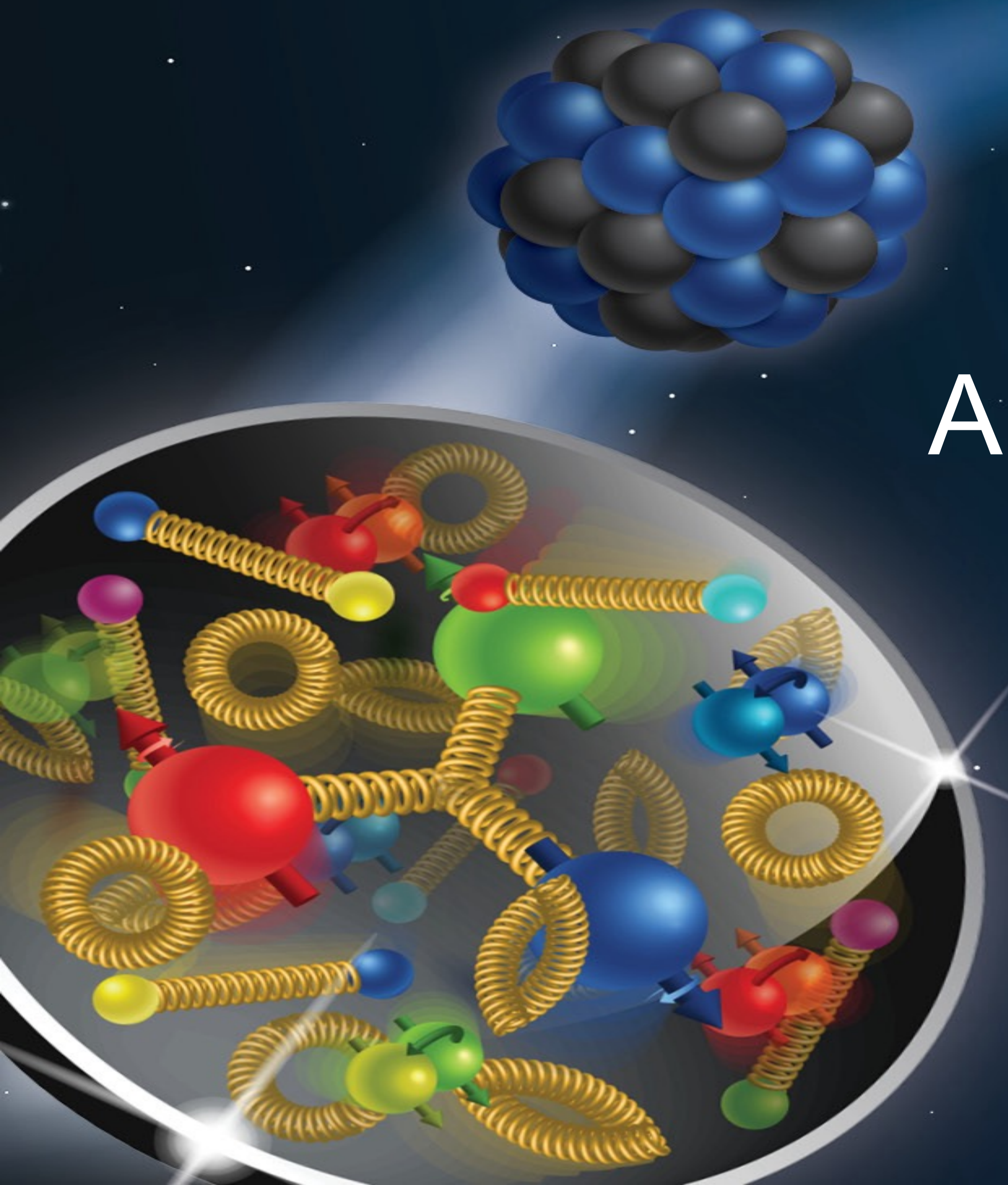


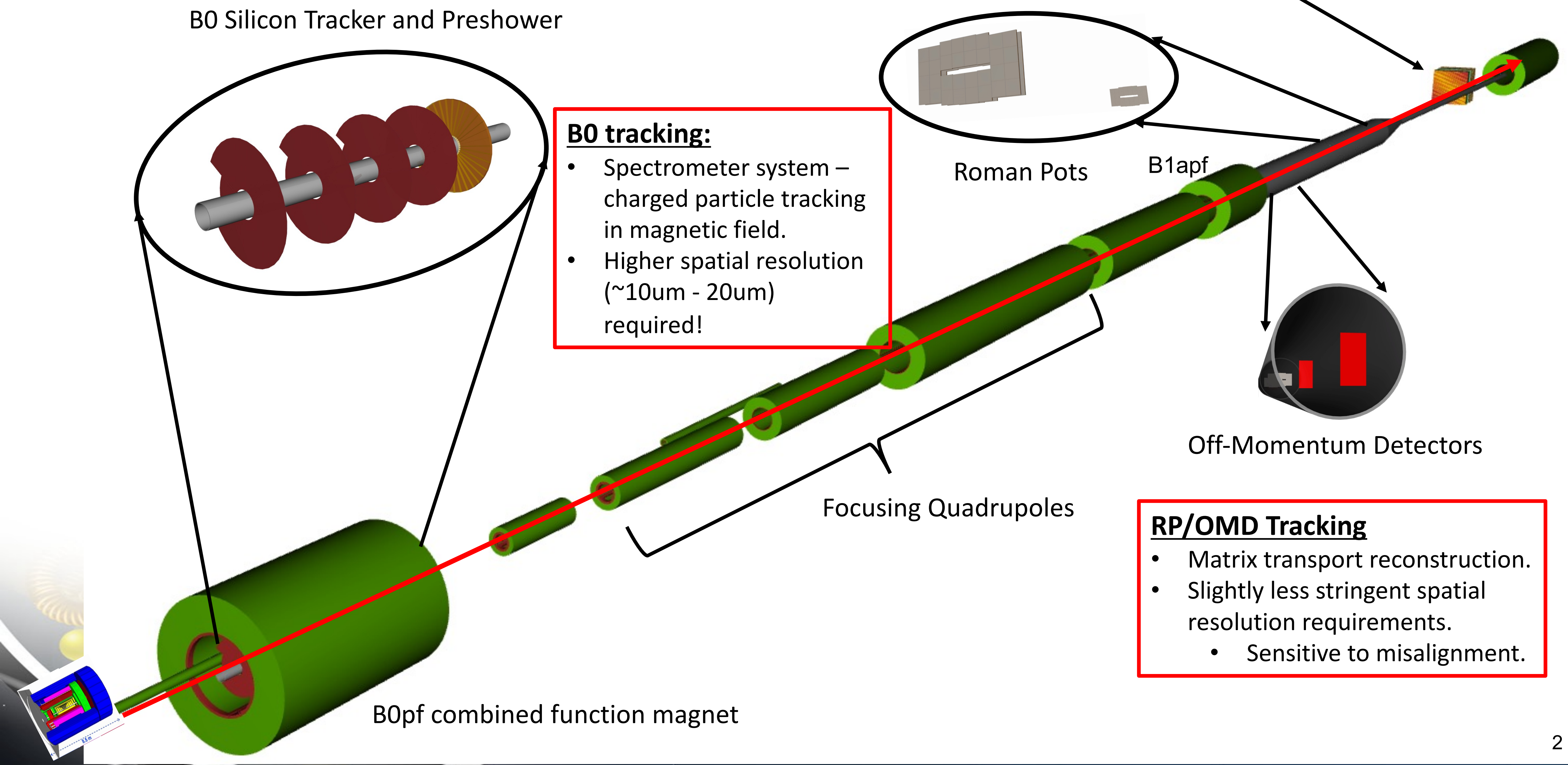
AC-LGAD for the Roman Pots Detectors at the EIC

Alex Jentsch (BNL)

TIC Meeting

July 17th, 2023

The Far-Forward Detectors



B0 tracking:

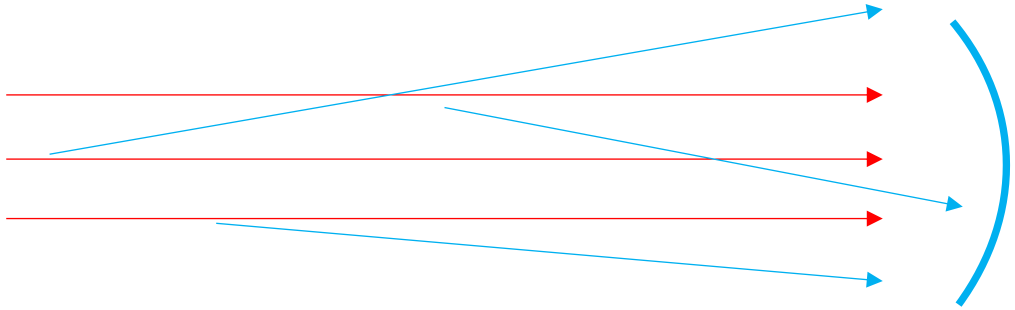
- Spectrometer system – charged particle tracking in magnetic field.
- Higher spatial resolution (~10um - 20um) required!

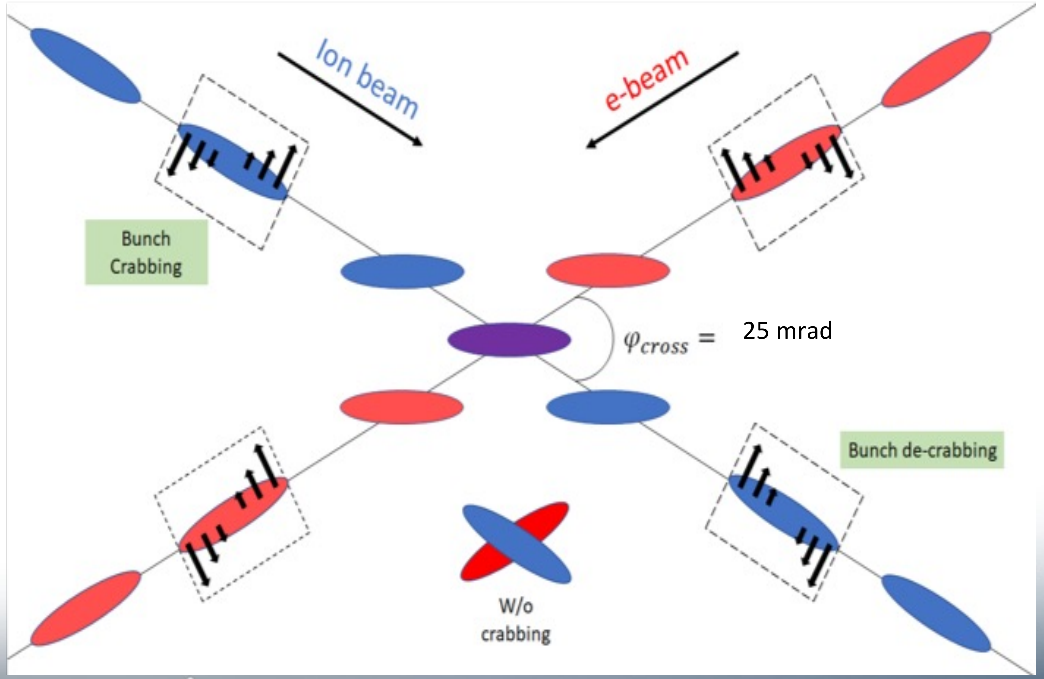
RP/OMD Tracking

- Matrix transport reconstruction.
- Slightly less stringent spatial resolution requirements.
    - Sensitive to misalignment.

Digression: particle beams

- Angular divergence
  - Angular "spread" of the beam away from the central trajectory.
  - Gives some small initial transverse momentum to the beam particles.
- Crab cavity rotation
  - Can perform rotations of the beam bunches in 2D.
  - Used to account for the luminosity drop due to the crossing angle – allows for head-on collisions to still take place.

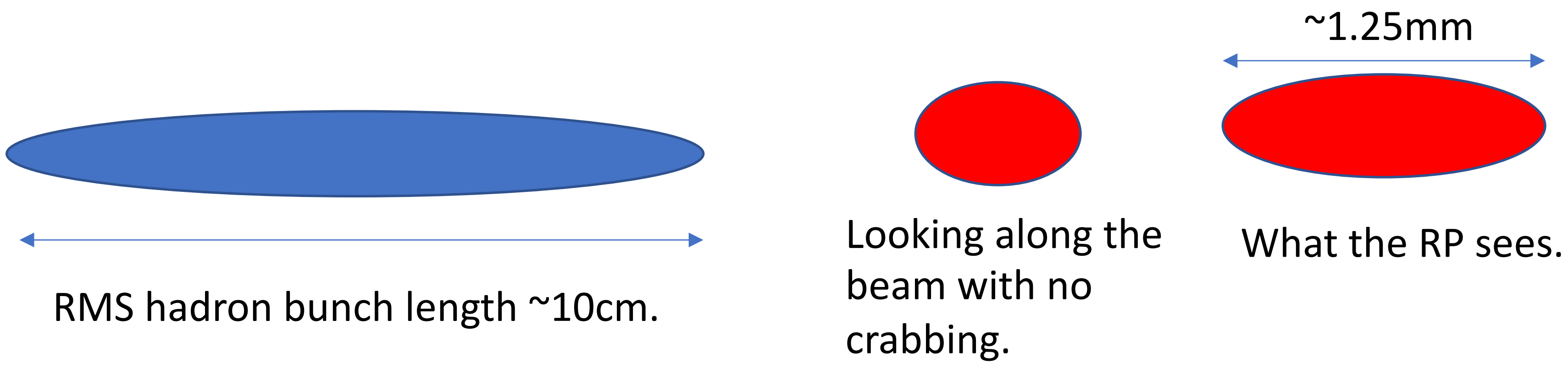




These effects introduce smearing in our momentum reconstruction.

Momentum Resolution – Timing

For exclusive reactions measured with the Roman Pots we need good timing to resolve the position of the interaction within the proton bunch. But what should the timing be?



- Because of the rotation, the Roman Pots see the bunch crossing smeared in x.
- Vertex smearing = 12.5mrad (half the crossing angle) * 10cm = **1.25 mm**
- If the effective vertex smearing was **for a 1cm bunch**, we would have **.125mm** vertex smearing.
- The simulations were done with these two extrema and the results compared.

> - **From these comparisons, reducing the effective vertex smearing to that of the 1cm bunch length reduces the momentum smearing to negligible from this contribution.**
> - **This can be achieved with timing of ~ 35ps (1cm/speed of light).**

Momentum Resolution – Comparison

- The various contributions add in quadrature (this was checked empirically, measuring each effect independently).

$$\Delta p_{t,total} = \sqrt{(\Delta p_{t,AD})^2 + (\Delta p_{t,CC})^2 + (\Delta p_{t,pxl})^2}$$

Angular divergence

Primary vertex smearing from crab cavity rotation.

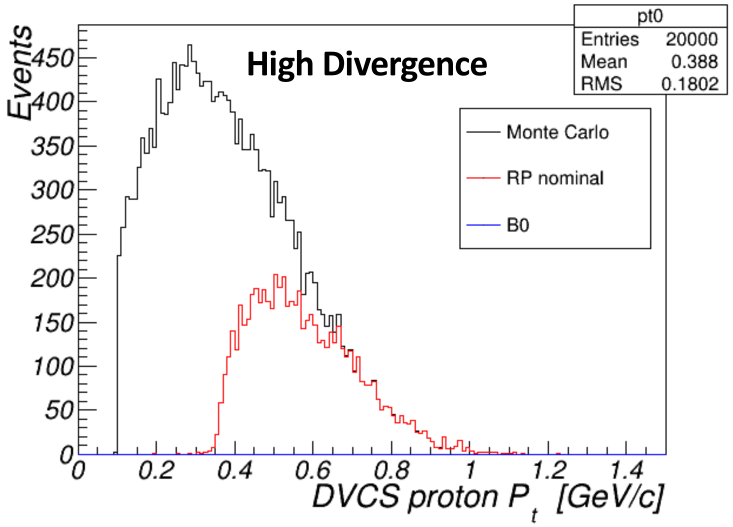
Smearing from finite pixel size.

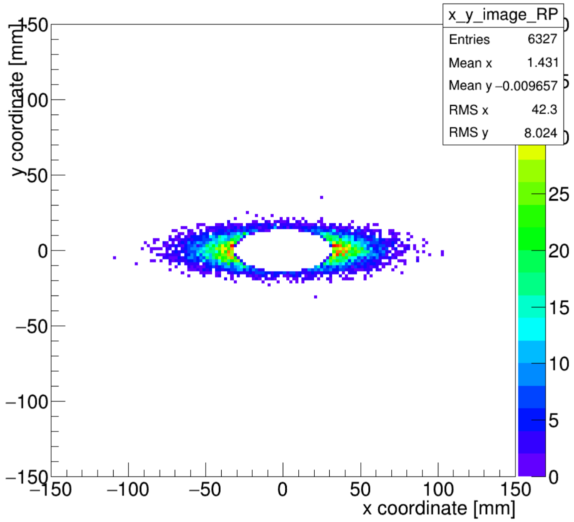
	Ang Div. (HD)	Ang Div. (HA)	Vtx Smear	250um pxl	500um pxl	1.3mm pxl
$\Delta p_{t,total}$ [MeV/c] - 275 GeV	40	28	20	6	11	26
$\Delta p_{t,total}$ [MeV/c] - 100 GeV	22	11	9	9	11	16
$\Delta p_{t,total}$ [MeV/c] - 41 GeV	14	-	10	9	10	12

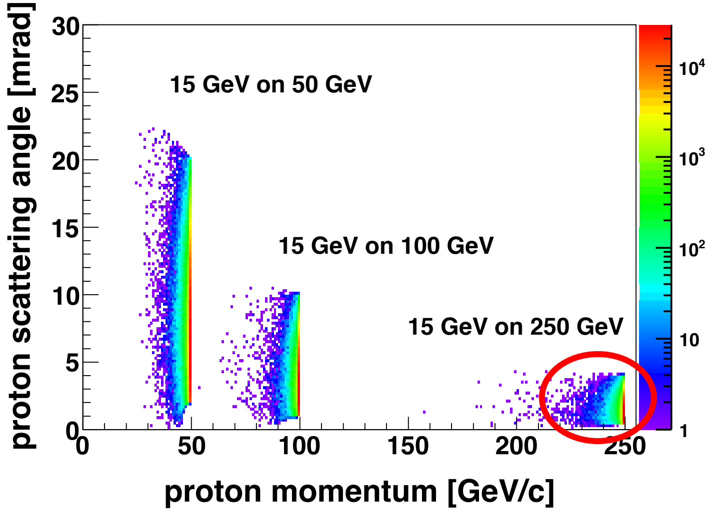
- **Beam angular divergence**
  - Beam property, can't correct for it – sets the lower bound of smearing.
  - Subject to change (i.e. get better) – beam parameters not yet set in stone
- **Vertex smearing from crab rotation**
  - Correctable with good timing (~35ps)
- **Finite pixel size on sensor**
  - 500um seems like the best compromise between potential cost and smearing

Digression: Machine Optics

275 GeV DVCS Proton Acceptance



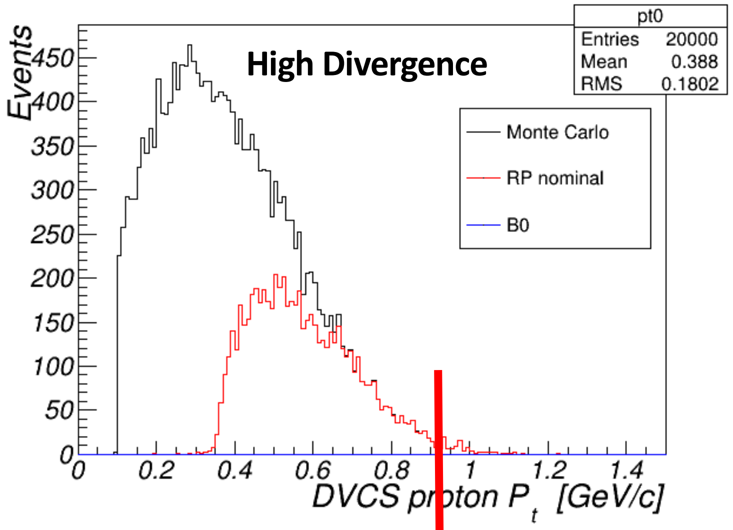


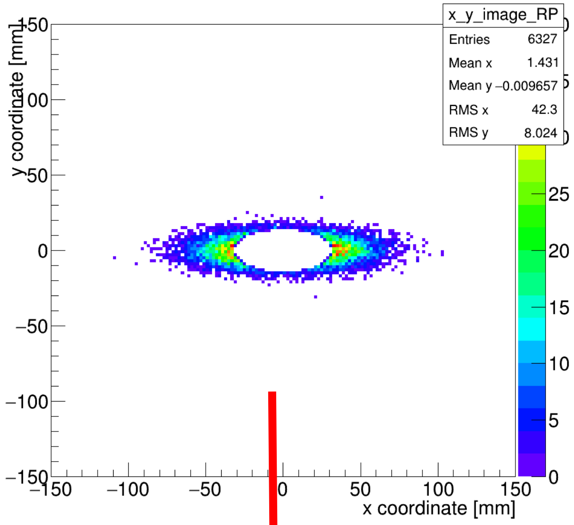


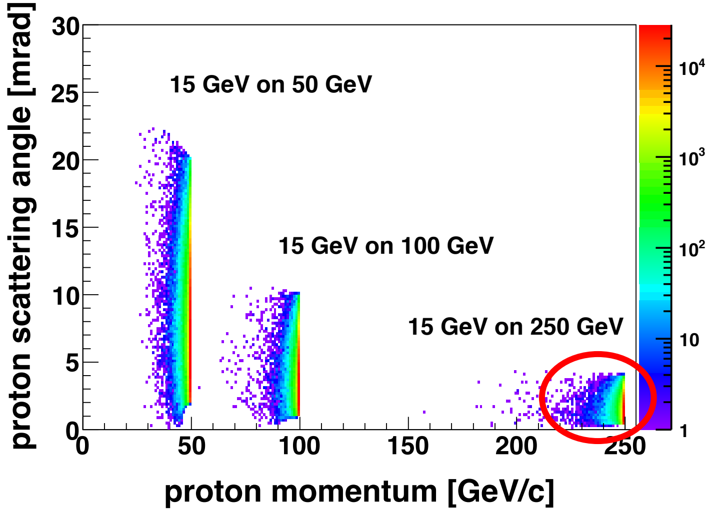
High Divergence: smaller β^* at IP, but bigger $\beta(z = 30m)$ -> higher lumi., larger beam at RP

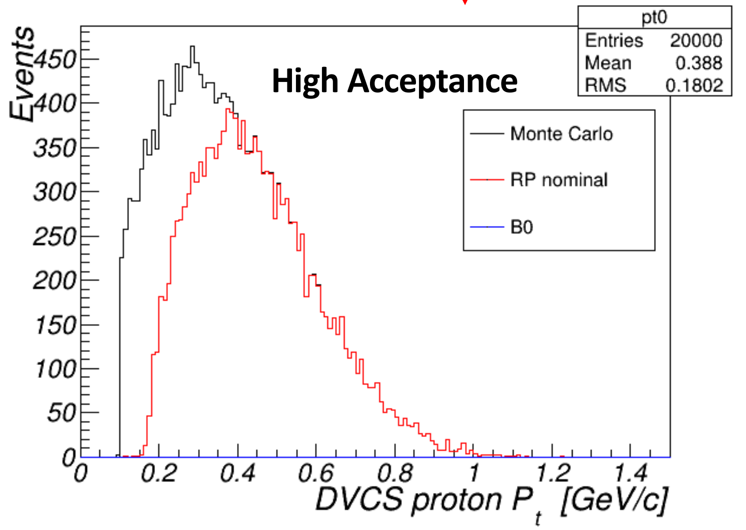
Digression: Machine Optics

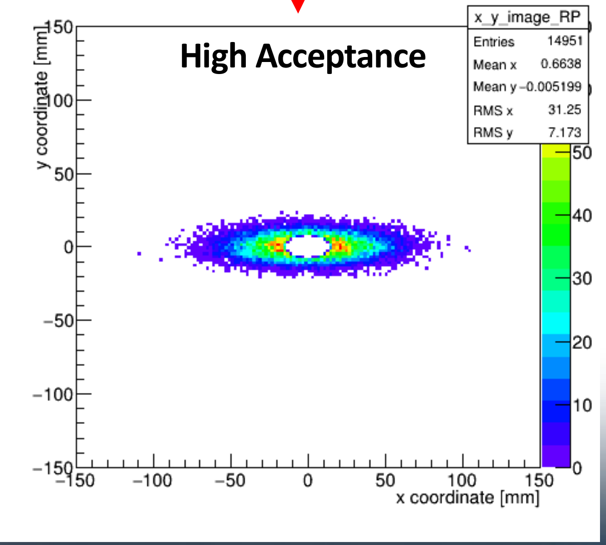
275 GeV DVCS Proton Acceptance











High Divergence: smaller β^* at IP, but bigger $\beta(z = 30m)$ -> higher lumi., larger beam at RP

High Acceptance: larger β^* at IP, smaller $\beta(z = 30m)$ -> lower lumi., smaller beam at RP

Digression: Machine Optics

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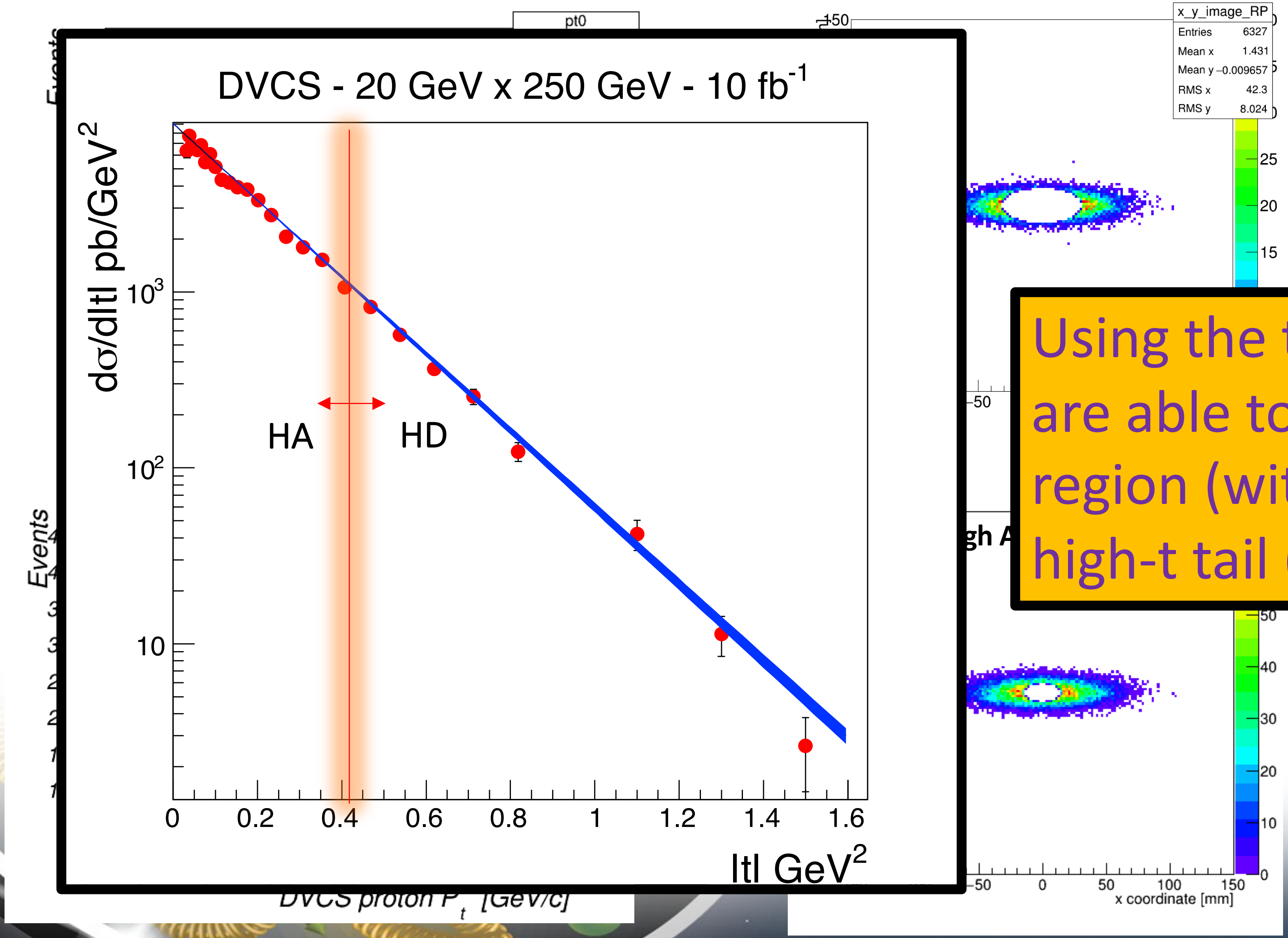
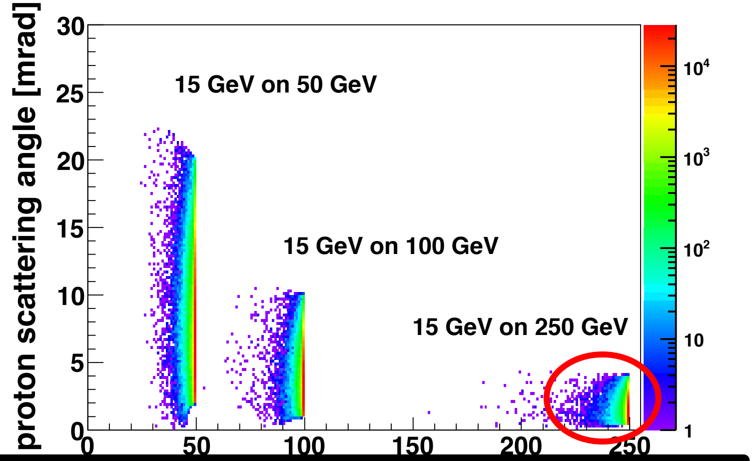
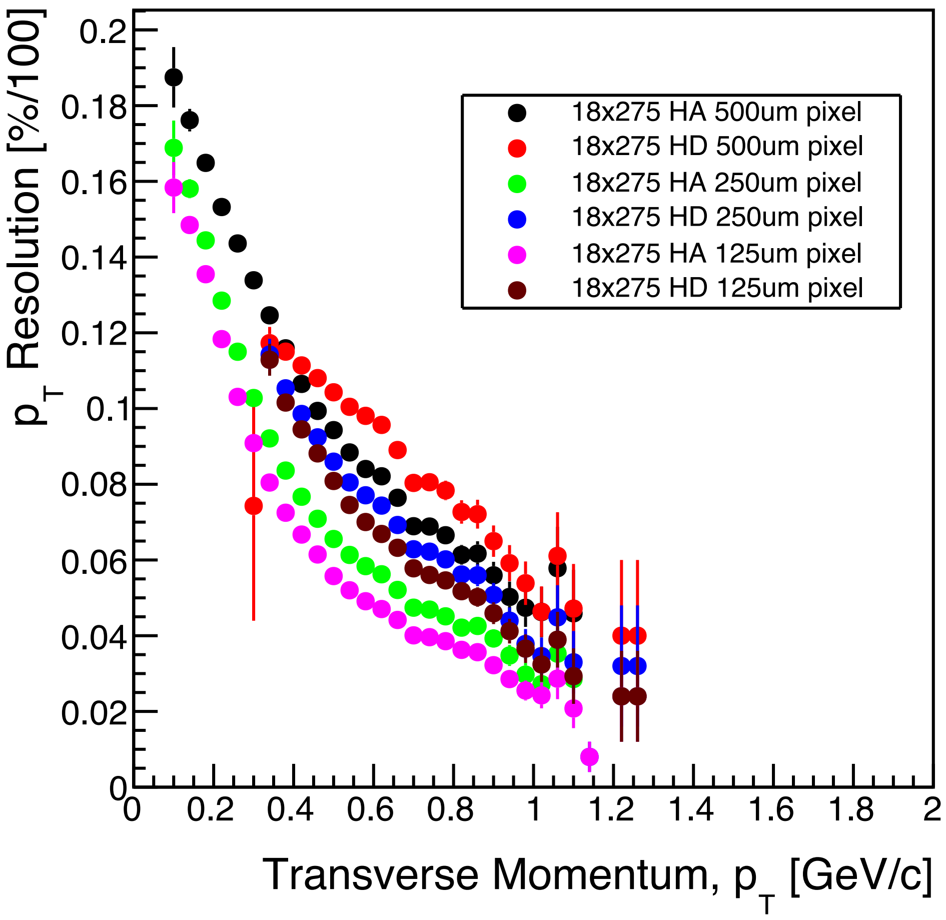


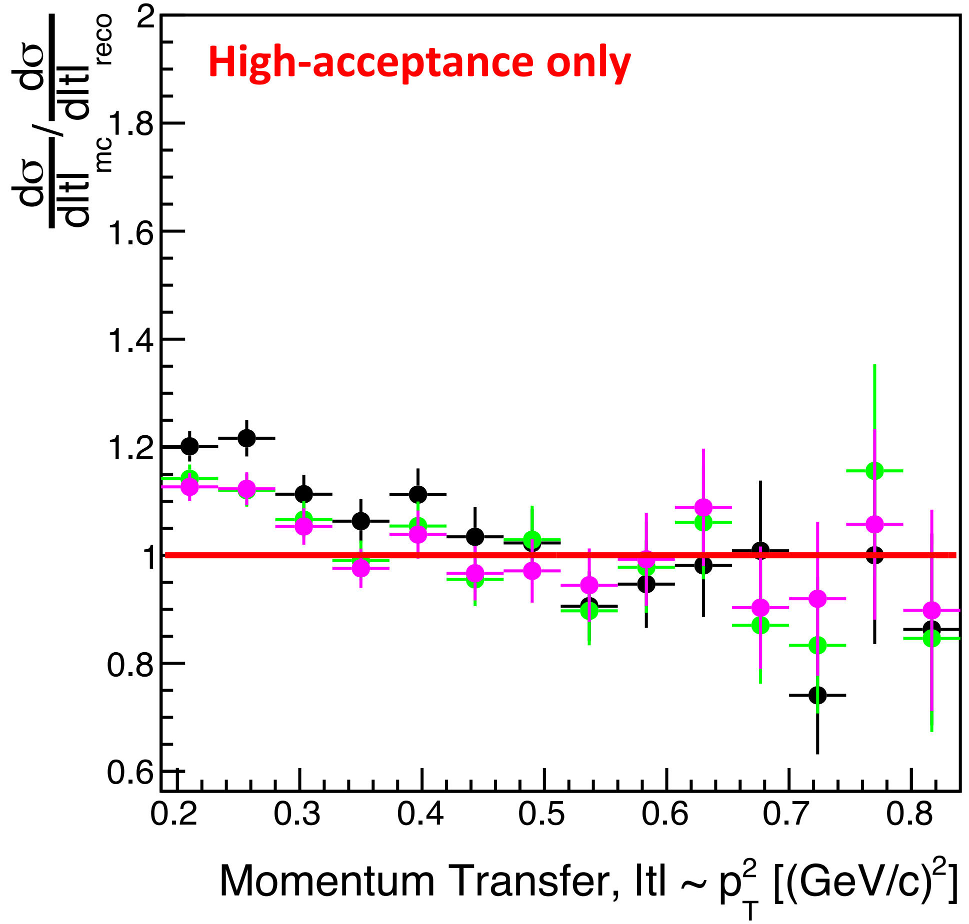


Using the two configurations, we are able to measure the low-t region (with better acceptance) and high-t tail (with higher luminosity).

High Acceptance: larger β^* at IP, smaller $\beta(z = 30m)$ -> lower lumi., smaller beam at RP

Detailed Momentum Resolution - 18x275 GeV

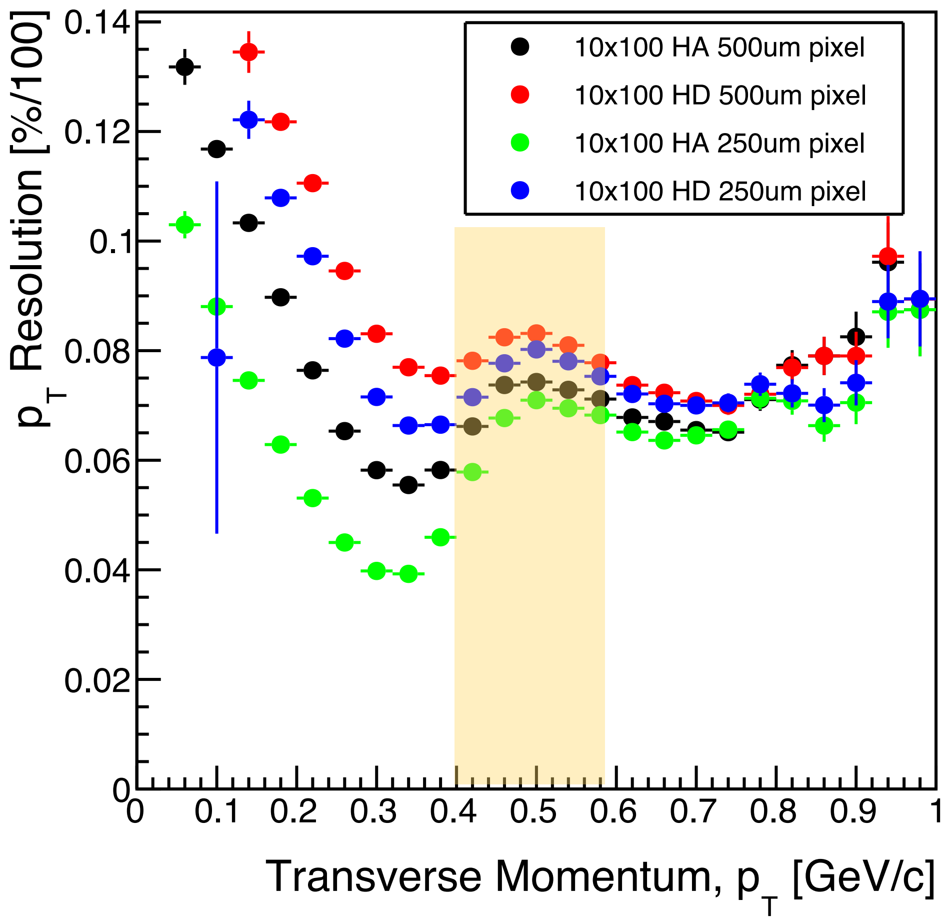


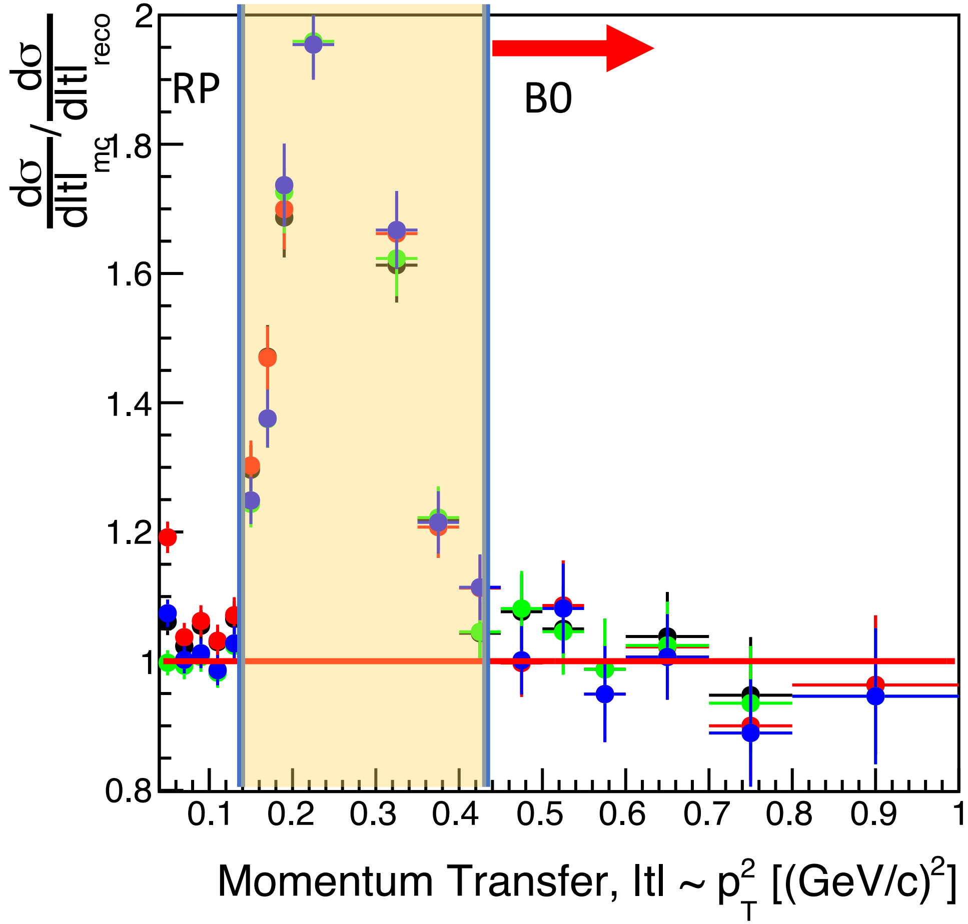


- Each case includes all beam effects.
- Updated transfer matrix reconstruction compared to eRD24.
- **Material thickness has not been evaluated in detail, but of course additional material will degrade resolution.**

- Goal is to extract slope of t-distribution.
- Ratio indicates expected capability.

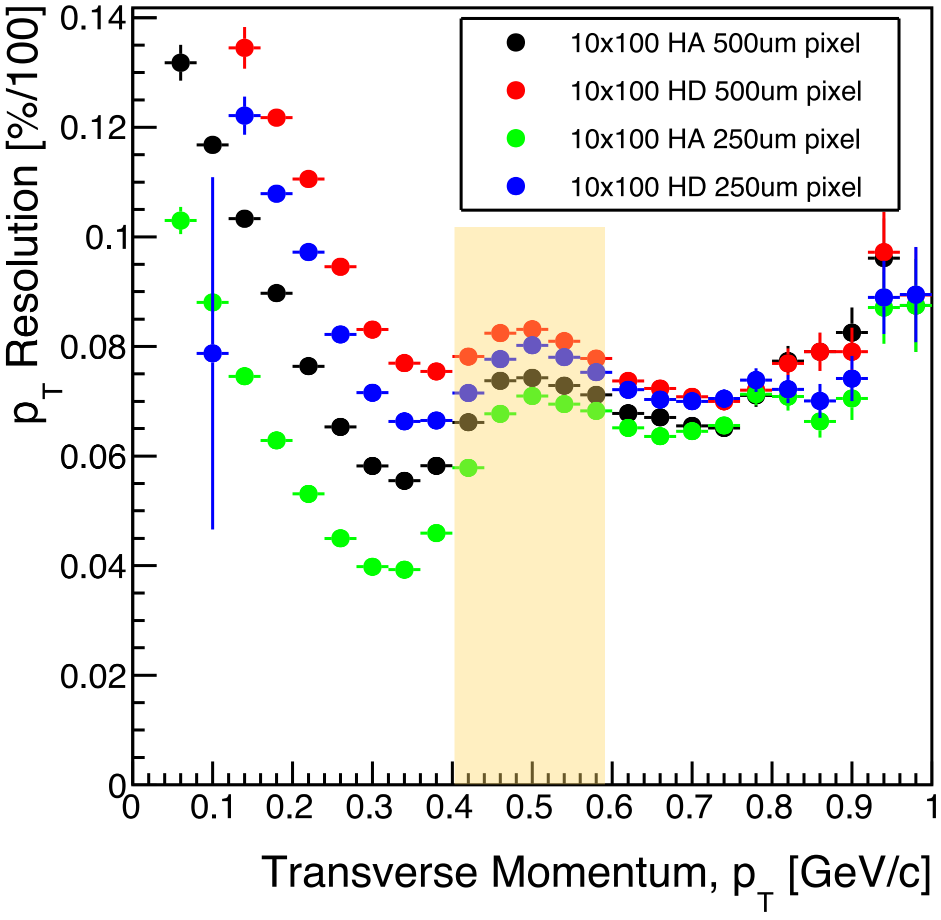
Detailed Momentum Resolution - 10x100 GeV

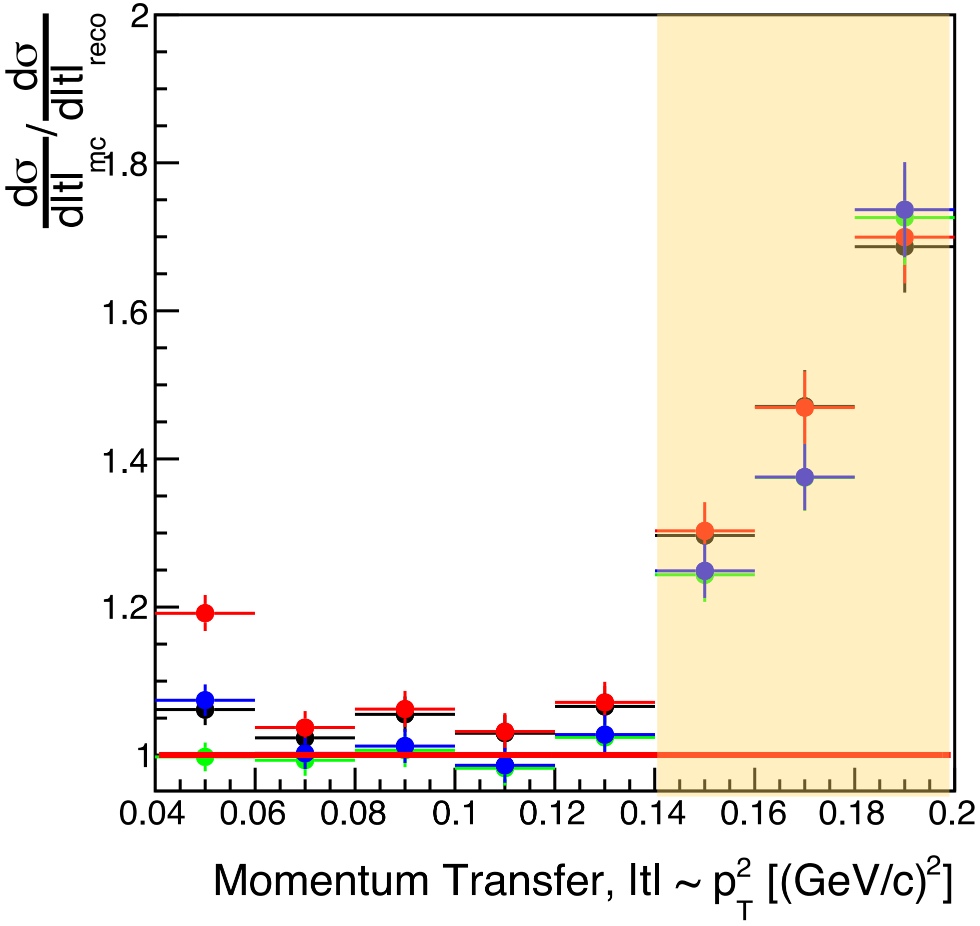




- Yellow shaded area is the acceptance gap between the detectors.
- No acceptance correction is applied here.

Detailed Momentum Resolution - 10x100 GeV





- Zoom-in to relevant RP range.
- Since angular divergence is smaller in the 100 GeV beam, the spatial resolution has a larger impact.

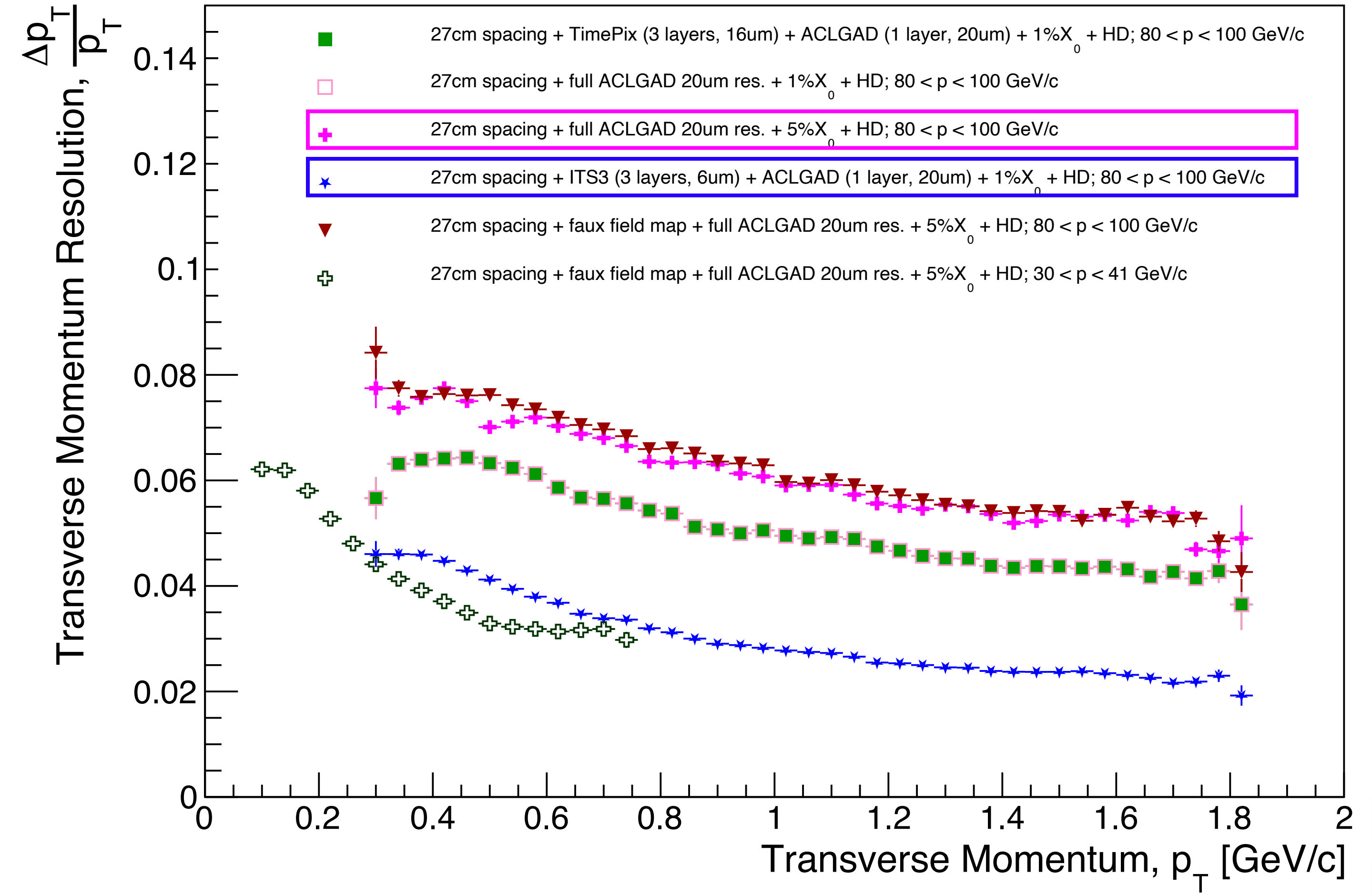
Detector Resolution Summary

- Modern studies support basic idea of eRD24 studies.
  - 500um pixels can do the job.
  - Expecting x2 improvement (super-conservative minimum) in (pixel size)/Sqrt(12) – reduces slope distortion in t-distribution.
  - Physics groups have not produced any further input on required performance – so we should ensure the detector choices do not hinder a possible measurement.
- Strips increase the number of needed planes x2, which increases cooling, needed space, engineering constraints, etc.
  - Strips can make background rejection much more challenging (experience of PPS @ CMS).
  - Long strips potential for RF pickup noise.
  - We have no real estimates on these things from the engineering design, so it makes it challenging to know what to include in the simulations.
  - The active area of the detectors is very large, and the whole system is directly in vacuum. Adding more planes means more services, impedance, etc.

What about the B0 tracker?

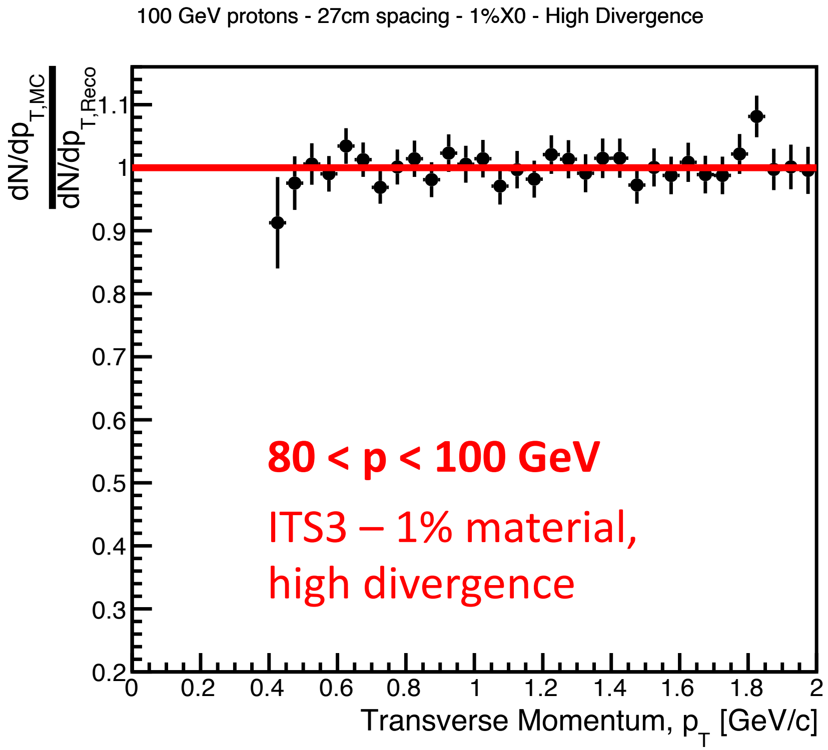
- Originally planned to use ITS3 (3 layers) + AC-LGAD (1 layer) to get 5-10um spatial resolution, combined with precise timing of AC-LGADs.
- Long integration window for ITS3 sensors a major problem for the high occupancy environment of the B0 tracker.
  - https://wiki.bnl.gov/EPIC/index.php?title=Background
- Looking at AC-LGADs as an option for the full subsystem → will the worsening of the spatial resolution be tolerable?
  - Beam tests demonstrate AC-LGADs achieving ~ 20um spatial resolution with charge sharing: https://indico.bnl.gov/event/19471/

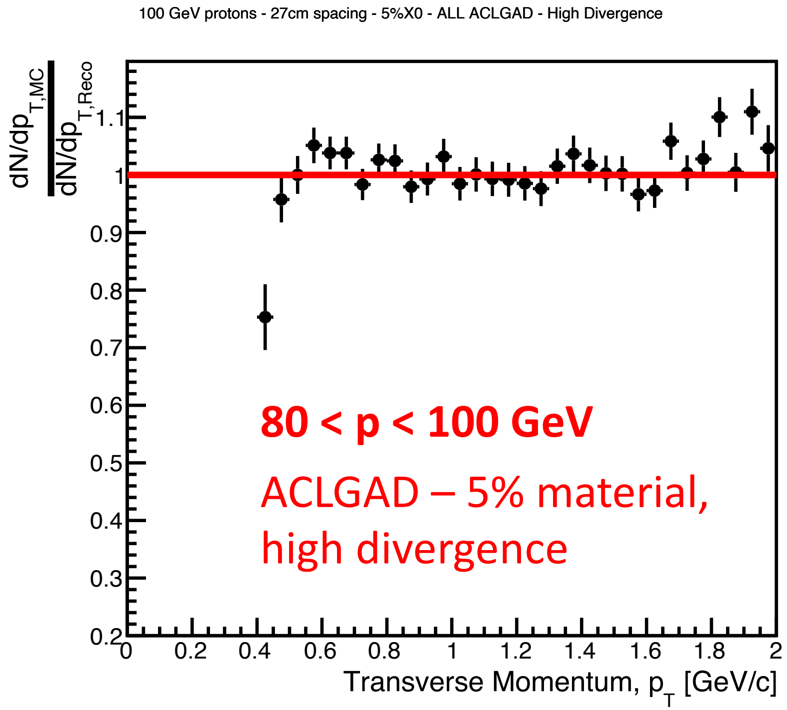
B0 tracking: new technology + material assumptions



- 27cm spacing with fully AC-LGAD system and 5% radiation length may be the most-realistic option.
  - Needs to be looked at with proper field map and layout.
  - Is this resolution going to be a problem?
- **Note:** p resolution is ~ 2-4%, depending on configuration.

B0 tracking: Impact on pT spectra



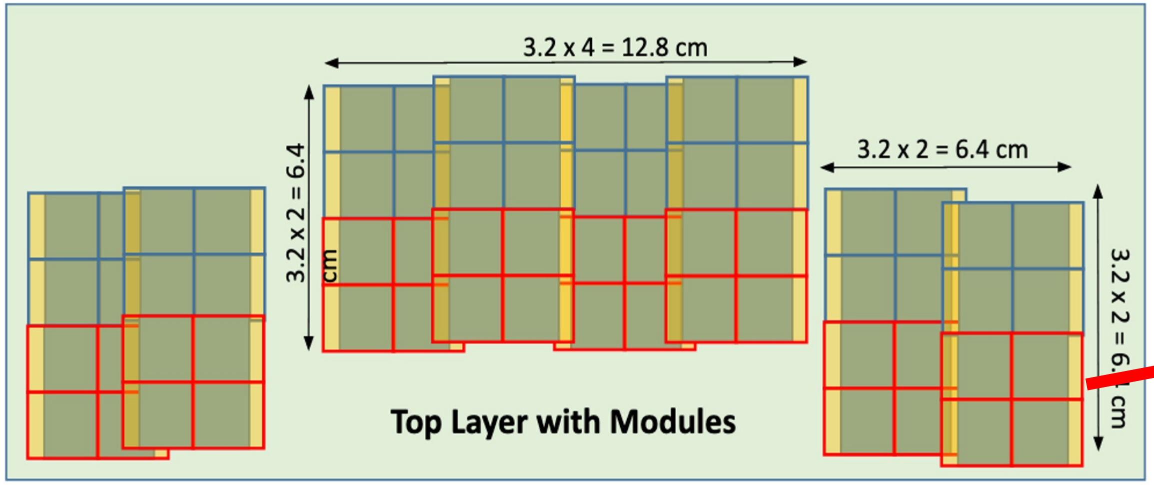


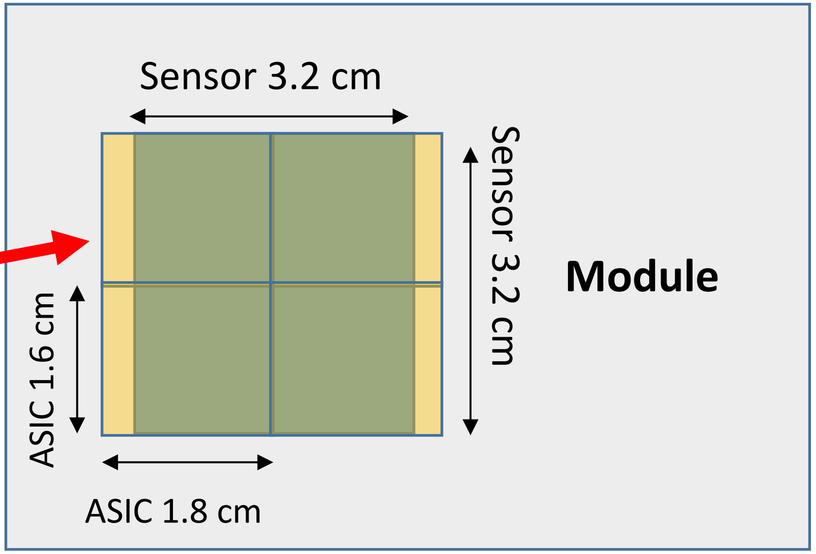
- Full study: https://indico.bnl.gov/event/19620/
- Information passed to PWG in early June.

Backup

Roman Pots

- Updated layout with current design for AC-LGAD sensor + ASIC.





- Current R&D aimed at customizing ASIC readout chip (ALTIROC) for use with AC-LGADs.

ASIC size	ASIC Pixel pitch	# Ch. per ASIC	# ASICs per module	Sensor area	# Mod. per layer	Total # ASICs	Total # Ch.	Total Si Area
1.6x1.8 cm^2	500 μm	32x32	4	3.2x3.2 cm^2	32	512	524,288	1,311 cm^2