sPHENIX LDRD Review:

Physics & Detector Simulations

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XTD-PRI / P-25

Physics Reminder

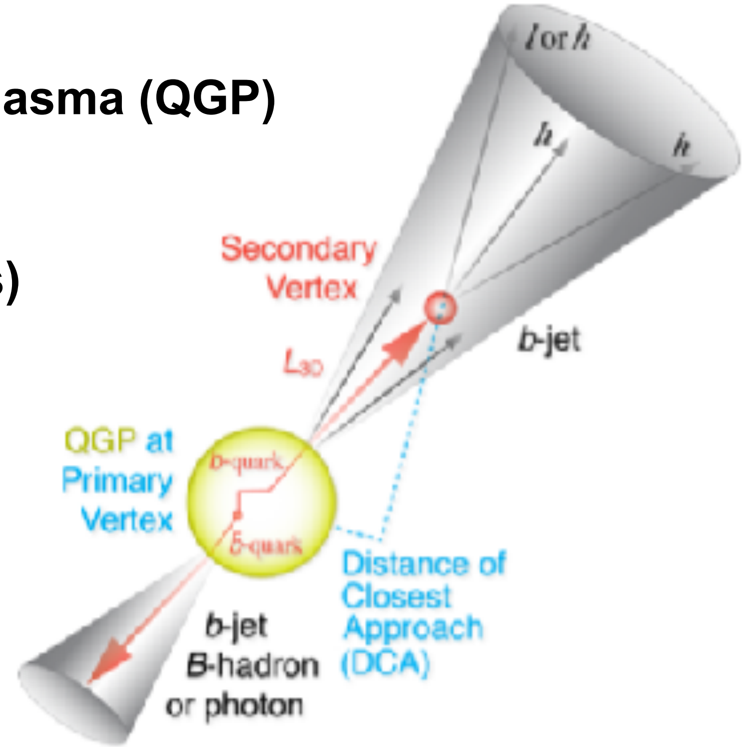
Physics Goal:

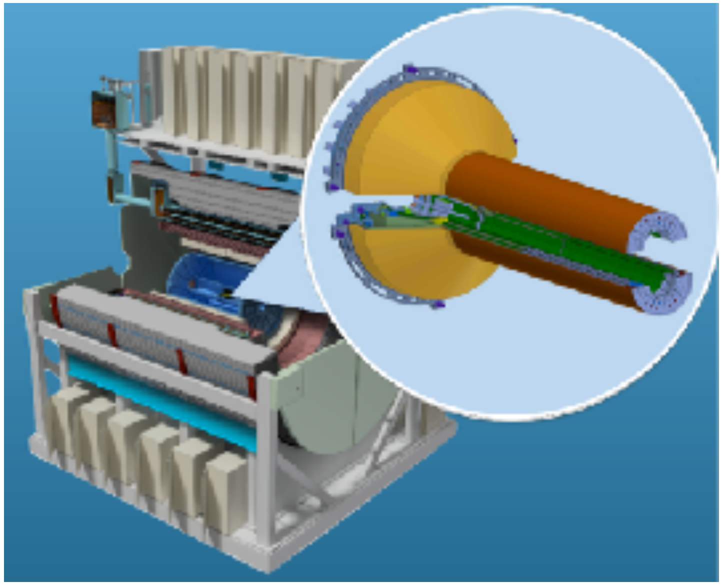
Study the properties of the Quark Gluon Plasma (QGP)

Experimental Observable:

Jets originating from bottom quarks (b-jets)

- Bottom quarks are heavy (4.2 GeV)
- Produced in initial collision, not QGP
- Well controlled in pQCD
- Provide access to fundamental transport properties



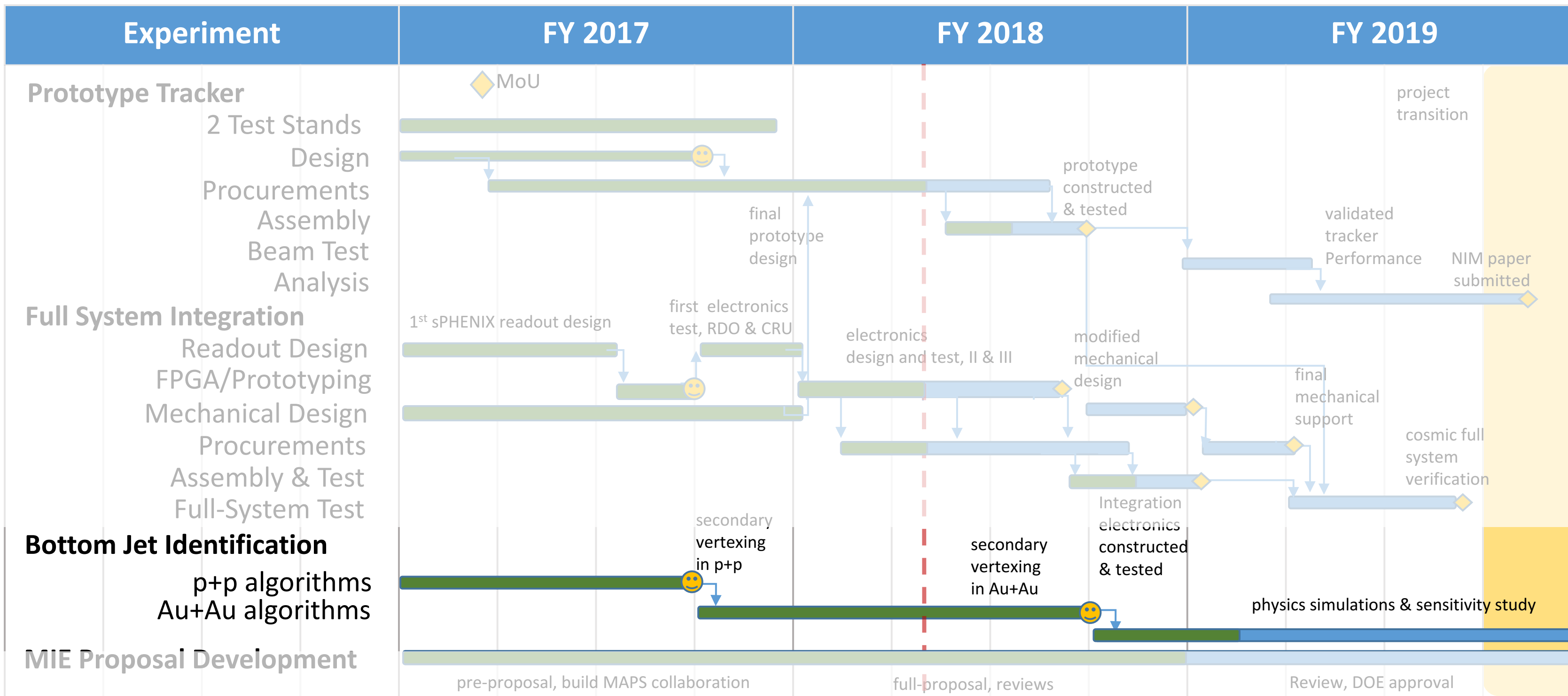


- Detected using the long lifetime of bottom quark hadrons
- Need excellent jet detection capabilities – **sPHENIX!**
- Need high precision tracking and vertex determination – **MVTX!**

… B-mesons are another important observable, but won't be discussed here

LDRD Deliverable:

Develop the software framework necessary for validation of the sPHENIX MAPS-based Vertex Detector (MVTX) design.



Manpower:

Sanghoon Lim (postdoc), Darren McGlinchey (postdoc), Xuan Li (staff)

sPHENIX Tracking Overview

3 layer MAPS Vertex Detector (MVTX):

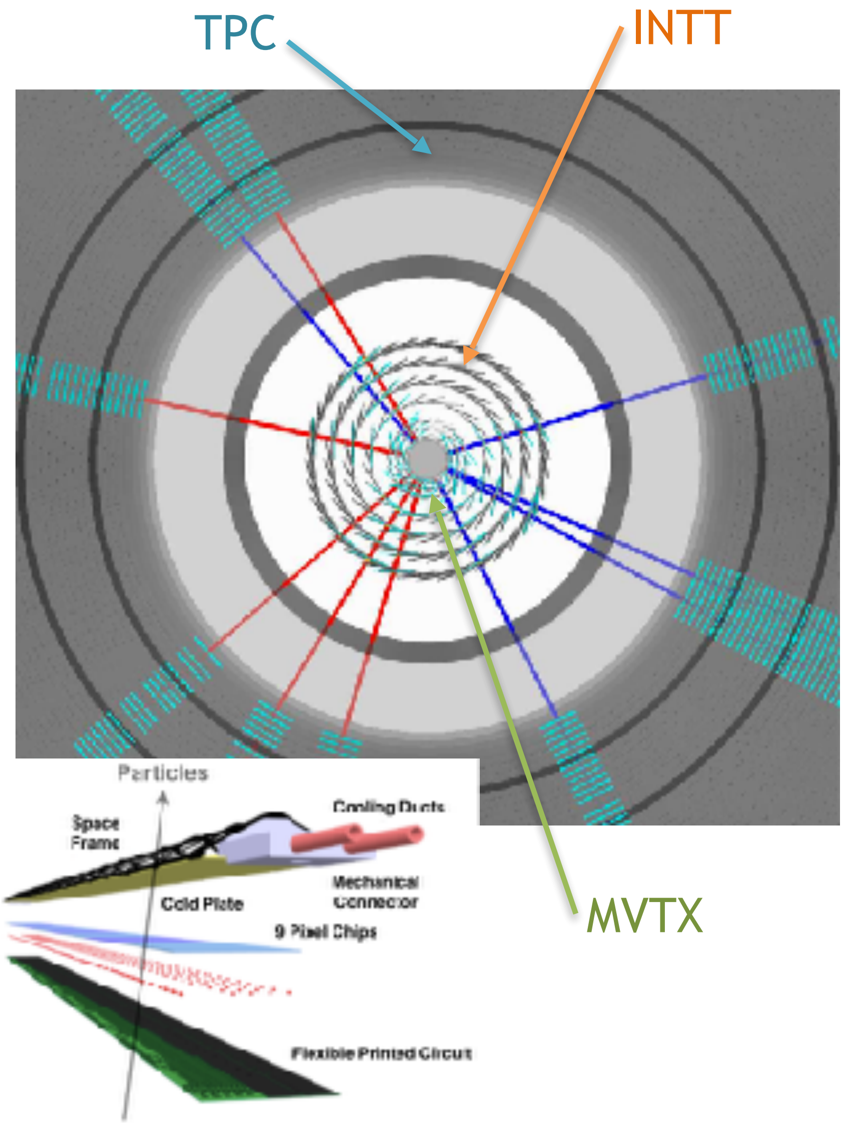
- R = 2.3, 3.2, 3.9 cm
- Thickness: 50 μm (0.3% X_0) per layer
- Cell dimension: 28 μm x 28 μm
- *Using realistic detector geometry*

4 layer Intermediate Silicon Strip Tracker (INTT):

- R = 6, 8, 10, 12 cm
- *Using realistic detector geometry*

40 layer Time Projection Chamber (TPC):

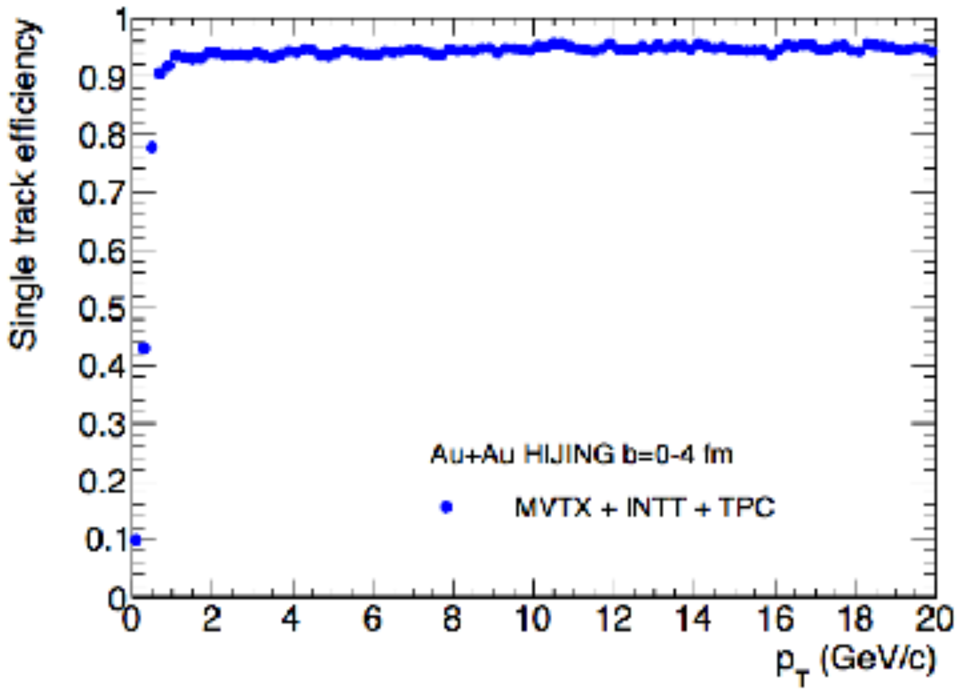
- R = 20 (40) — 80 cm



Progress highlight:

- **Detailed stave geometry imported and used in all tracking studies**

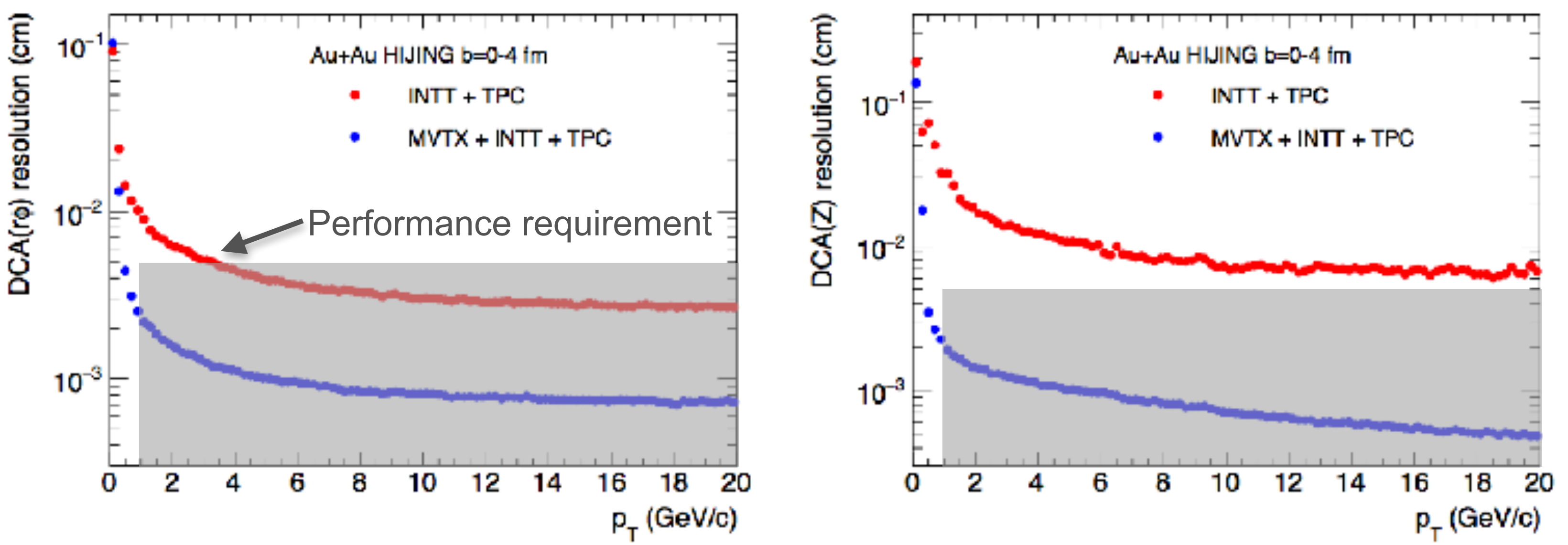
sPHENIX Tracking Performance (I)



Tracking performance:

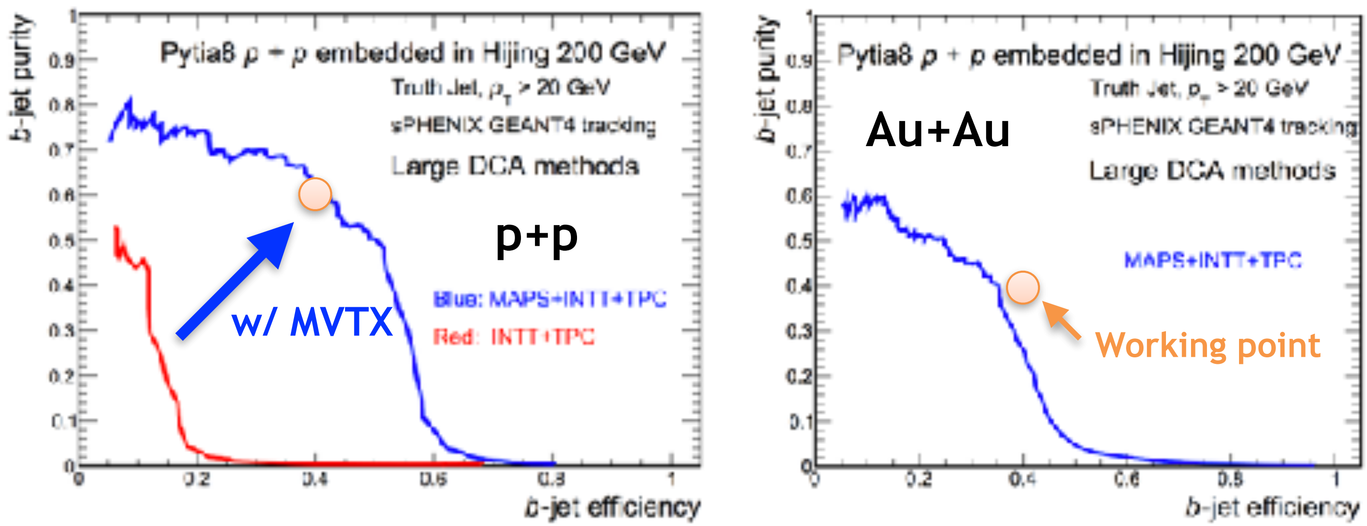
- Simulations of pions embedded in central Au+Au collisions (HIJING)
  - *100% detector efficiency, no event pile-up*
- Hough transform for pattern recognition
- Kalman-filter (GenFit) for track propagation and fitting
- **Single track efficiency ~95%**

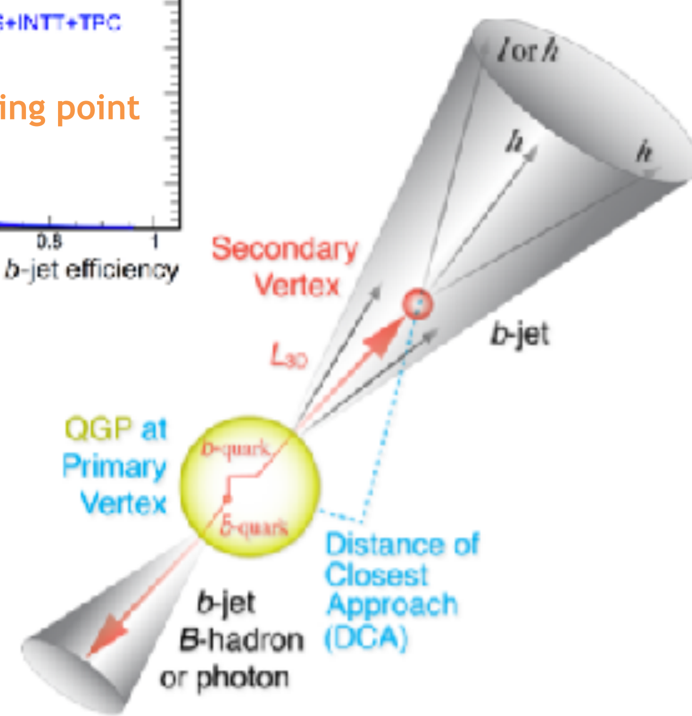
sPHENIX Tracking Performance (II)



Tracking performance:

- Simulations of pions embedded in central Au+Au collisions (HIJING)
  - *100% detector efficiency, no event pile-up*
- Significant improvement in **Distance of Closest Approach (DCA)** resolution with MVTX
- **DCA(rϕ) resolution < 20 μm for p_T > 1 GeV** (target of < 50 μm for p_T > 1 GeV)
- **DCA(z) resolution < 20 μm for p_T > 1 GeV** (target of < 50 μm for p_T > 1 GeV)





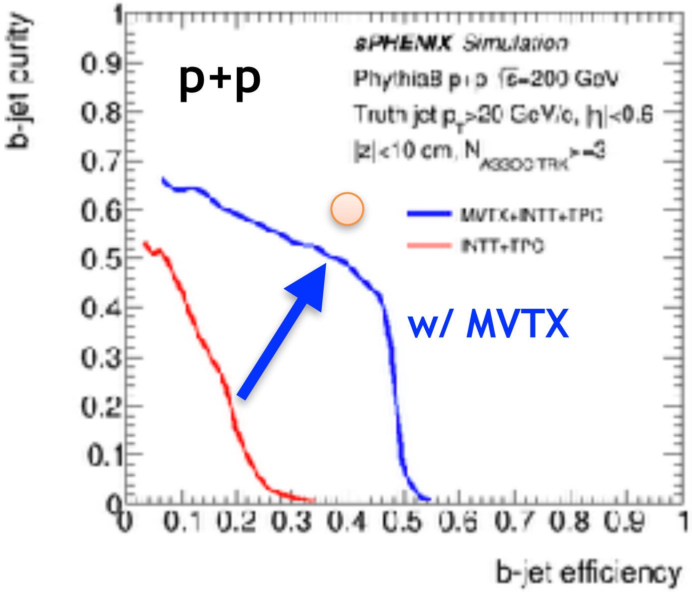
Algorithm I:

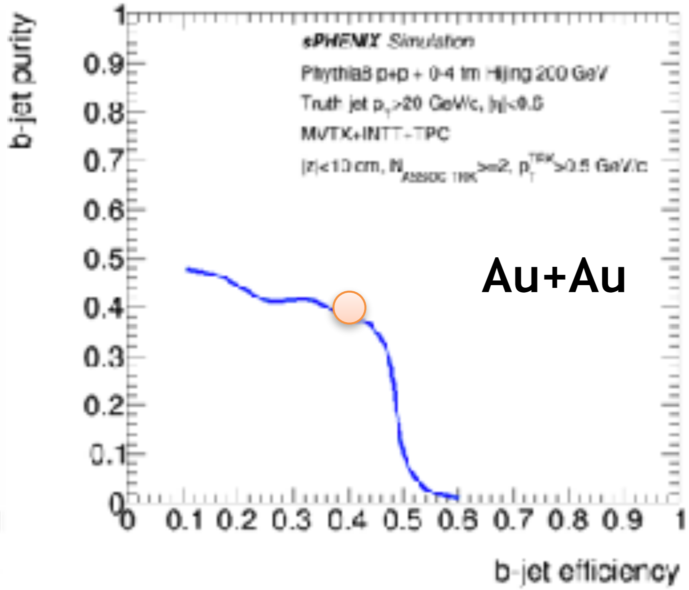
- Utilize Distance of Closest Approach (DCA)
- Count the number of tracks in the jet with DCA larger than your cut
- **Full Geant-4 simulation of p+p (pythia 8) and central Au+Au (Hijing) + reconstruction & tracking software**
- *No pile-up included (under development)*

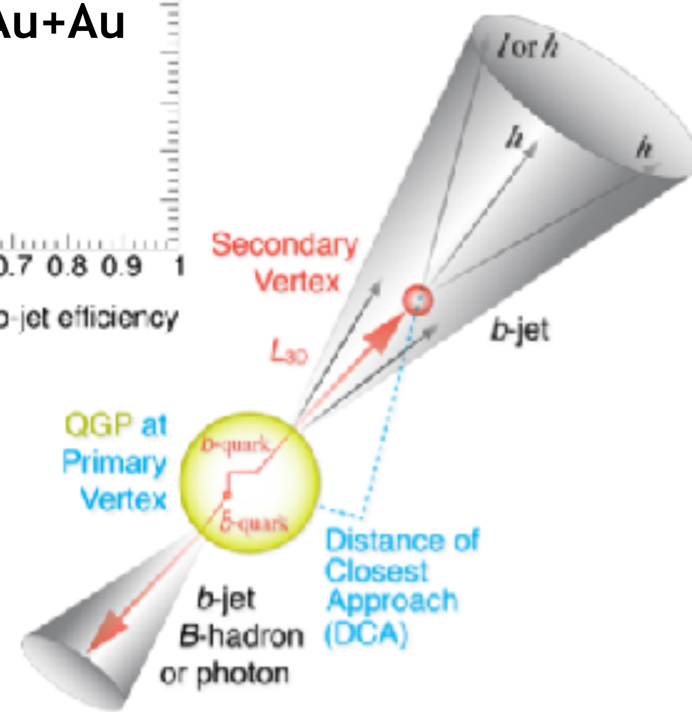
Progress highlight:

- **Algorithm successfully tested in p+p and Au+Au collisions!**

b-jet Tagging: Algorithm II







Algorithm II:

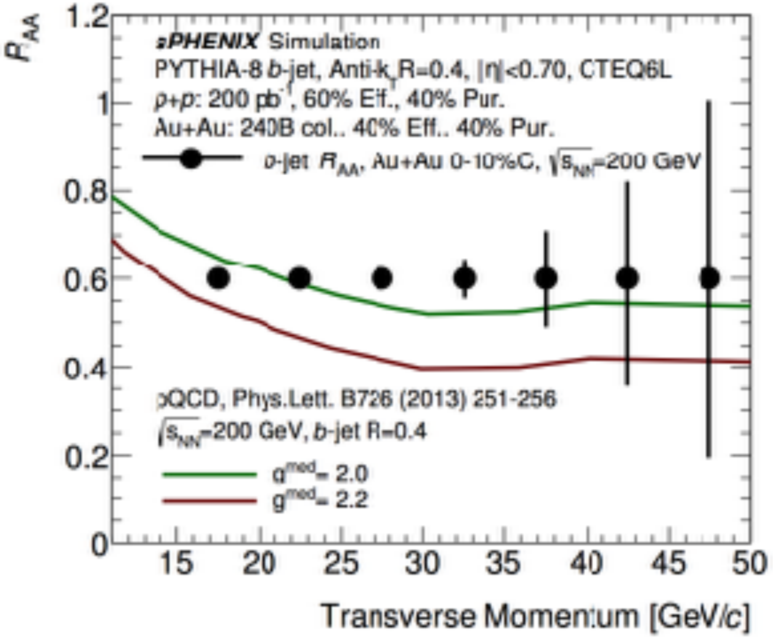
- Utilize **Secondary Vertex** reconstruction
- Reconstruct secondary vertex & require ≥ 2 tracks associated with it
- **Full Geant-4 simulation of p+p (pythia 8) and Au+Au (Hijing) + reconstruction & tracking software**
- *No pile-up included (under development)*

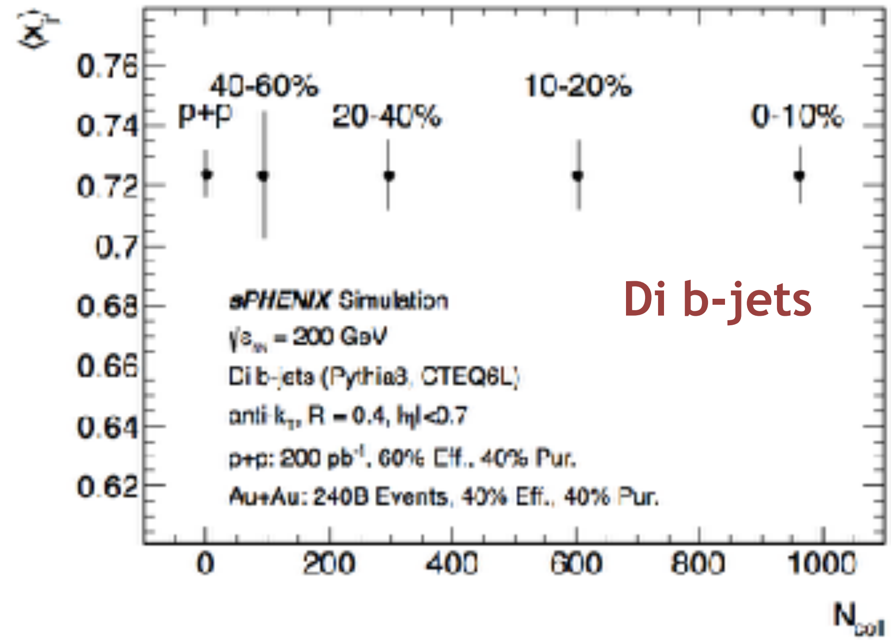
Progress highlight:

- **Algorithm successfully tested in p+p and Au+Au collisions!**

b-jet: Physics Projections

Performance projections included in MVTX proposal submitted to DOE





$$R_{AA} = \frac{\text{Yield in Au + Au}}{N_{Coll} \times \text{Yield in p + p}}$$

$$x_j = \frac{p_T^A - p_T^B}{p_T^A + p_T^B} = (\text{Momentum imbalance})$$

Progress highlight:

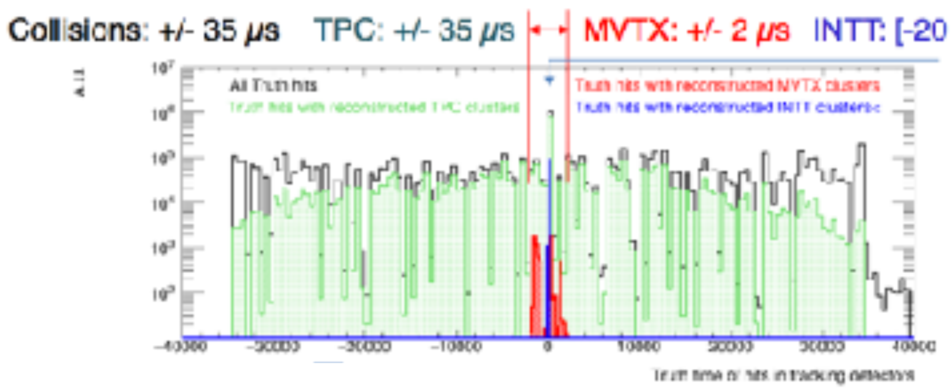
- **Full physics projections included in proposal!**

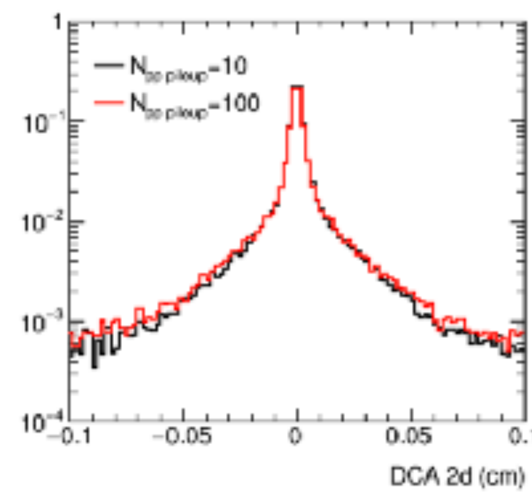
Improving Realism: Event pile-up

Detector	Integration window [μs]	p+p [13 MHz]	Au+Au [200 kHz]
MVTX	[-5.0, +5.0]	130 (<<1% occ)	2 (<<1% occ)
INTT	[-0.02,+0.08]	1	1
TPC	[-35, +35]	910	14 (~35% occ)

Event pile-up:

- With high luminosity, expect multiple collisions per trigger due to integration times
- Largest effect in the Time Projection Chamber (TPC)
- Now have a full framework to test this in simulations (as of ~Nov 2017)
- Working on improving tracking algorithms to mitigate effect

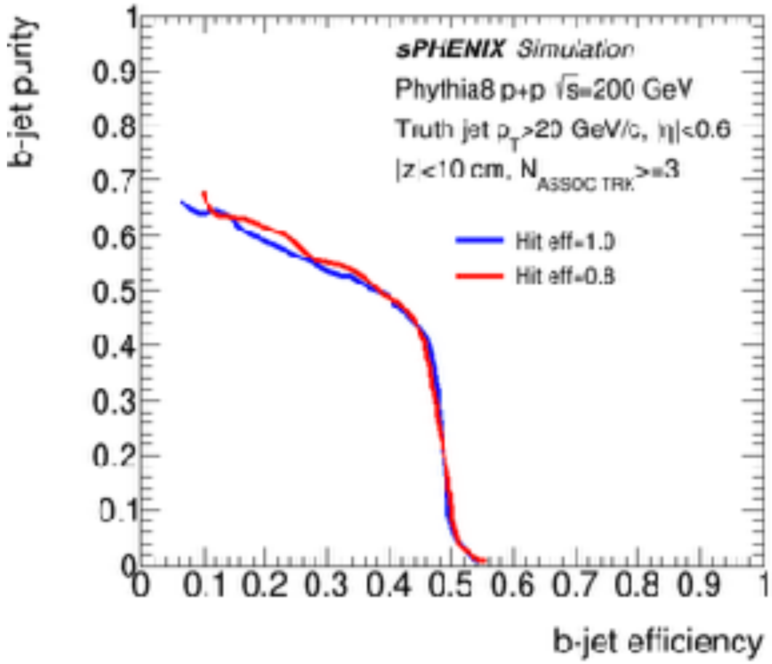




Goal for 2018:

- **Test pile-up effect on b-jet performance**

Improving Realism: Detector efficiency & alignment



Detector efficiency:

- Current efficiency studies test effect of random hit inefficiency
- 80% hit (channel) efficiency → little degradation in b-jet tagging efficiency & purity
- Need to test effect of dead chips & ladders on b-jet performance

Goal for 2018:

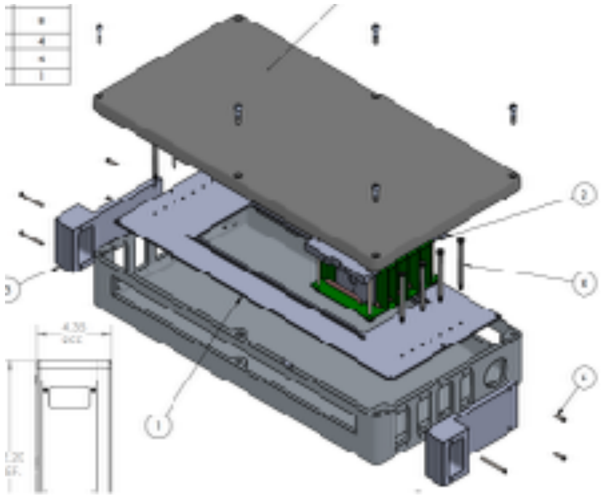
- **Provide framework for detailed eff studies**

Detector alignment:

- Currently assume perfect detector alignment
- Detector misalignment can worsen DCA resolution
- Add ability to mis-align detector between simulation & reconstruction stages
- Develop method for aligning the detector in real data
- The group has significant experience from PHENIX silicon detectors

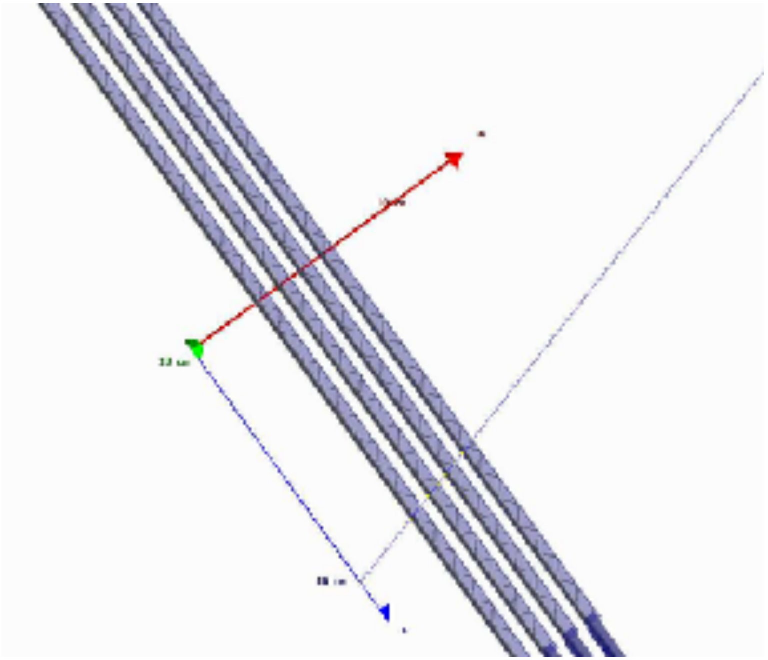
Goal for 2019:

- **Provide sPHENIX MVTX alignment procedure**



MVTX Prototype:

- Key deliverable of LDRD is 4 stave (or chip) telescope for cosmic ray & beam test studies
- Discussed in detail later by Sho Uemura



Software & simulation goals:

- Use the same software for simulation & data reconstruction
- Validate charge sharing in simulations
- Test alignment procedure

Goal for 2018:

- **Validate charge sharing in simulations using real data**

Summary

Deliverable:

Develop the software framework necessary for validation of the MVTX design.

Progress:

- **Simulations now include realistic detector geometry**
- **B-jet tagging performance studied in both p+p and Au+Au using two methods**
  - **p+p: 60% efficiency, 40% purity**
  - **Au+Au: 40% efficiency, 40% purity**
  - ***(assumes 100% detector efficiency and no event pile-up)***
- **Provided physics projections for b-jet R_{AA} in MVTX proposal**
  - ***We also have physics projections for other observables, b-jets highilighted here.***

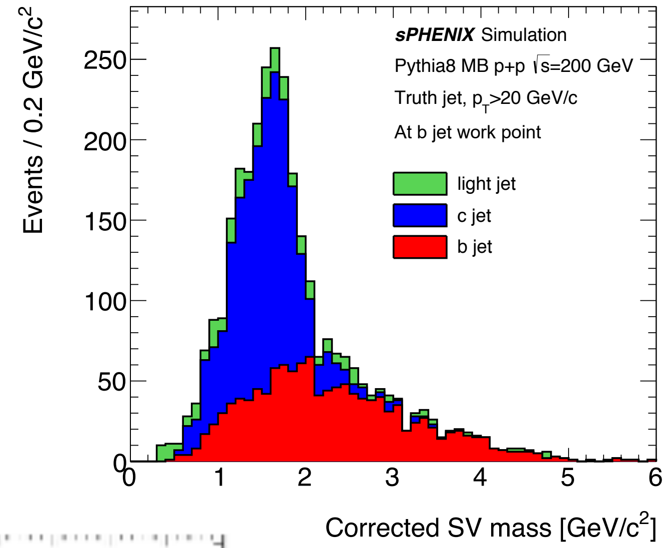
Goals for 2018-2019:

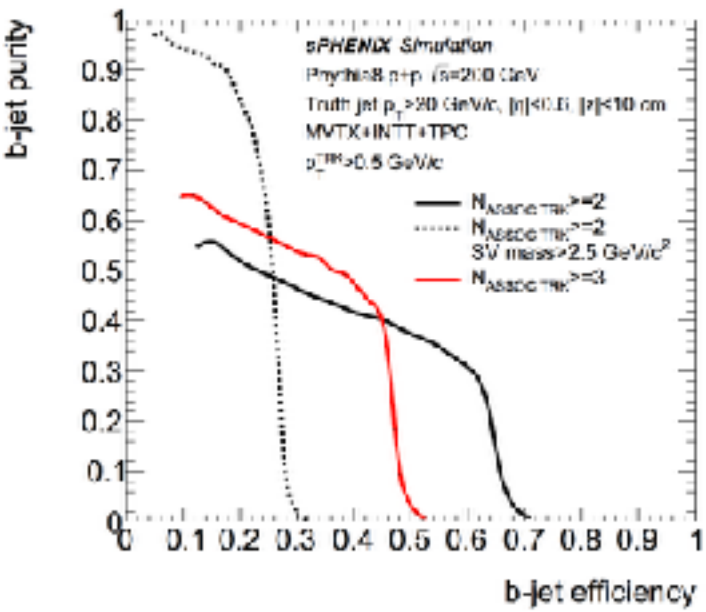
- **[2018] Test pile-up effect on b-jet performance**
- **[2018] Make detailed efficiency studies**
- **[2018] Validate charge sharing in simulations using MVTX prototype data**
- **[2019] Provide sPHENIX MVTX alignment software and procedure (tested on MVTX prototype data)**

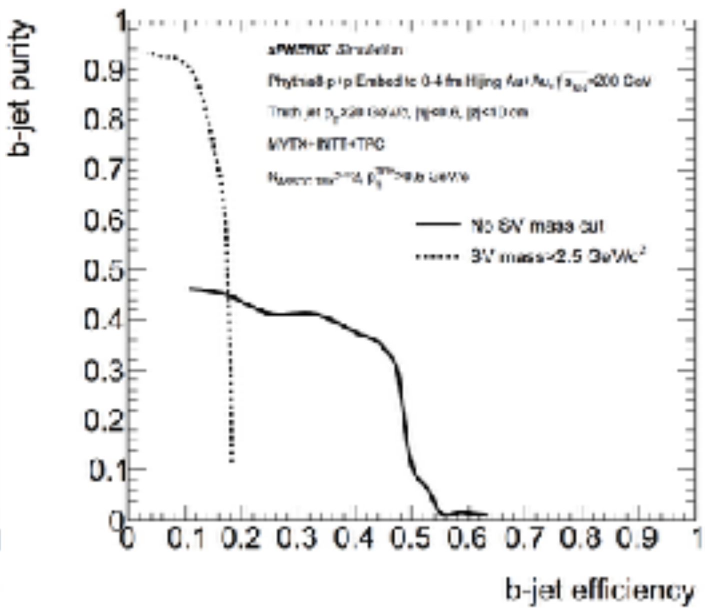
Backup: SV Mass

Using the secondary vertex mass:

- The corrected secondary vertex mass can help distinguish between light-, c-, and b-jets
- Adding a cut on the SV mass can drastically increase b-jet purity at the expense of efficiency







Backup: MVTX Projections