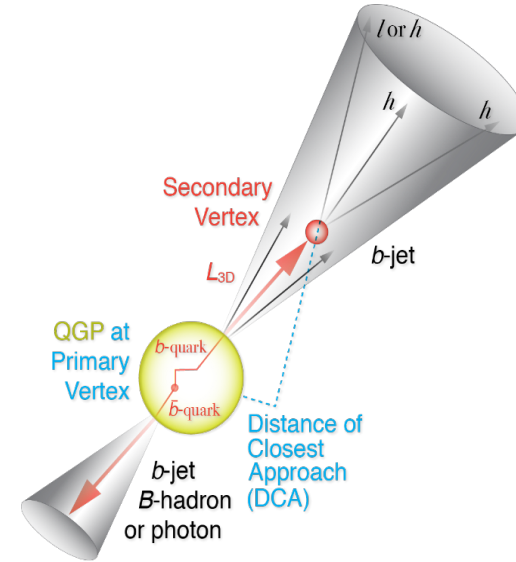
MVTX Ladders modeled in details



MVTX
sensors

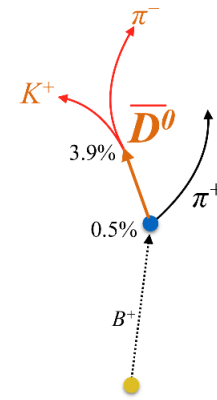
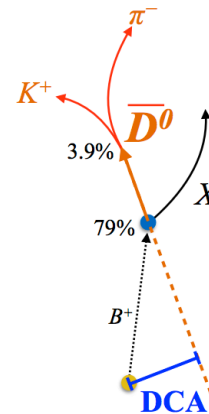
Physics Channels Simulated: Open Charm and Beauty

Hadron	Abundance	$c\tau$ (μm)
D^0	61%	123
D^+	24%	312
D_s	8%	150
Λ_c	6%	60
B^+	40%	491
B^0	40%	455
B_s	10%	453
Λ_b	10%	435



$$B \rightarrow \bar{D}^0 + X$$

$$B^+ \rightarrow \bar{D}^0 \pi^+$$



b -tagged jet and cor.

$p_T > 15 \text{ GeV}$

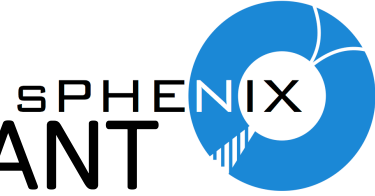
$$B \rightarrow \bar{D}^0 + X \quad 60\%$$

$$B^+ \rightarrow \bar{D}^0 \pi^+ \quad 0.5\%$$

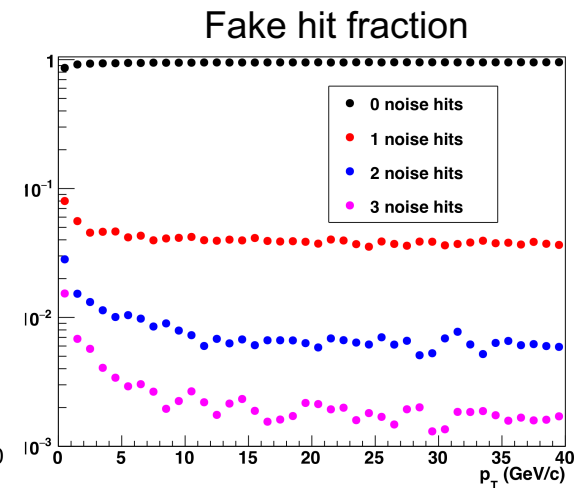
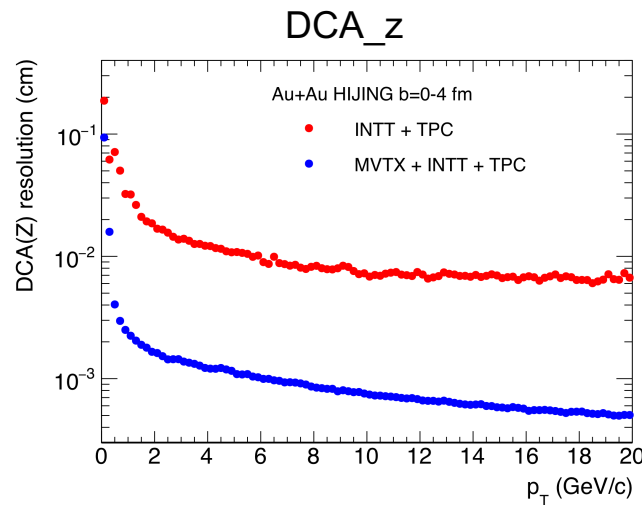
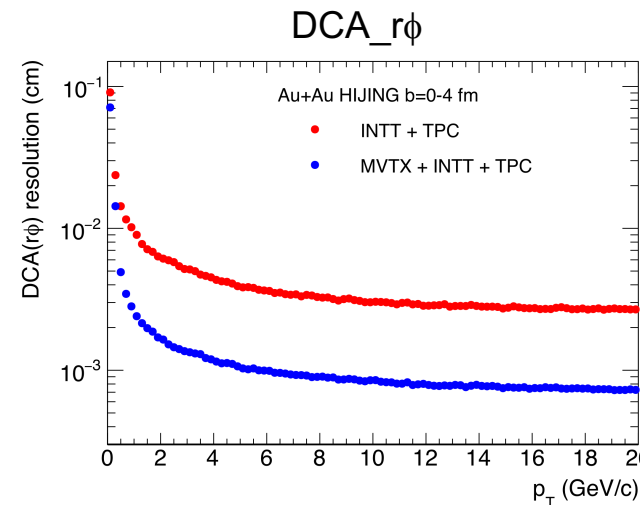
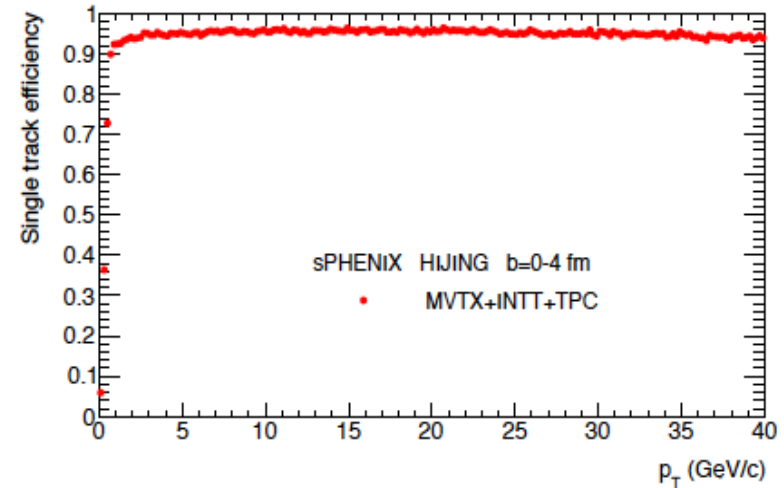
$p_T < 15 \text{ GeV}$

Exploring $B \rightarrow J/\psi + X$ and more

Tracking Performance with Full GEANT

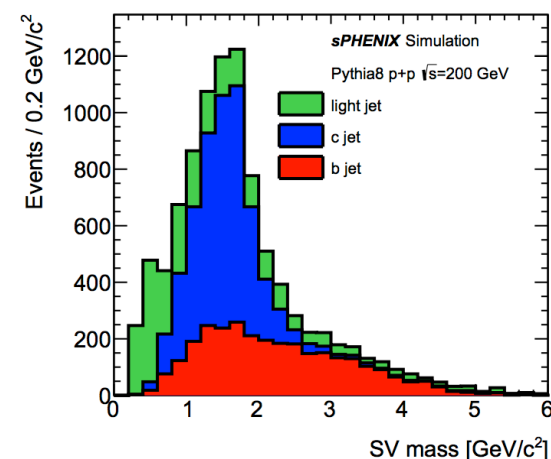
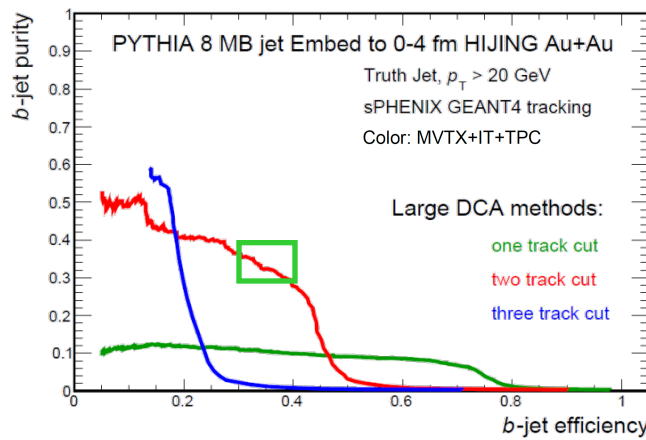
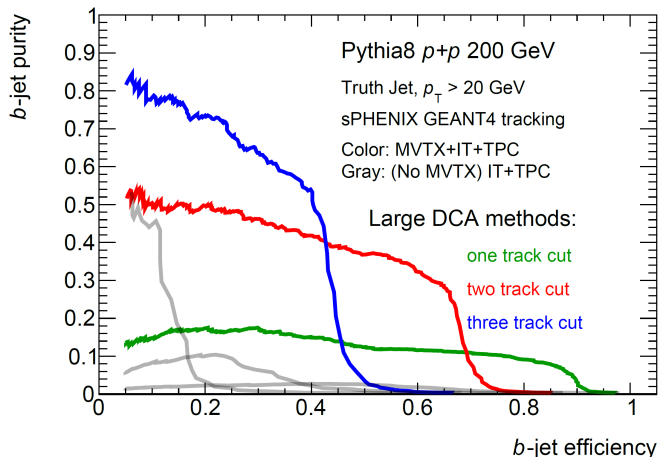
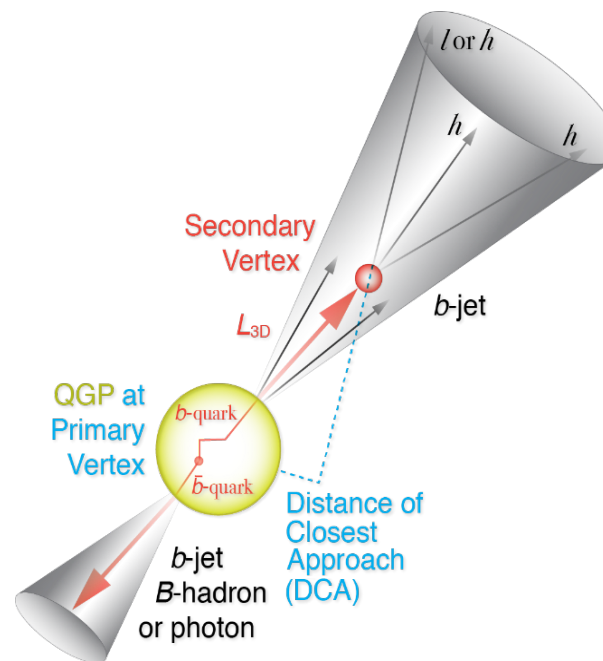


- MVTX geometry modeled and digitized according to ALICE ITS/IB
- Cluster resolution: $\sim 5 \mu\text{m}$
- DCA_{2D} , $\text{DCA}_z < 30 \mu\text{m}$ down to 1 GeV



B-jet tagging

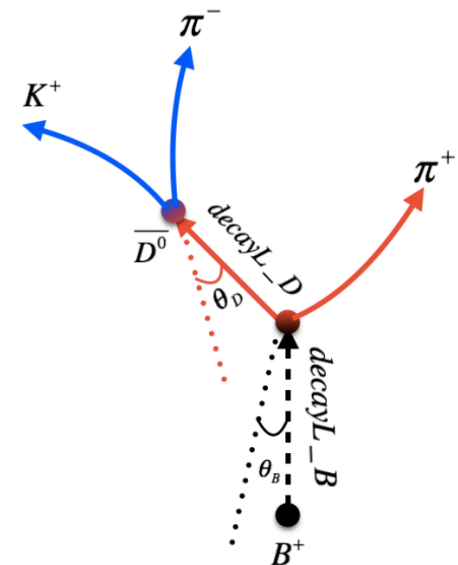
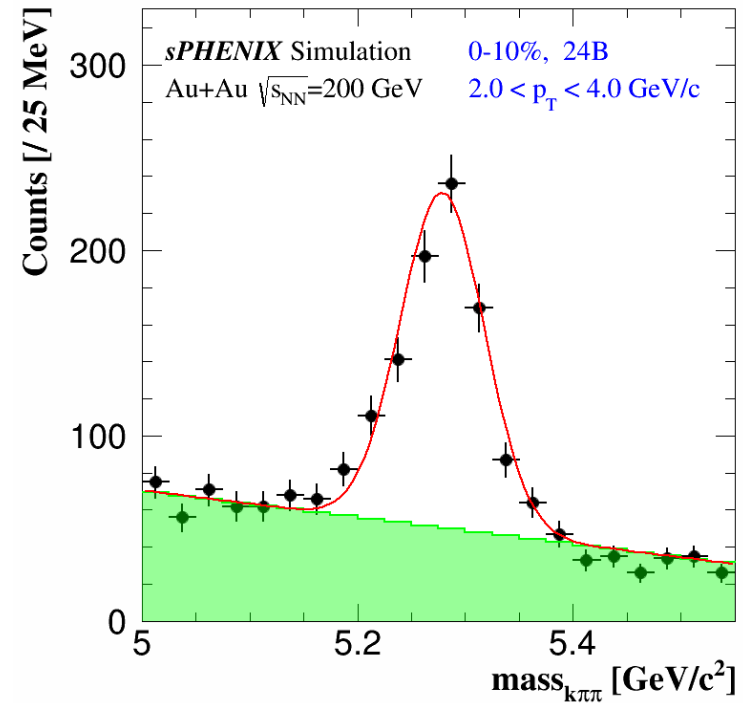
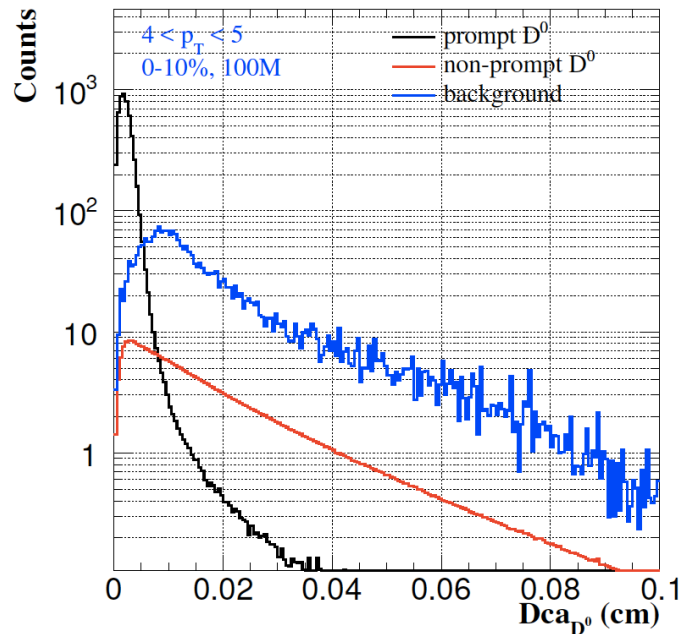
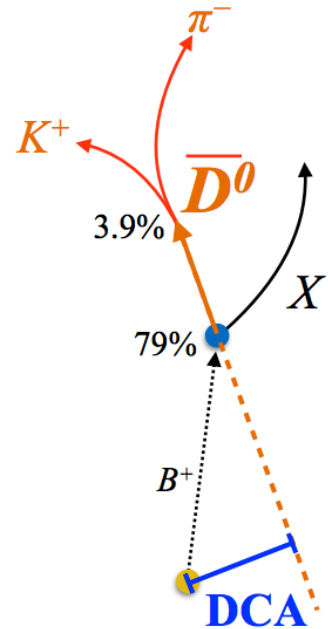
- Multi-tracks w/ large DCA
- 2nd vertex mass reco'ed



 CMS work-point, Phys. Rev. Lett. 113, 132301 (2014)

B-hadron Tagging

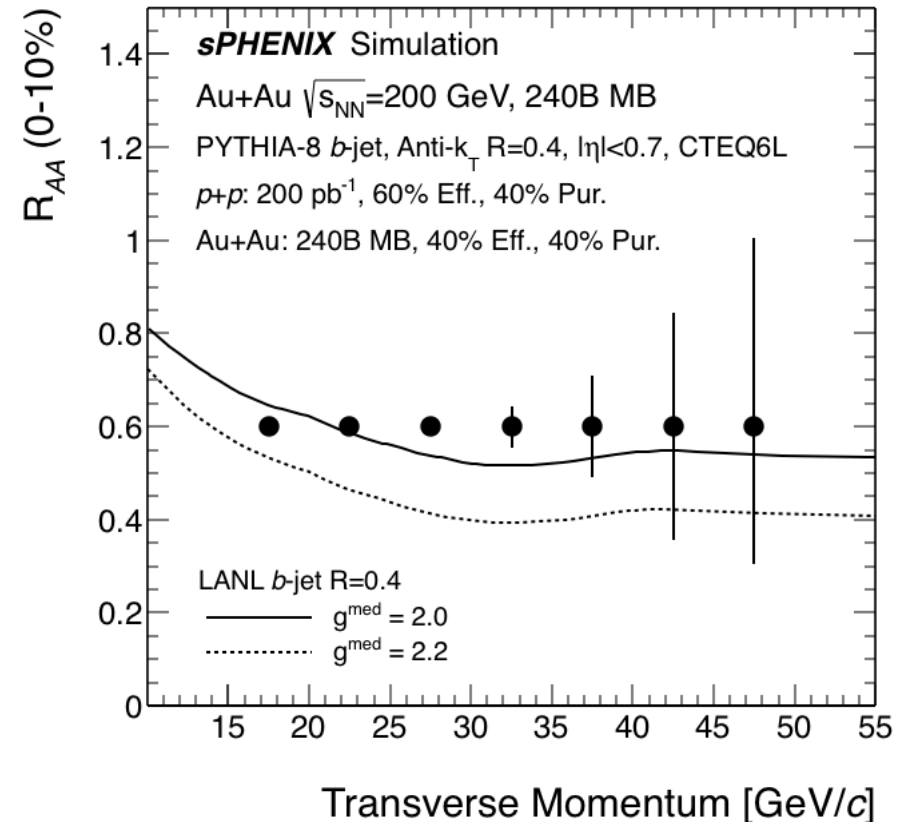
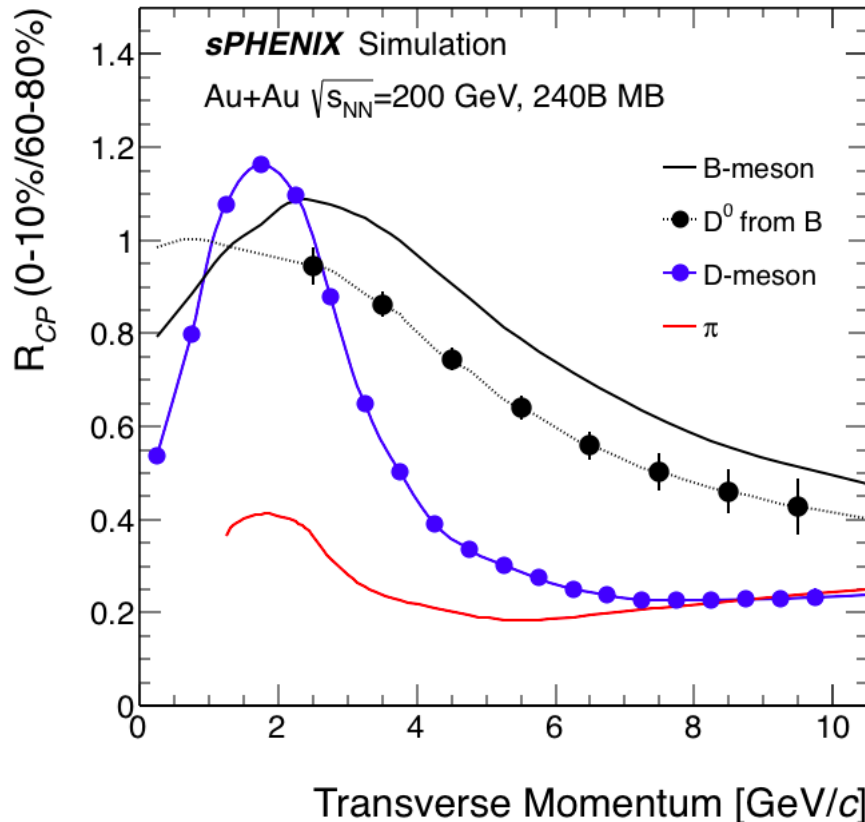
- Impact parameter (DCA) method to tag non-prompt D^0 from B -meson decays
- Inclusive and exclusive channels possible



Projected R_{AA}

Open questions:

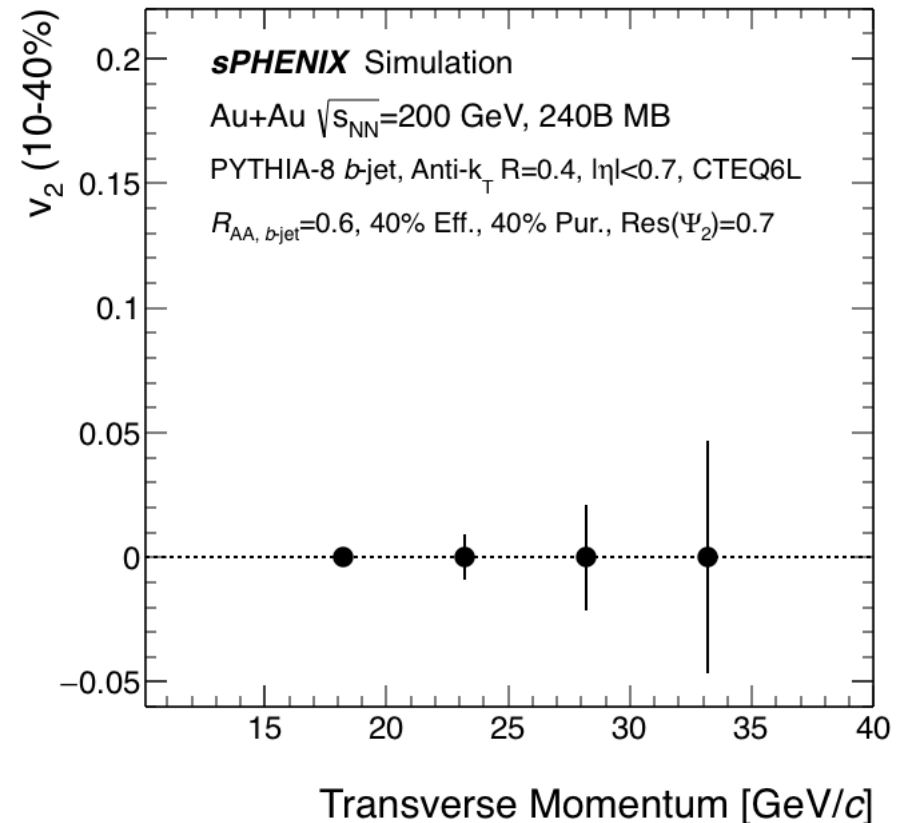
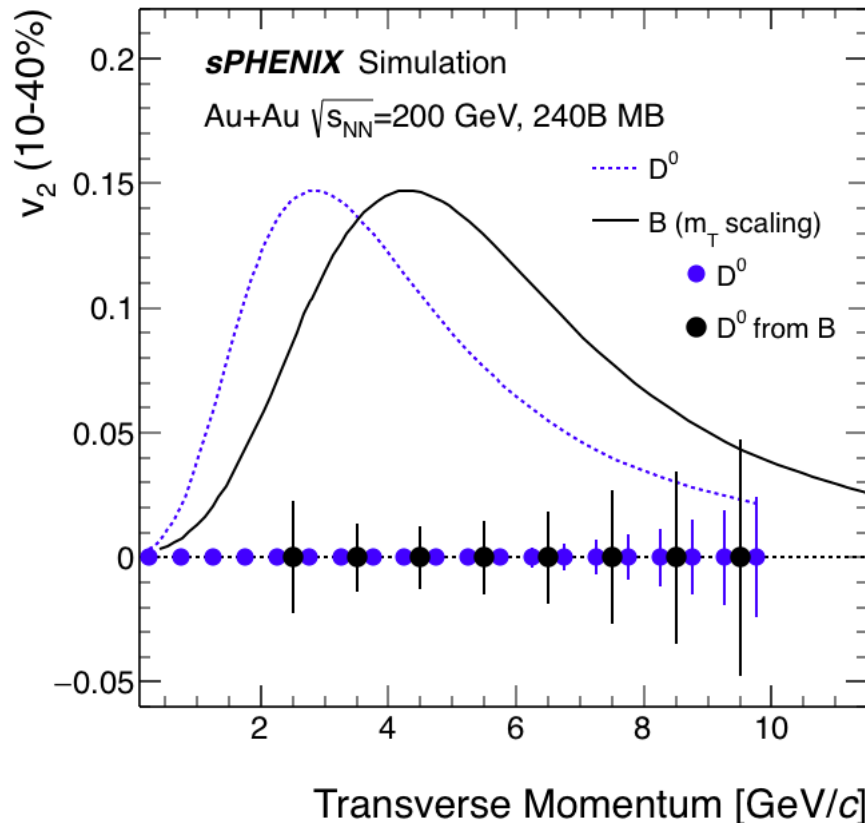
energy loss mechanisms, fragmentation/coalescence, QGP medium etc.



Project Elliptical Flow v_2

Open questions:

quasi-particles, medium interactions, fragmentation/coalescence etc.

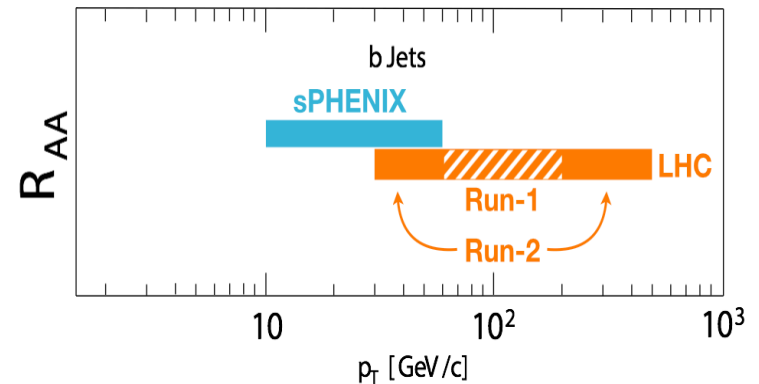


Summary



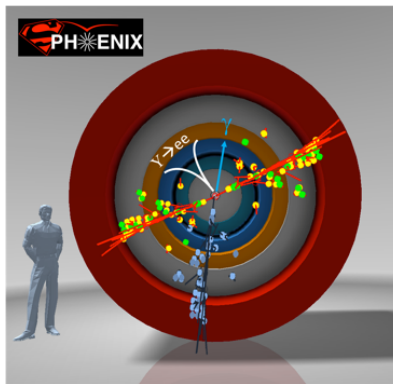
- sPHENIX is the next flagship heavy ion physics experiment in the US (NSAC LRP2015)
 - Jets
 - Upsilon's
 - **B-jets and B hadrons**
- MVTX upgrade will complete QGP heavy flavor physics
 - Unambiguous determination of key parameters of QGP properties and interactions
 - Precision study of the “inner workings of QGP”(LRP15)

Complement & extend current and future RHIC and LHC QGP programs

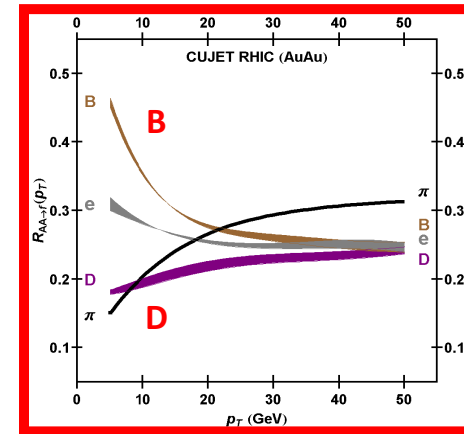
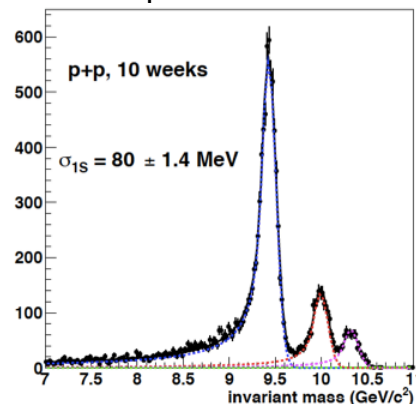


sPHENIX Three Physics Pillars

Jets



Upsilon's Frawley's Talk

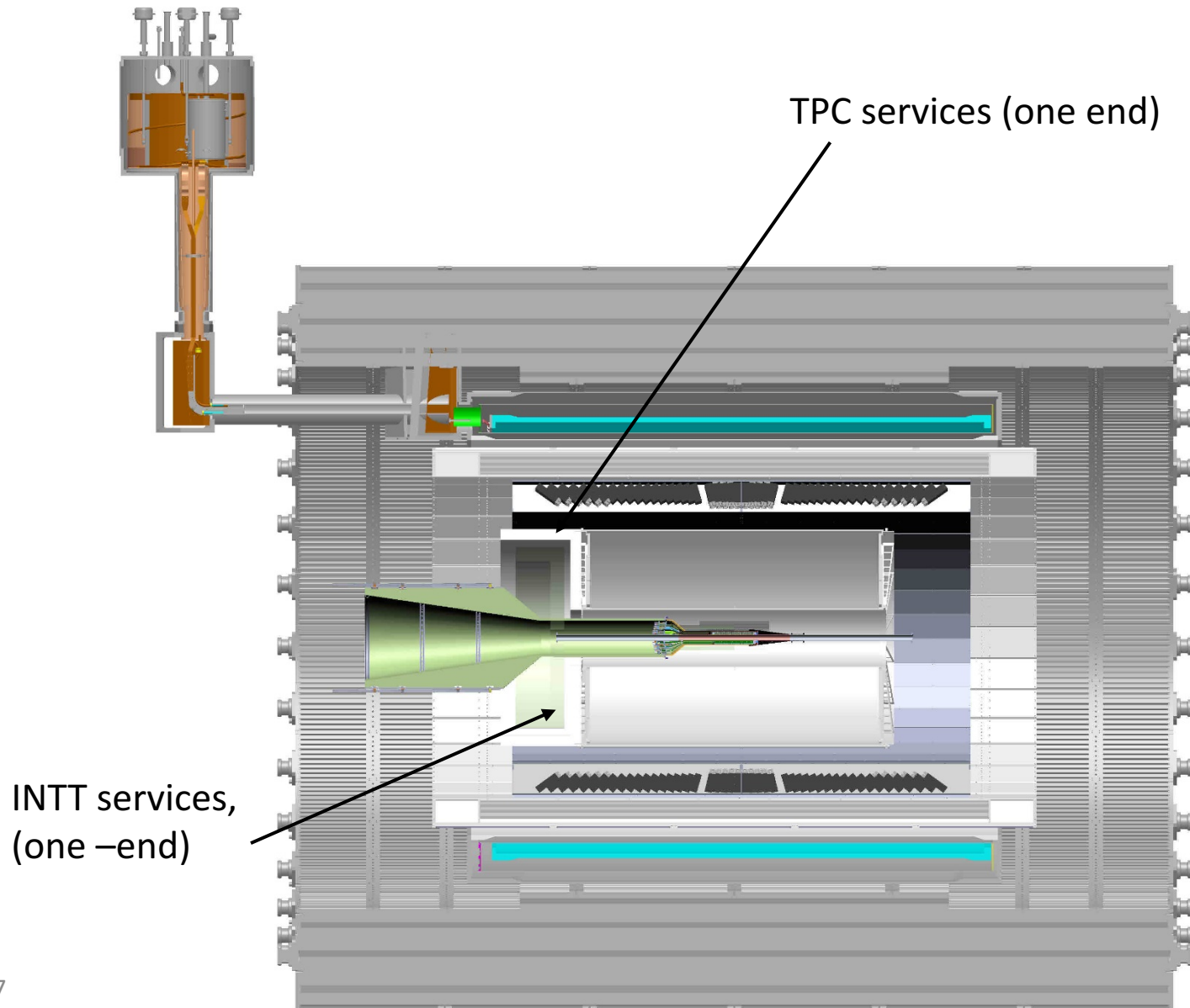


4th sPHENIX Collaboration Meeting at BNL, June 2017

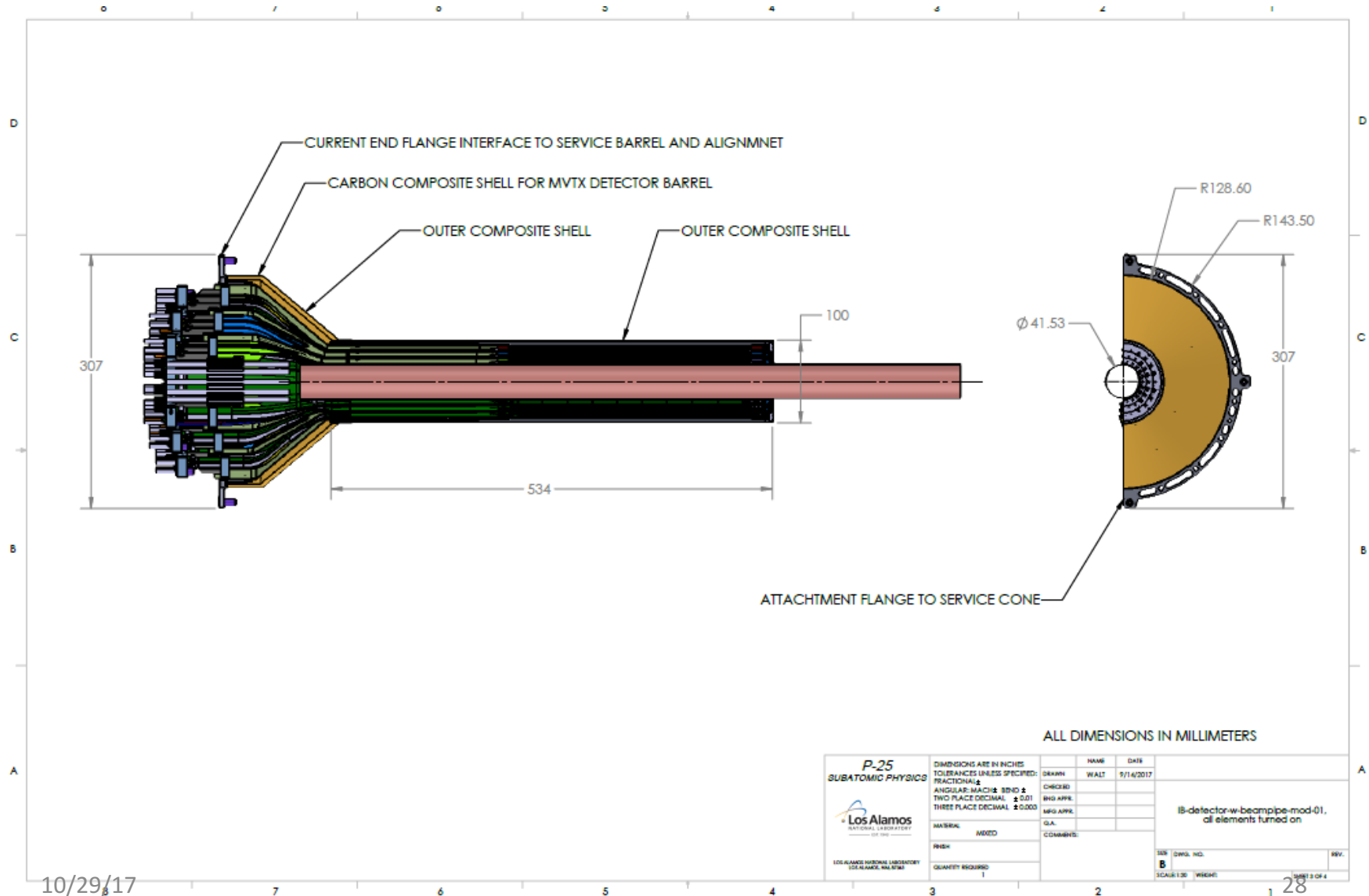
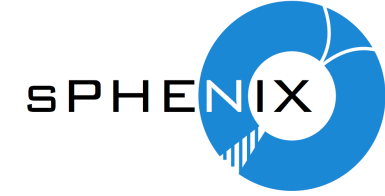
64 institutions and counting ...



sPHENIX cross-section view, including envelope for services; TPC and INTT

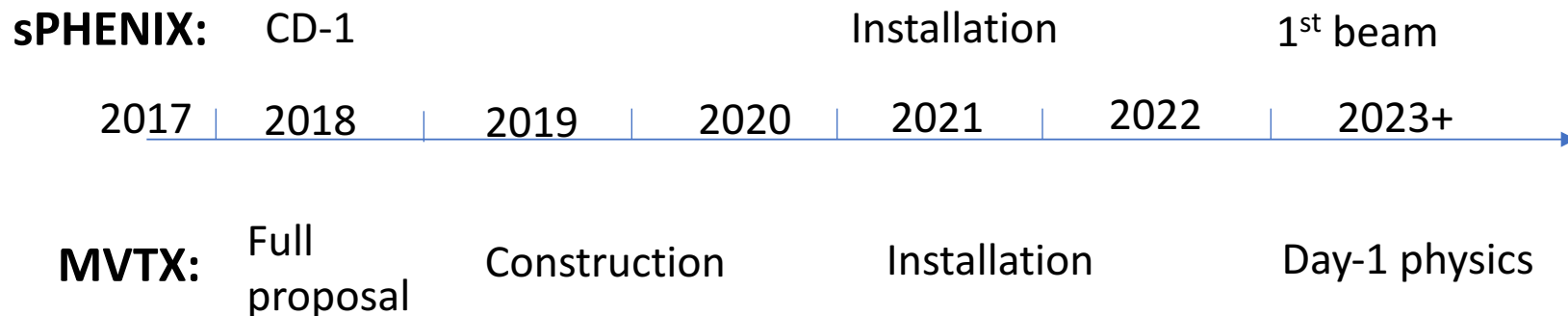


Extended inner tracker with current outer composite shell



Outlook

- sPHENIX collaboration fully engaged toward physics in early 2020s with the baseline detectors
- MVTX upgrade will bring in the 3rd science pillar – open heavy flavor physics and more
- Strong support from the community, LANL LDRD etc.
- Great opportunity to advance our understanding of the inner workings of QGP



MVTX Funding & Schedule

- Tied to sPHENIX and ALICE schedule
 - Stave production
 - Readout electronics
 - Minimize technical risk and R&D cost
- Cost based on ALICE/ITS and similar recent STAR & PHENIX upgrade projects
 - STAR HFT
 - PHENIX FVTX

Schedule

- sPHENIX ready for installation: 4/2021
- sPHENIX installed and ready for commission 7/2022
- sPHENIX commission complete 9/2022
- First beam 1/2023
- sPHENIX CD-4 1/2024

- Install INTT 4/22/2022

- MVTX ready for installation: ~1/2022 (or with INTT, ~4/2022)
- MVTX installed and ready for commission 7/2022
- MVTX ready for beam: 1/2023
-

B $\rightarrow$ D $\rightarrow$ K + π

