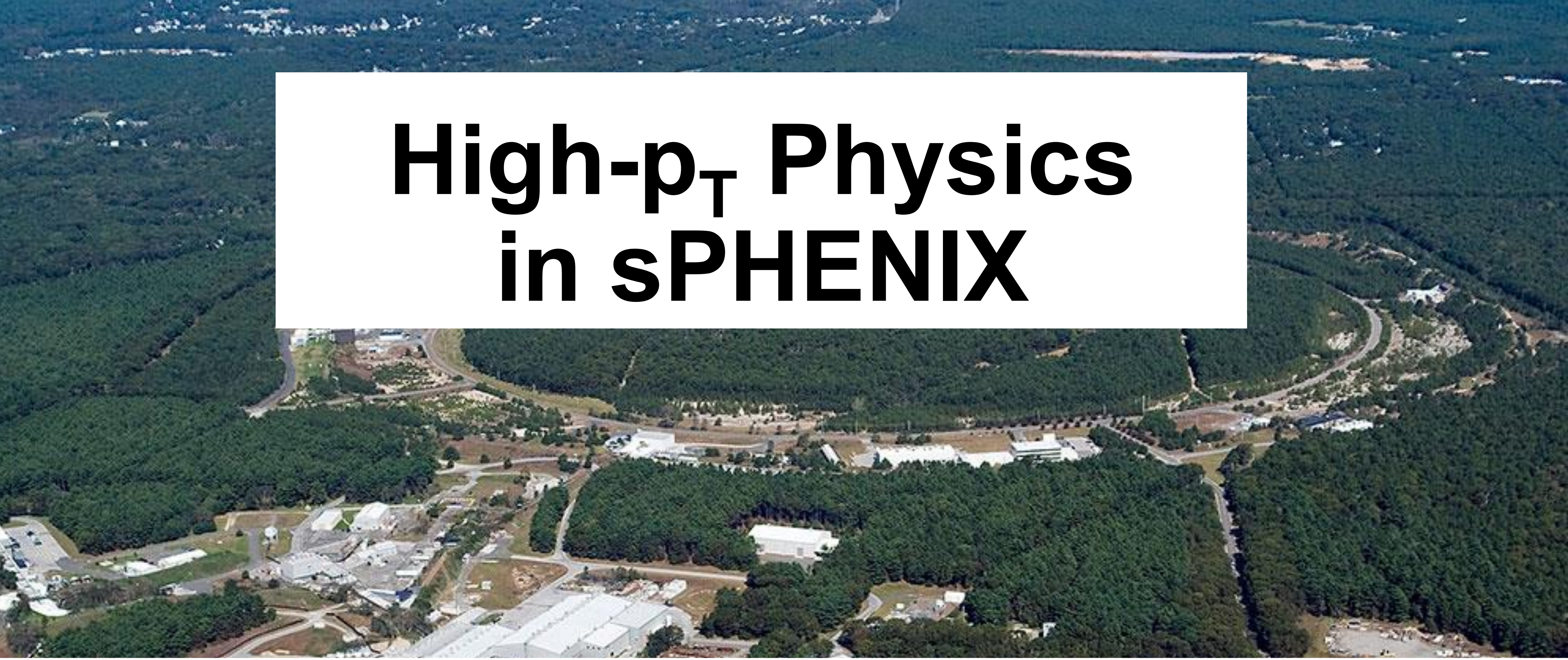


High-p_T Physics in sPHENIX

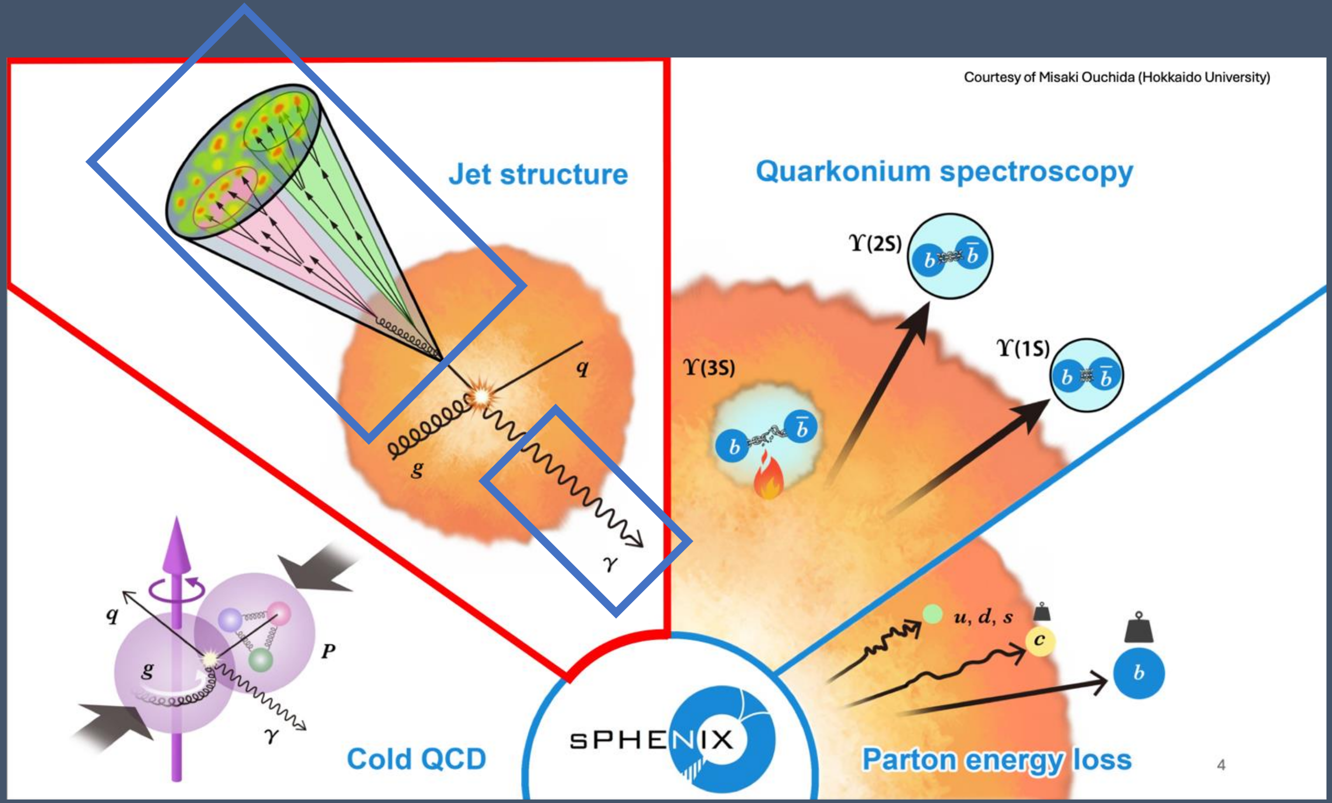
Daniel Lis, University of Colorado Boulder
on behalf of the sPHENIX Collaboration

sPHENIX Physics Program

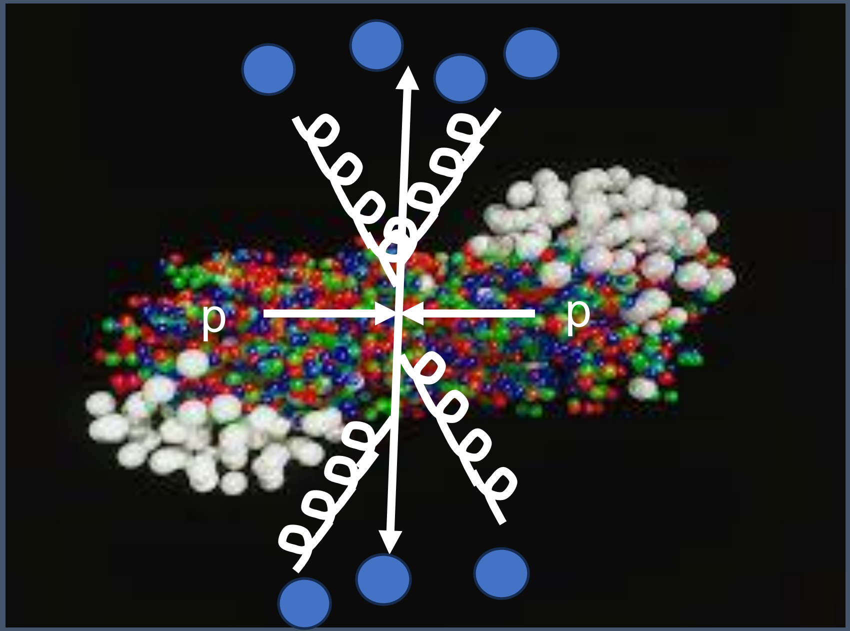
sPHENIX was designed with 4 core physics programs in mind

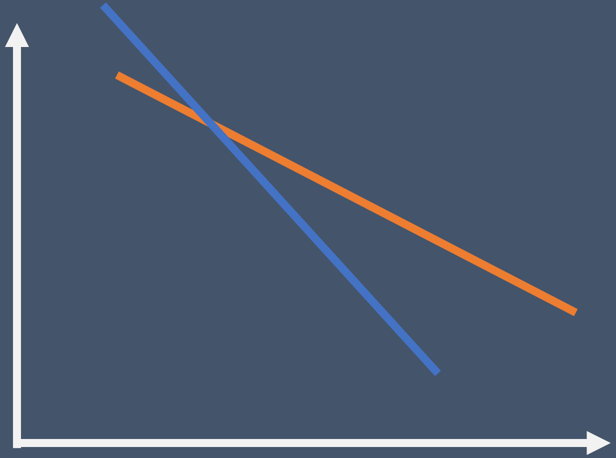
This talk presents a holistic look at the jet and photon physics program

From the motivations, detector and trigger design, calibration and understanding of our detector, ending with jet and photon results from last years p+p run



High p_T probes at RHIC





Jets at RHIC:

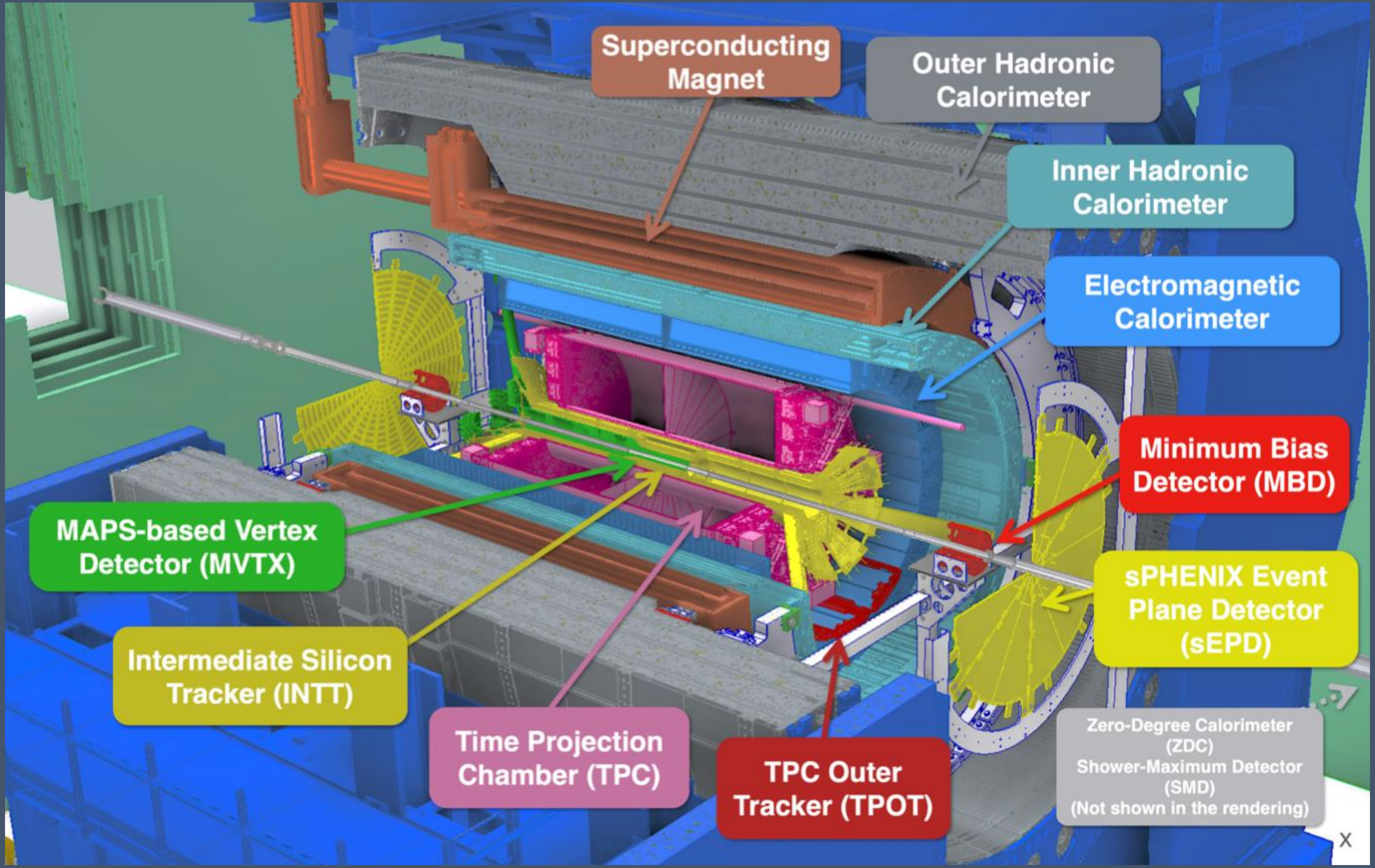
- Steeper p_T spectrum
- Larger quark fraction in jet production
- Probed length scales are more adequately matched to the QGP scale

Isolated Photons:

- Majority are produced in hard-scattering
- Unmodified by QGP

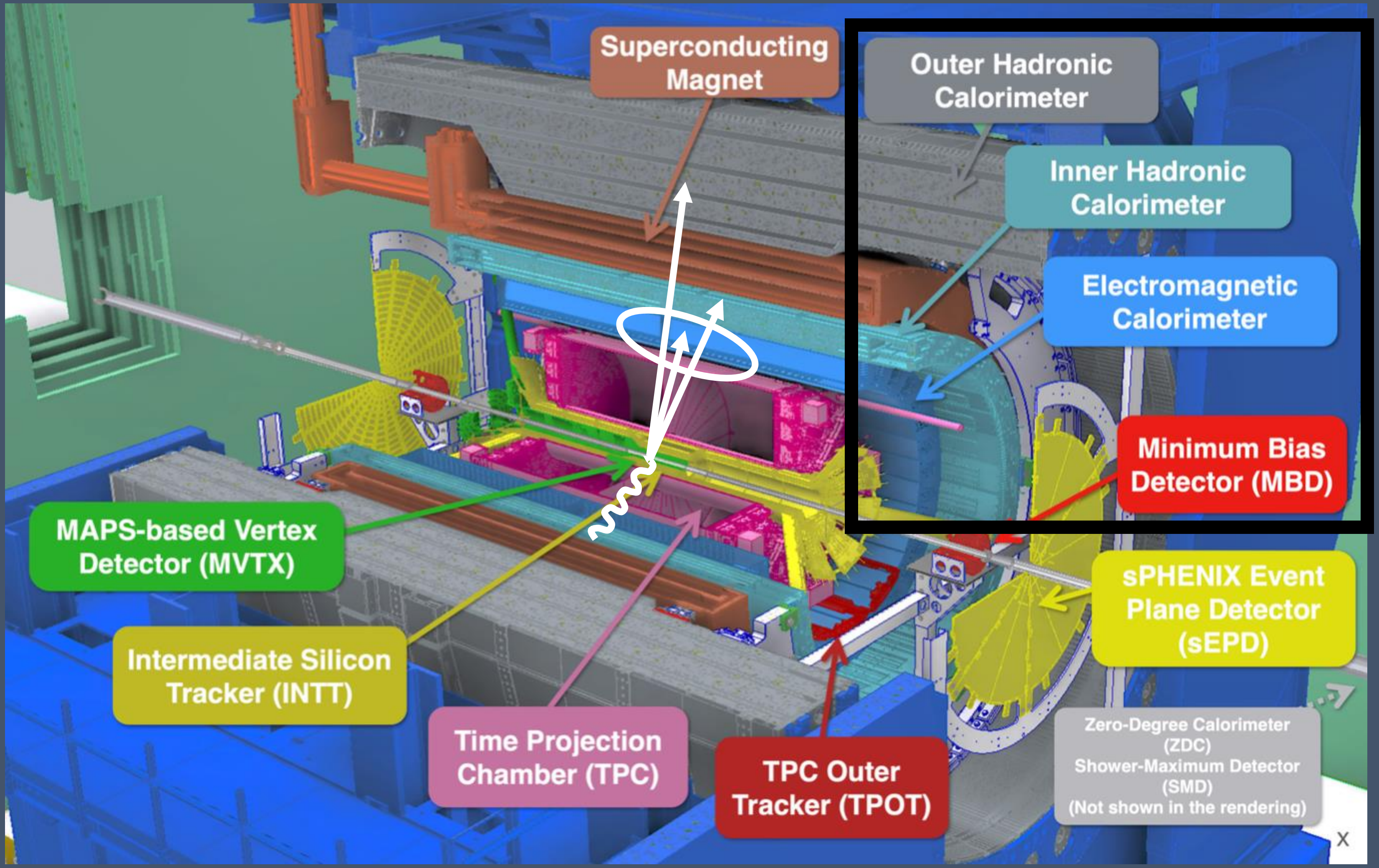
How did we build a detector and optimize it for measuring jets and photons at RHIC energies?

The sPHENIX detector



- Silicon tracking for vertex determination (HF physics)
- TPC and TPOT gas detectors for high momentum resolution
- Electromagnetic and Hadronic calorimetry
- MBD and sEPD for event classification

The sPHENIX detector



For these first measurements:

Photons:
Clusters are built from EMCAL towers

Jets:
anti-k_t R=0.4 jets are clustered with calorimeter towers in the EMCAL, IHCAL, and OHCAL.

First mid-rapidity hadronic calorimeter at RHIC, accessing the neutral hadron component of jets

MBD is used for vertex determination

sPHENIX Calorimeter System

Covers $-1.1 < \eta < 1.1$ and a full 2π in azimuth

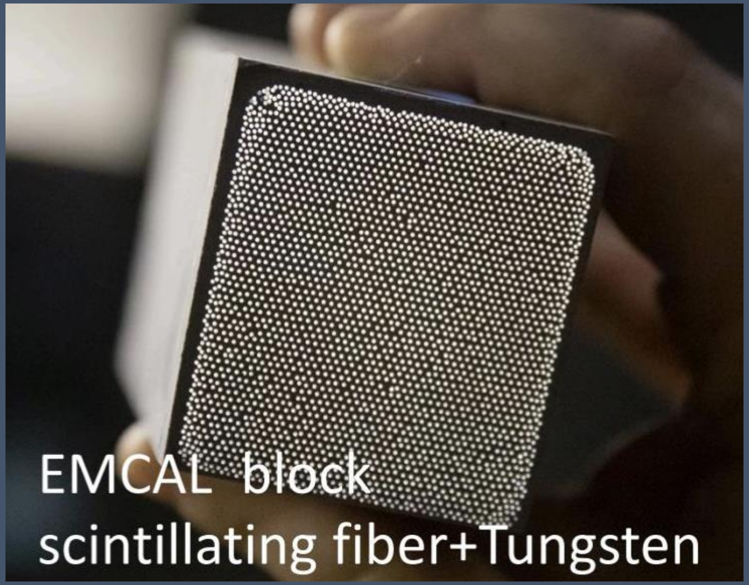
- With a 20 GeV jet, we reconstruct the other dijet 60% of the time
- At 40 GeV, this is at about 90% of the time

EMCAL

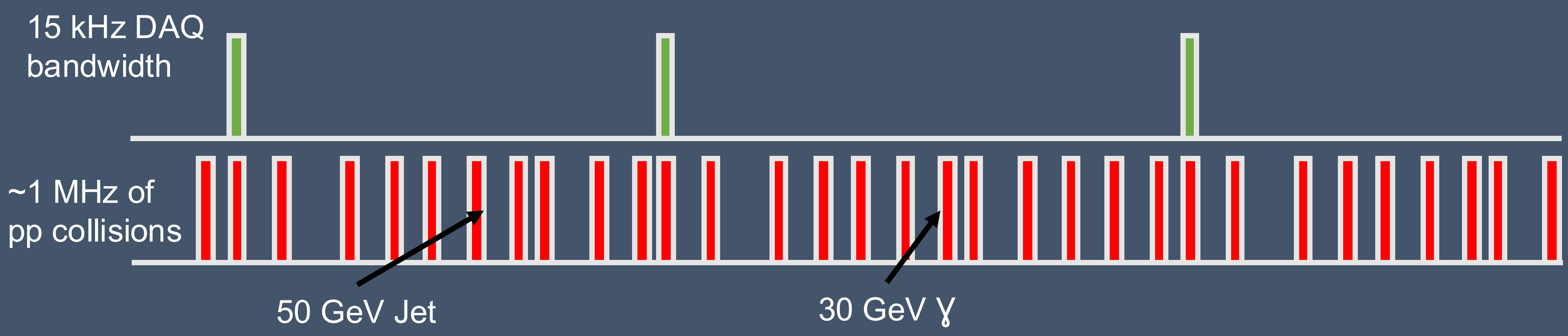
- 0.025 x 0.025 in $\Delta\eta \times \Delta\phi$
  - about the size of 1 Molière radius
- 20 X_0 radiation length and about 1 interaction length

IHCAL/OHCAL

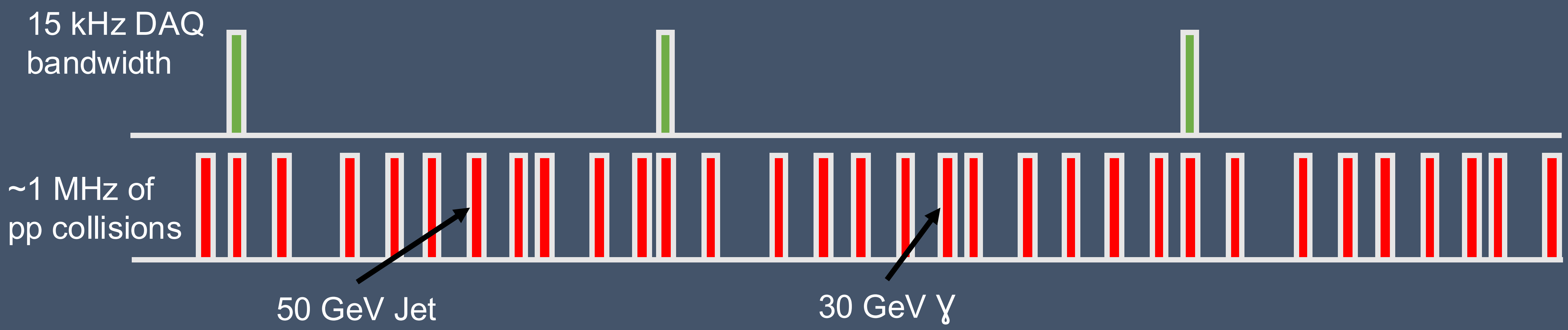
- 0.1 x 0.1 in $\Delta\eta \times \Delta\phi$
- About 5 interaction lengths in total



sPHENIX Rare-probes Trigger System

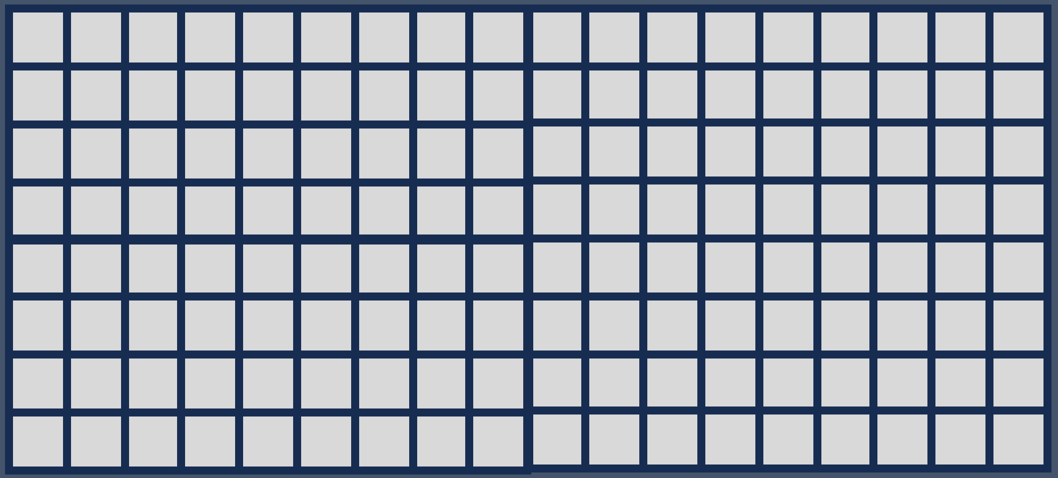


sPHENIX Rare-probes Trigger System



Add signal in 0.2 x 0.2 $\Delta\eta \times \Delta\phi$ grid of towers in the EMCAL

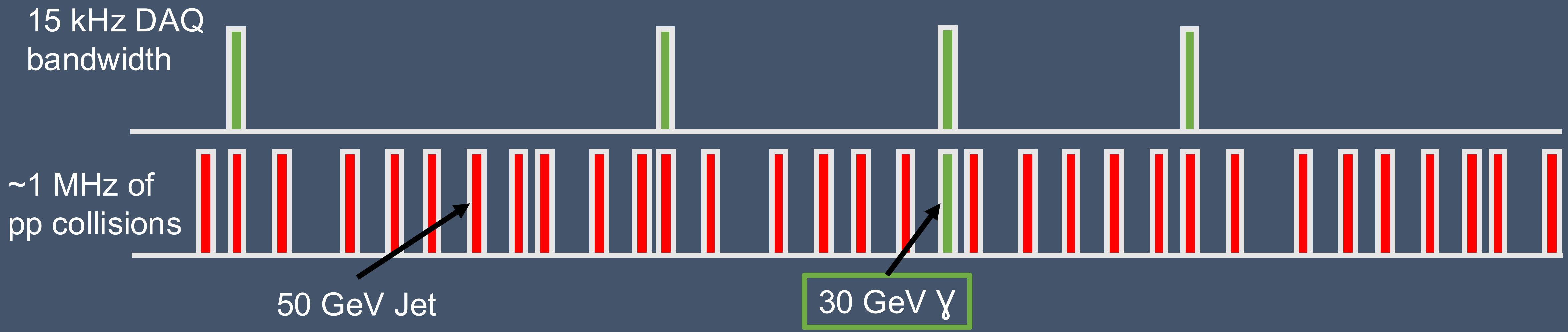
Add signal in 0.2 x 0.2 $\Delta\eta \times \Delta\phi$ grid of towers in I/O HCAL



Monitored hardware level-1 trigger

Sends out trigger to DAQ system in under 4 us

sPHENIX Rare-probes Trigger System



Add signal in 0.2 x 0.2 $\Delta\eta \times \Delta\phi$ grid of towers in the EMCAL

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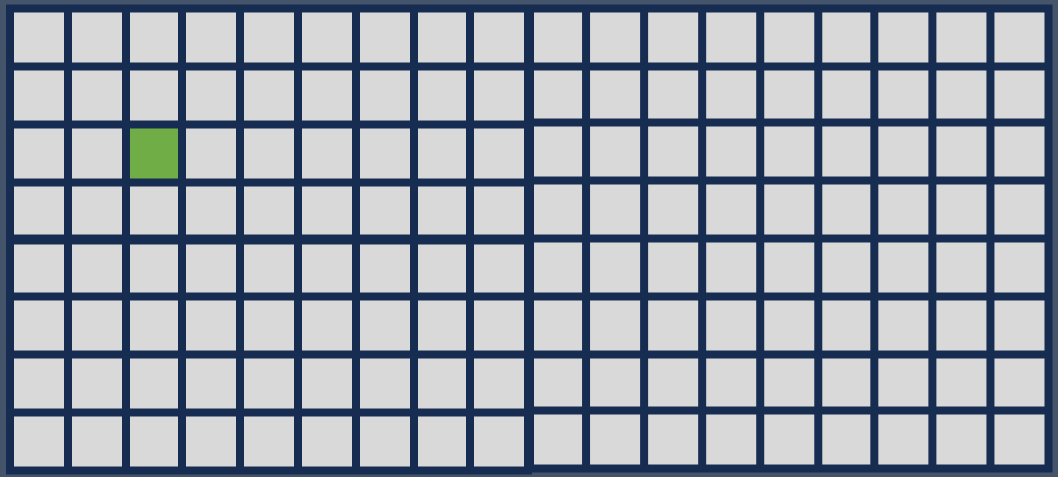
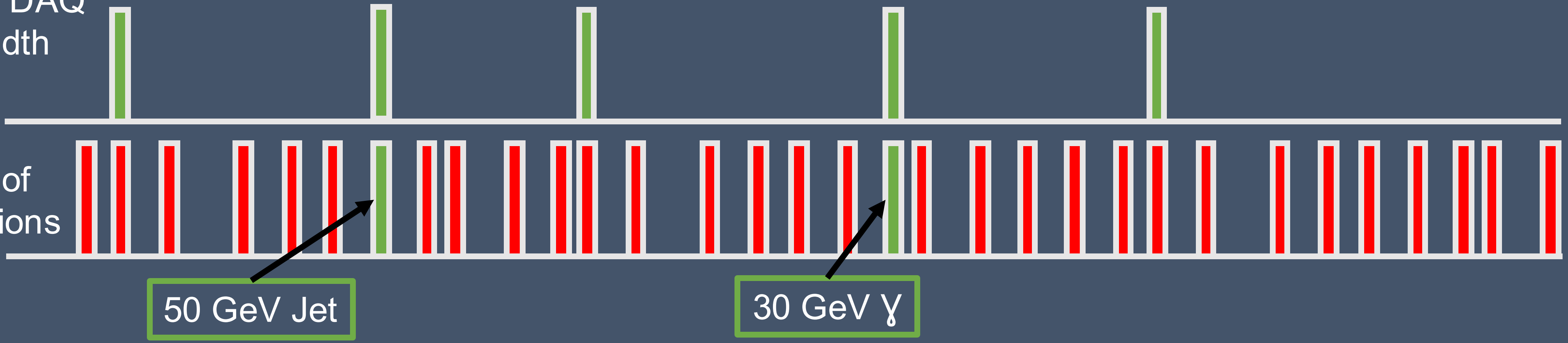


A single, gain balanced EMCAL above threshold satisfies photon trigger condition

sPHENIX Rare-probes Trigger System

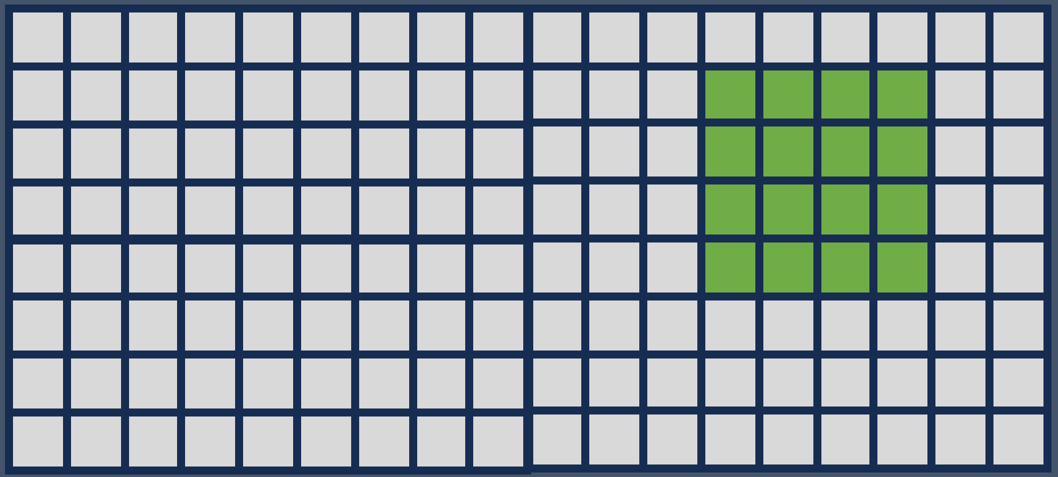
15 kHz DAQ bandwidth

~1 MHz of pp collisions



Add signal in 0.2 x 0.2 $\Delta\eta \times \Delta\phi$ grid of towers in the EMCAL

Add signal in 0.2 x 0.2 $\Delta\eta \times \Delta\phi$ grid of towers in I/O HCAL



0.8 x 0.8 $\Delta\eta \times \Delta\phi$ sliding window (square R=0.4 Jet) in the full calorimeter satisfies jet trigger

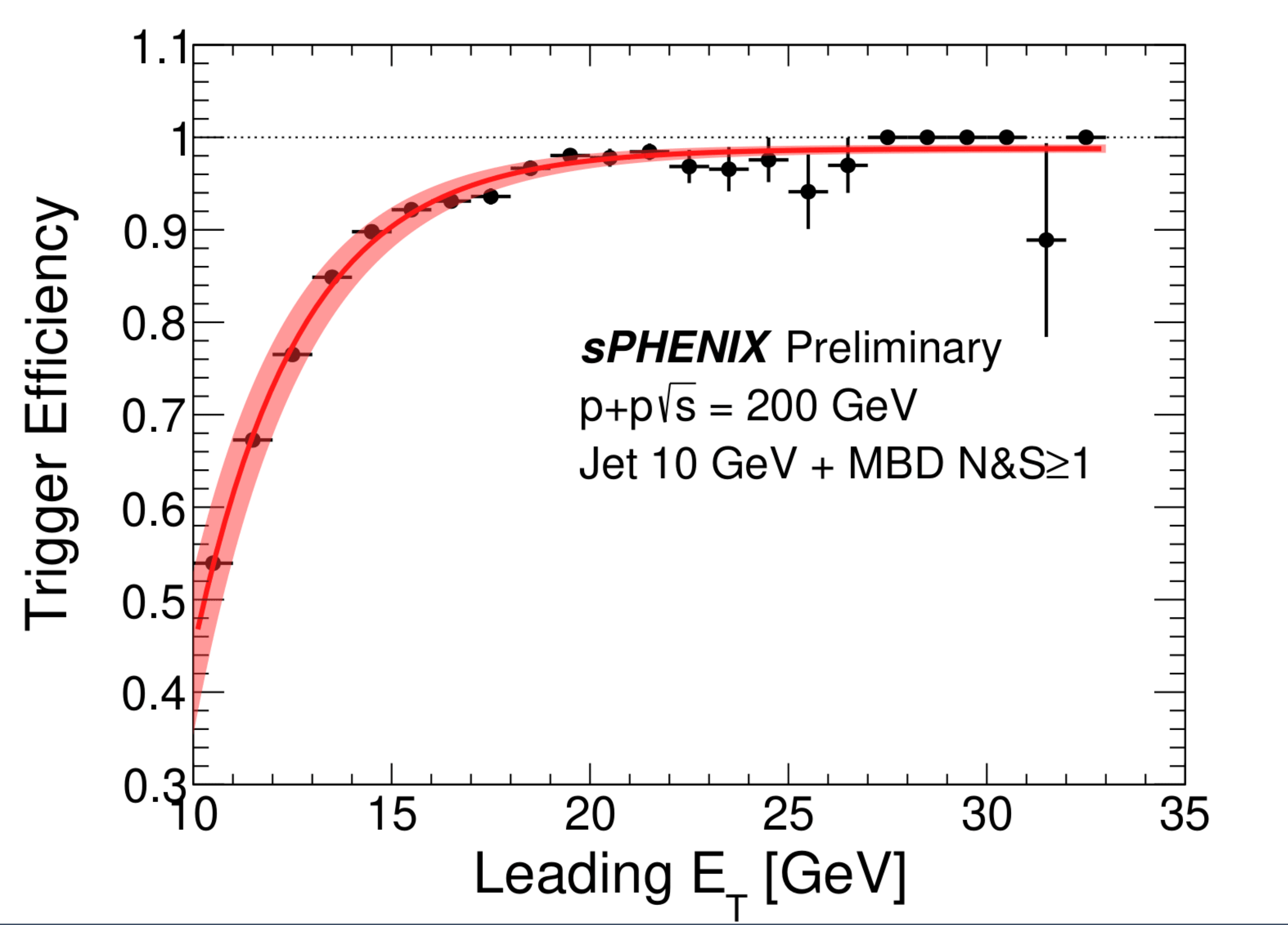
sPHENIX Rare-probes Trigger System

Good performance in jet and photon trigger

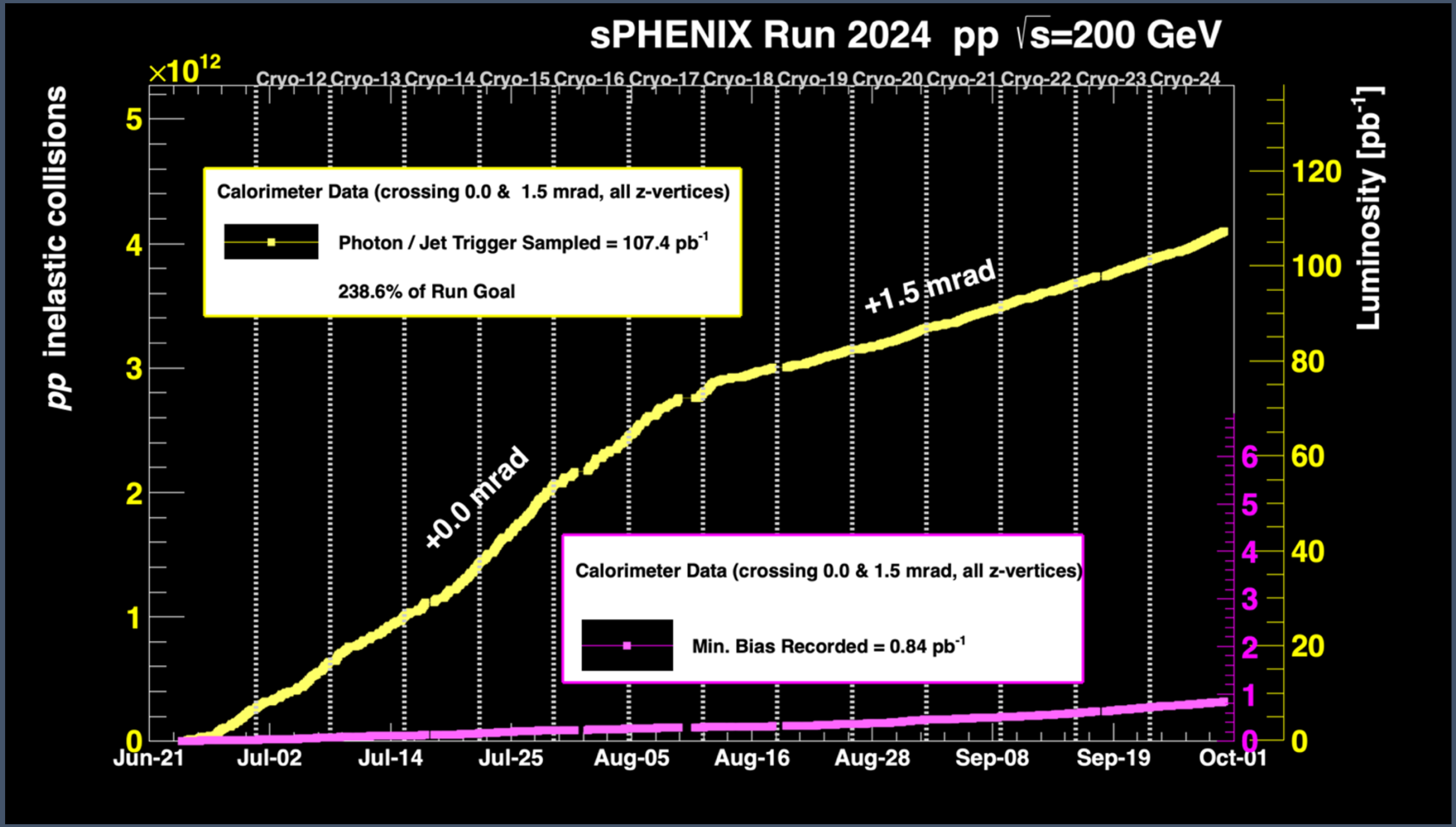
Enables reach into large kinematic range

Data-driven efficiency using min-bias p+p data to characterize all our triggers

- A correction used in all analyses



Run-24 p+p Sampled Luminosity



This allows the sPHENIX experiment to sample the entirety of RHIC's delivered luminosity

Preliminary results (in this talk):

- Isolated photons in p+p 200 GeV
- Inclusive Jets in p+p 200 GeV
- Dijet correlations in p+p 200 GeV

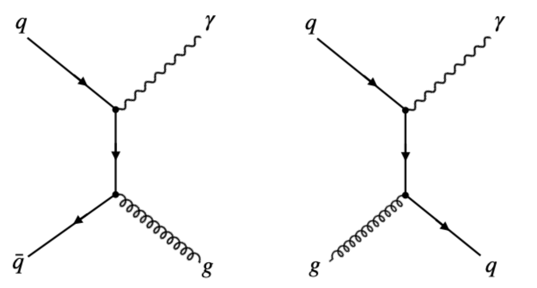
All produced in several months after the end of run-24!

Isolated Photons with sPHENIX

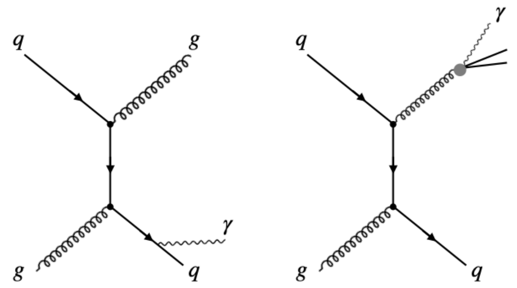
Isolated Photons

Isolated Photons include **most** direct, and include some fragmentation

Direct Photons

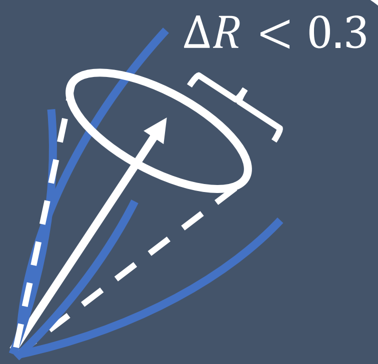


Fragmentation Photons



Isolation Energy E_T^{iso}:

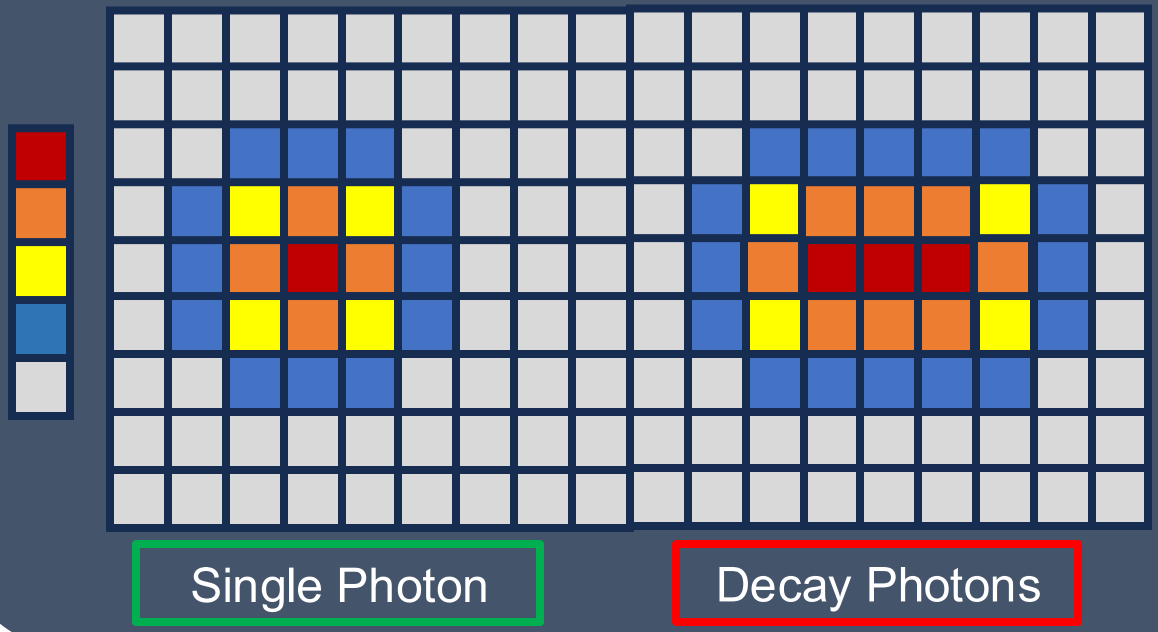
Sum of E_T within $\Delta R < 0.3$ of photon candidate in all calorimeters



Shower-shape variables:

$$w_\eta = \frac{\sum_i E_i(\eta_i - \bar{\eta})}{\sum_i E_i}$$ → Energy weighted 2nd moment of EMCAL cluster

$$E_{t1} = \frac{\sum_i^4 E_i}{E_{clus}}$$ → Core energy fraction



[Conference Note](#)

Isolated Photons

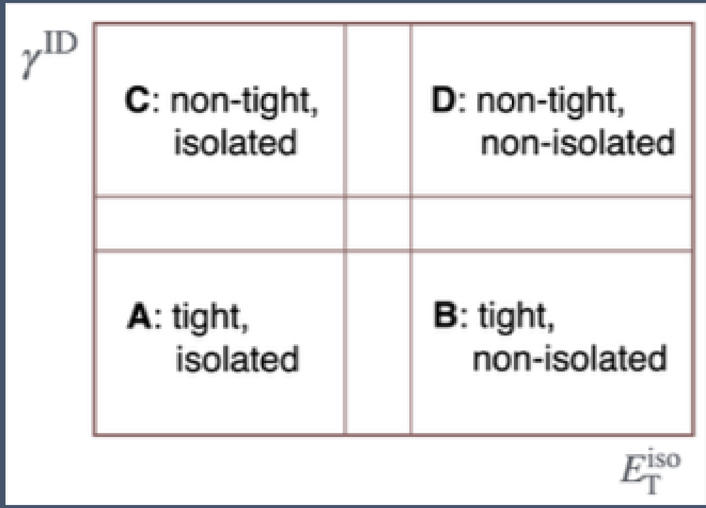
$$N^A_{\text{signal}} = N^A_{\text{raw}} - \left[\left(N^B_{\text{raw}} - f^{B,\text{MC}}\, N^A_{\text{signal}}\right) \frac{\left(N^C_{\text{raw}} - f^{C,\text{MC}}\, N^A_{\text{signal}}\right)}{\left(N^D_{\text{raw}} - f^{D,\text{MC}}\, N^A_{\text{signal}}\right)} \right]$$

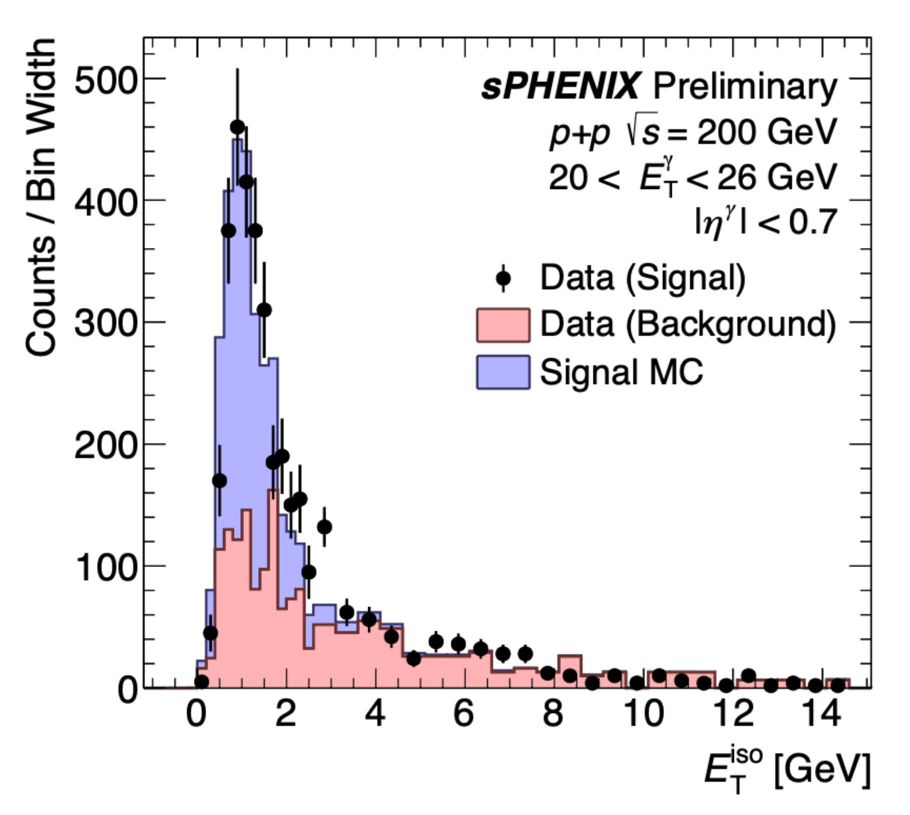
Signal is extracted using 2D sideband method

- Assumes E_T^{iso} distribution is the same

Includes corrections for leakage $f^{X,MC}$

Cuts are optimized for efficiency and purity of signal





Conference Note

Isolated Photons

$$N^A_{\text{signal}} = N^A_{\text{raw}} - \left[\left(N^B_{\text{raw}} - f^{B,\text{MC}} N^A_{\text{signal}} \right) \cdot \frac{\left(N^C_{\text{raw}} - f^{C,\text{MC}} N^A_{\text{signal}} \right)}{\left(N^D_{\text{raw}} - f^{D,\text{MC}} N^A_{\text{signal}} \right)} \right]$$

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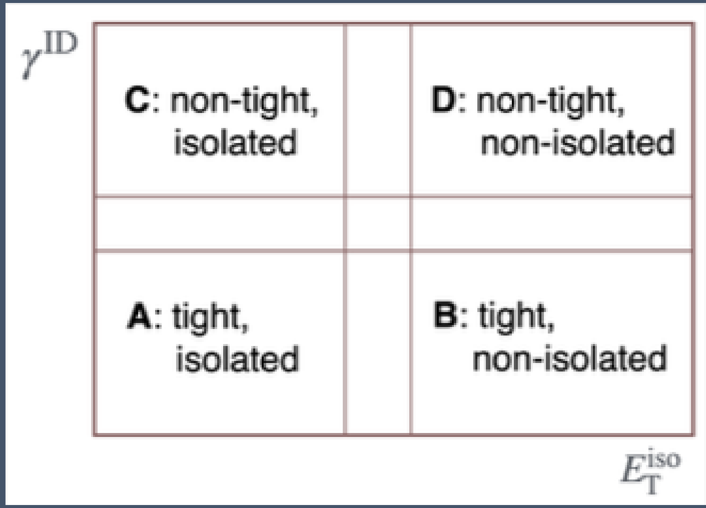
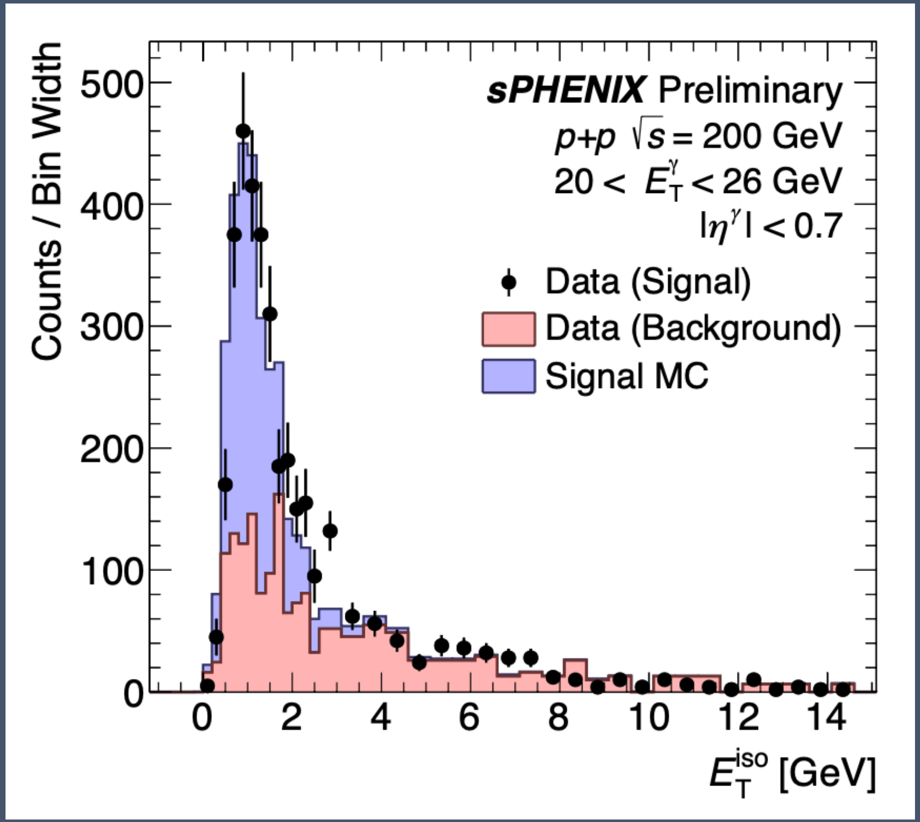




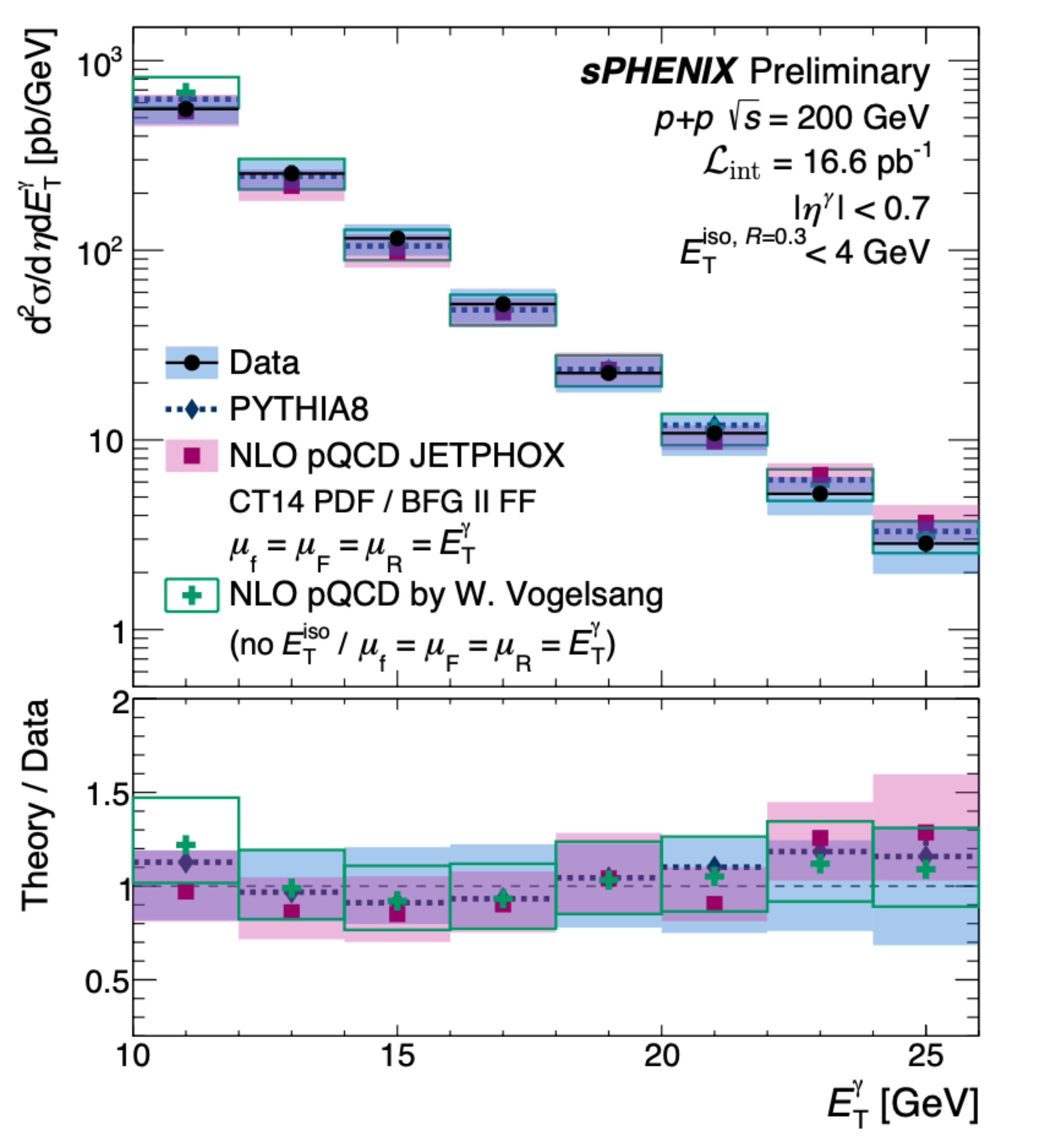
Direct Photon Results

Fully-unfolded isolated photon cross-section

$$\frac{d^2\sigma}{dE_T^\gamma d\eta} = \frac{1}{\mathscr{L}} \frac{Y^{\text{rec}}}{\mathcal{E}\Delta E_T^\gamma \Delta\eta^\gamma},$$

Separation of signal from the background done through 2D sideband method using shower-shape variables and isolation energy in the combined calorimeter system

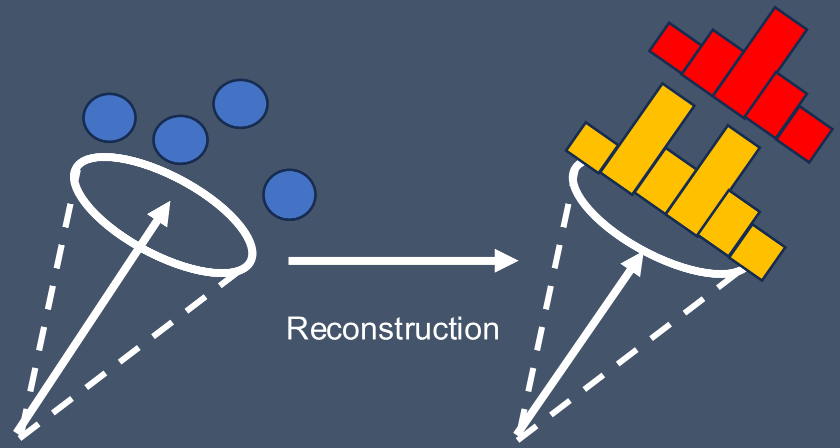
Comparing our spectrum with leading theories and models, consistent within systematic uncertainties

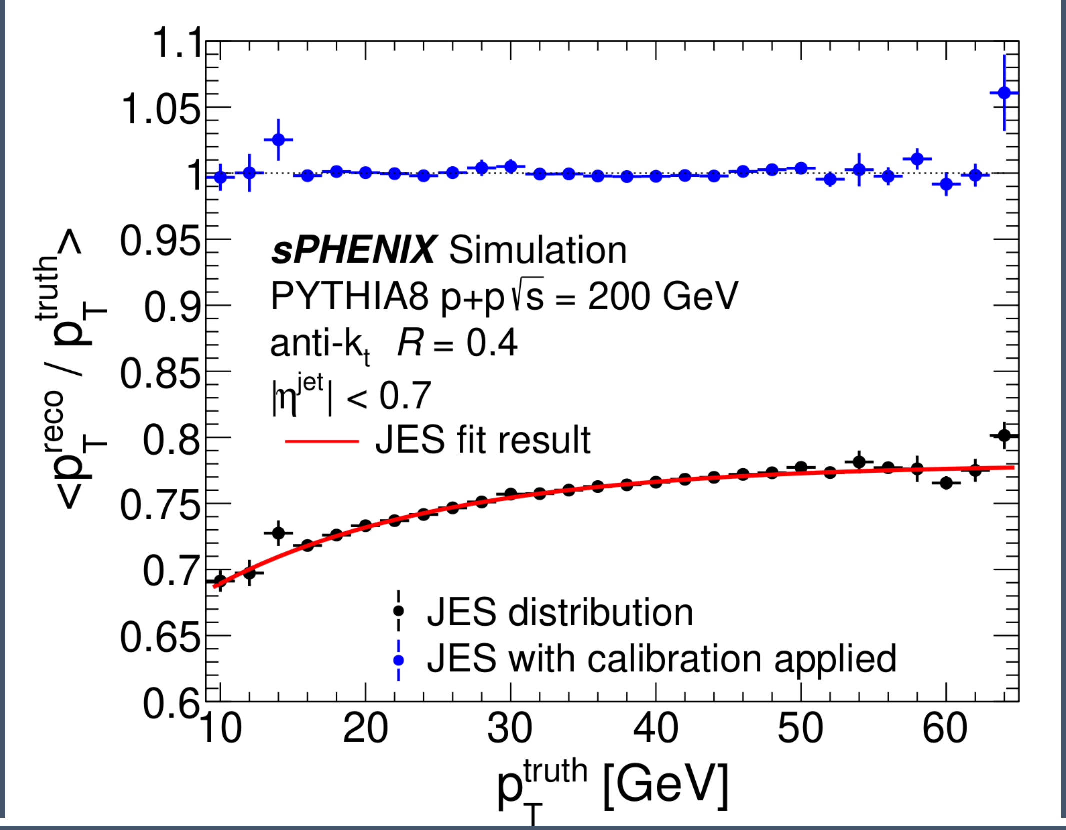


Jets with sPHENIX

How well do we measure Jets at sPHENIX?

Jet Energy Scale:
- Using Pythia8 + GEANT4 simulation to determine the average response of our calorimeters to a truth-level particle jet
- JES is then calibrated so that the average response to a truth-level jet is 1





With the excellent development in photon ID, photon-jets will be used as a data-driven method to characterize our JES

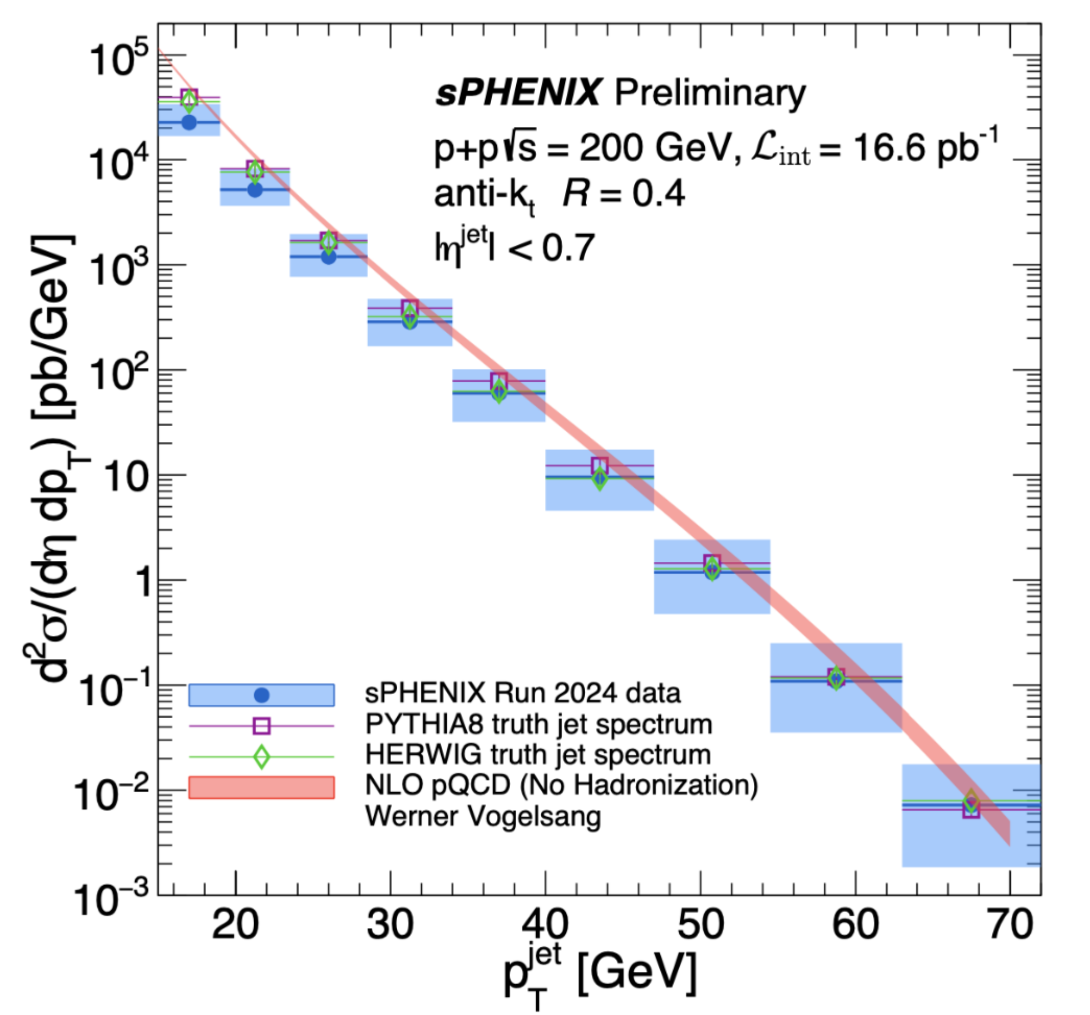
Jets in p+p collisions with sPHENIX

With this basic understanding of our detector, we can begin measuring our first jet observables

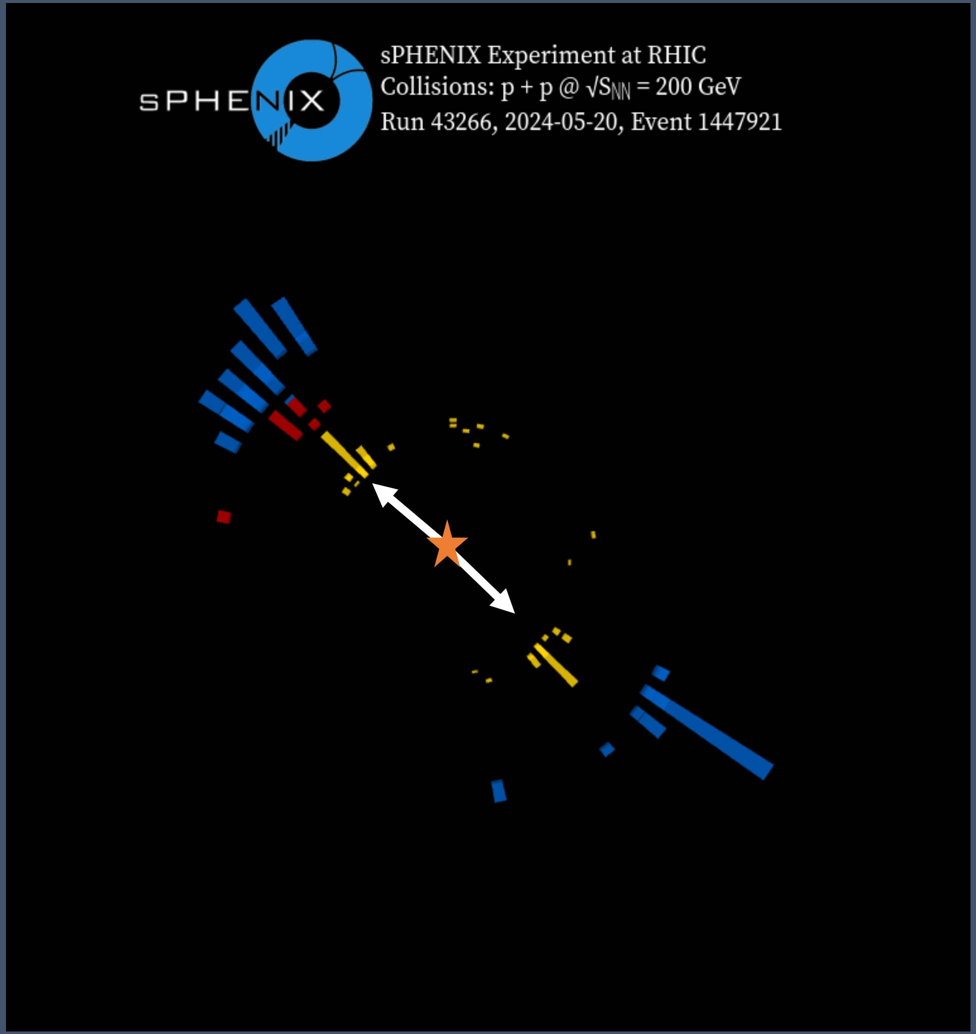
For our preliminary results, we have ~50% uncertainties on the unfolded cross-section

- The dominant uncertainty here is the Jet Energy Scale

With only a fraction of integrated luminosity, our kinematic reach pushes further than what has been measured at RHIC in p+p 200 GeV



Jet Energy Resolution

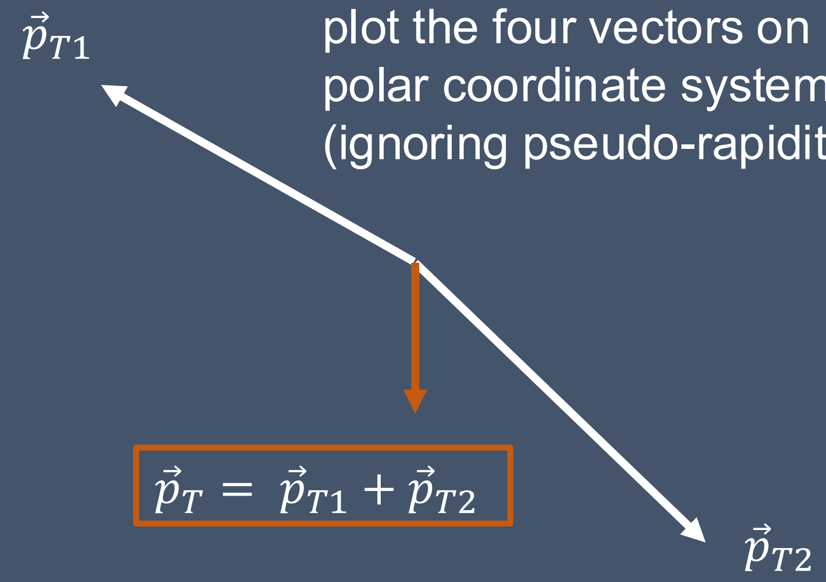


[1]

Need in-situ method of determining JER:

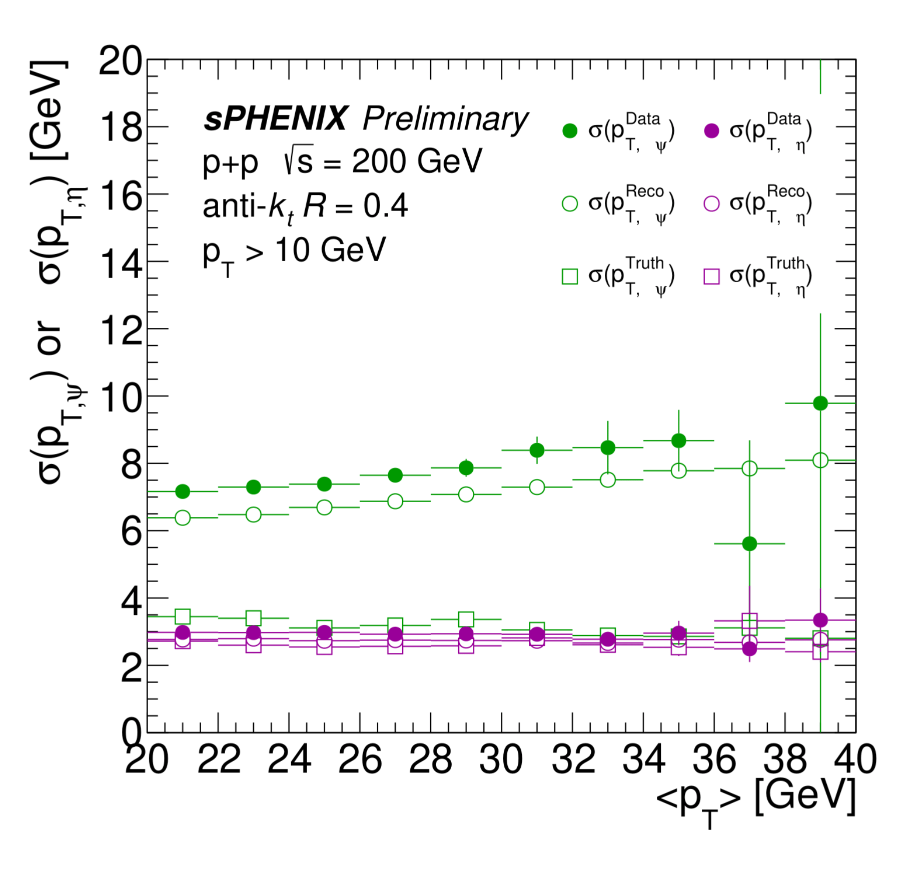
We will use calorimeter dijets!
With the dijet bisector method used by ATLAS [citation]

Take a single dijet event, then plot the four vectors on a 2-D polar coordinate system (ignoring pseudo-rapidity)



$$\vec{p}_T = \vec{p}_{T1} + \vec{p}_{T2}$$

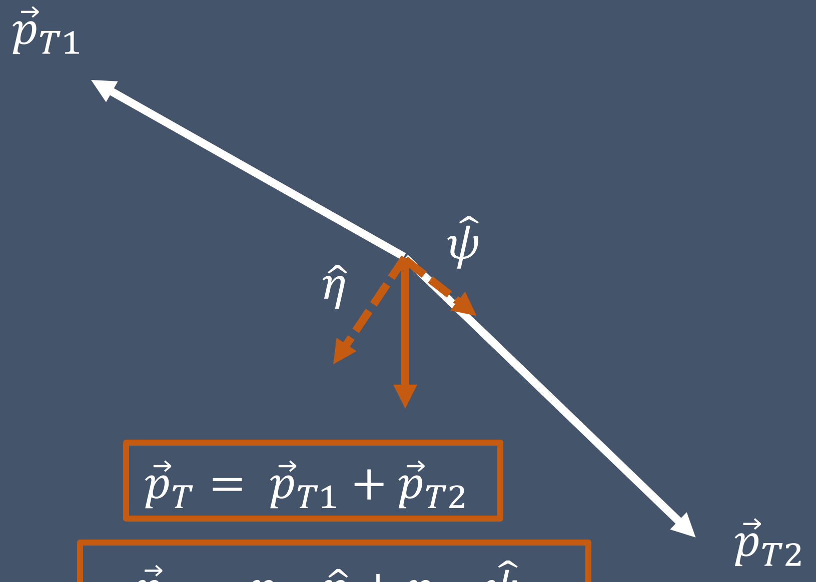
Dijet Bisector Method



$\hat{\eta}$ - direction of $\frac{\Delta\phi}{2}$

$\hat{\psi}$ - direction perpendicular to $\hat{\eta}$

The idea: the width of $p_{T\eta}$ is less sensitive to detector resolution affects than $p_{T\psi}$, but $p_{T\eta}$ and $p_{T\psi}$ are equally sensitive to isotropic initial state radiation



$$\vec{p}_T = \vec{p}_{T1} + \vec{p}_{T2}$$

$$\vec{p}_T = p_{T\eta}\hat{\eta} + p_{T\psi}\hat{\psi}$$

Dijet Bisector Method

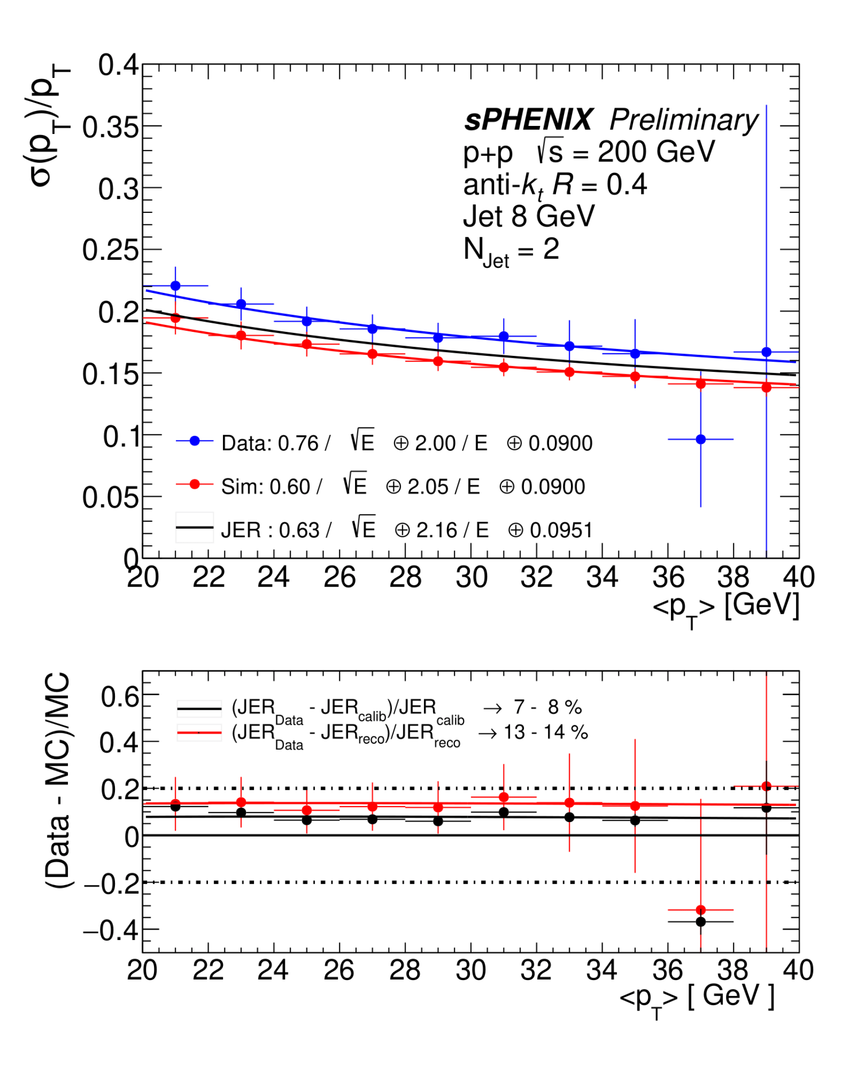
Using the below equation, we can take these two widths of the $p_{T\psi}$ and $p_{T\eta}$ distributions in each $< p_T >$ bin, then calculate $\sigma(p_T)/p_T$

$$\frac{\sigma(p_T)}{p_T} = \frac{\sqrt{\sigma_\psi^{2\ \mathrm{calo}} - \sigma_\eta^{2\ \mathrm{calo}}}}{\sqrt{2}\, p_T \sqrt{\langle|\cos\Delta\phi_{12}|\rangle}}$$

A p_T independent 10% nominal additional smear is chosen with a 5% systematic variation

- From further study, we can reduce these uncertainties

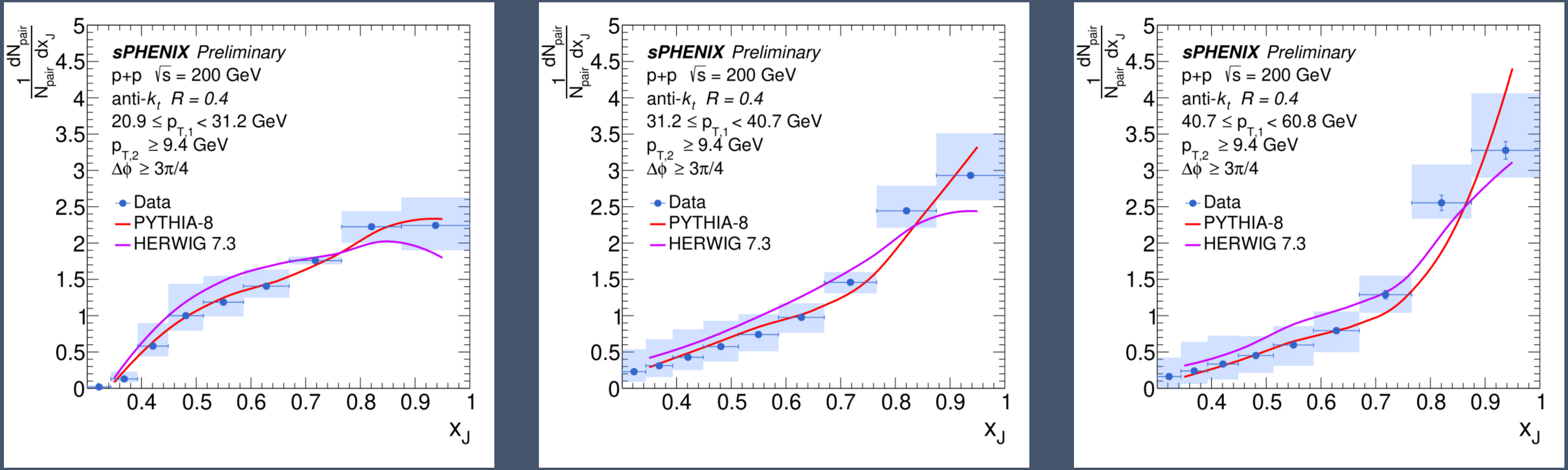
Note: In AuAu collisions, the underlying event is the dominating contribution to the JER, minimizing uncertainty in p+p is essential



Conference Note

Dijet Imbalance

Increasing p_{T1} selections



Unfolded dijet imbalance in pp collisions were measured

The steepness of the distribution is extremely sensitive to the difference between our Geant4 simulation and the data, dominating the systematic uncertainties.

[Conference Note](#)

Dijet Acoplanarity

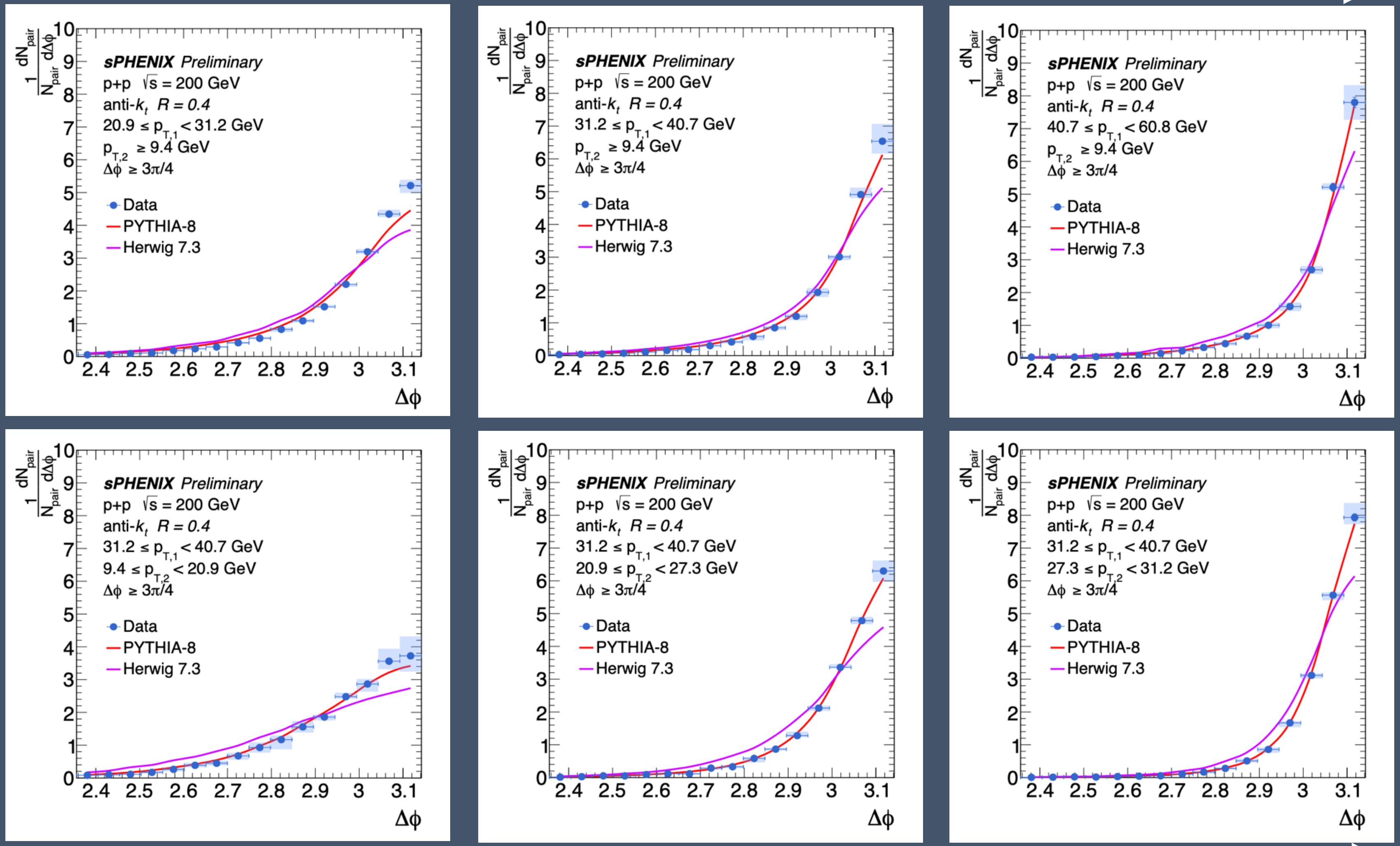
Increasing p_{T1} selections

Dijet acoplanarity measured in pp-collisions

Corrected for angular resolution and jet energy resolution

JES calibration applied

Steepening shown in increasing p_{T1} selections and in more symmetric dijet events



Increasing p_{T2} selections

Dijet Acoplanarity

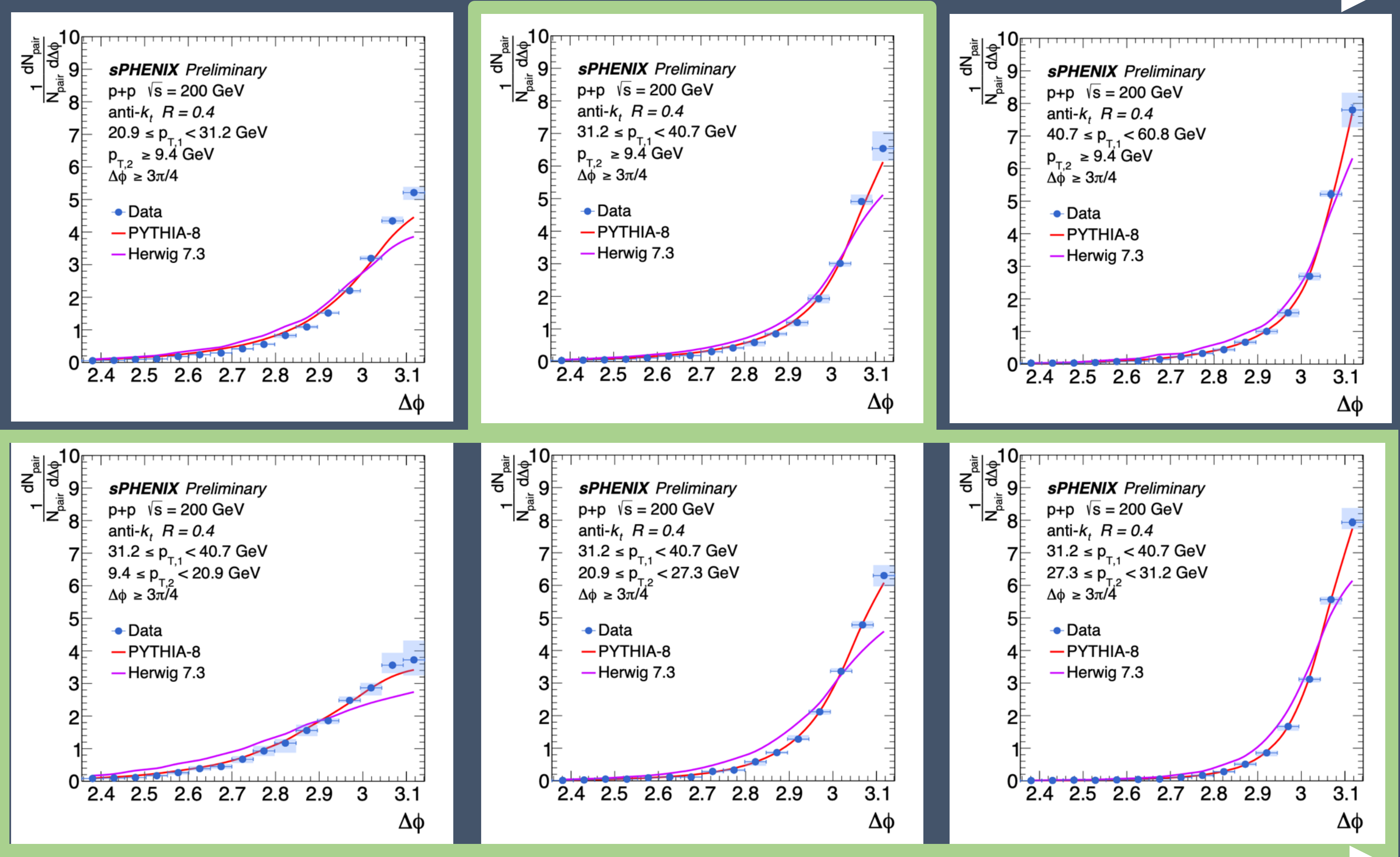
Increasing p_{T1} selections

Dijet acoplanarity measured in pp-collisions

Corrected for angular resolution and jet energy resolution

JES calibration applied

Steepening shown in increasing p_{T1} selections and in more symmetric dijet events



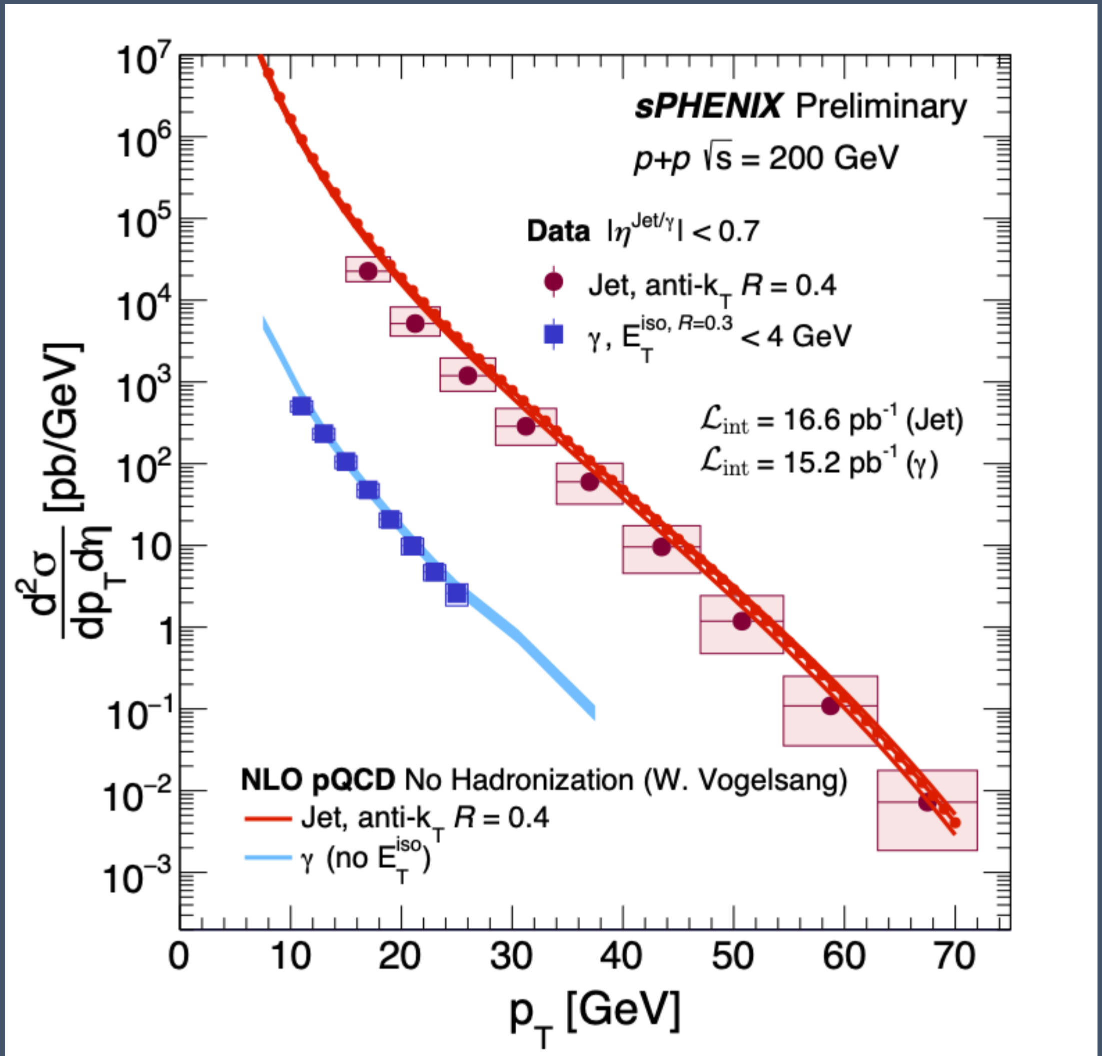
Increasing p_{T2} selections

Summary

sPHENIX has analyzed the run-24 pp data-set and has produced many preliminary physics results with high-p_T probes with fast turn-around!

Upcoming run-25 Au+Au running will provide a large data-set for QGP physics

Thank you!



sPHENIX Talks:

sPHENIX Heavy Flavor Overview – Alexander P. Tue. 9:30 am
The Cold QCD Program at sPHENIX – Virgile M. Tue. 1:55 pm
sPHENIX Run 25 Report – Rosi R. Thur. 11:20 am
sPHENIX Highlights – Jaebeom P. Thur. 1:30 pm

And many posters!