Requirements for the RP and OMD

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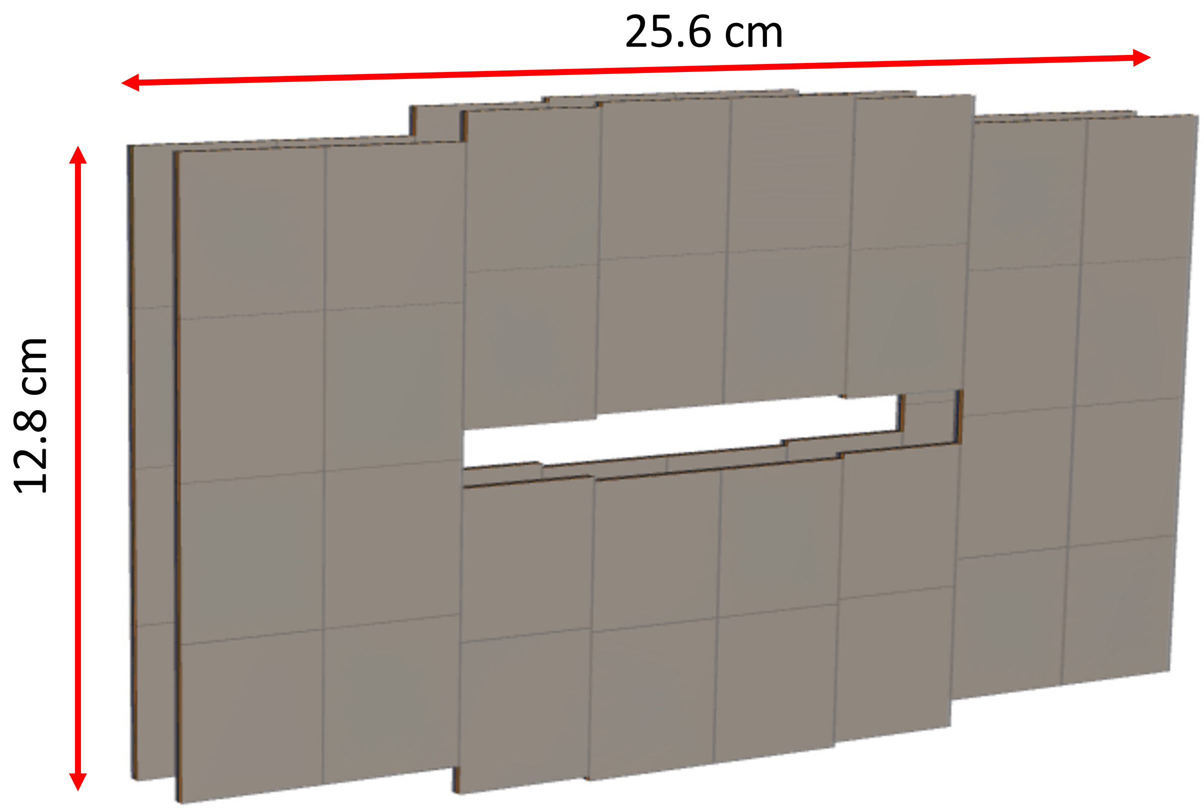
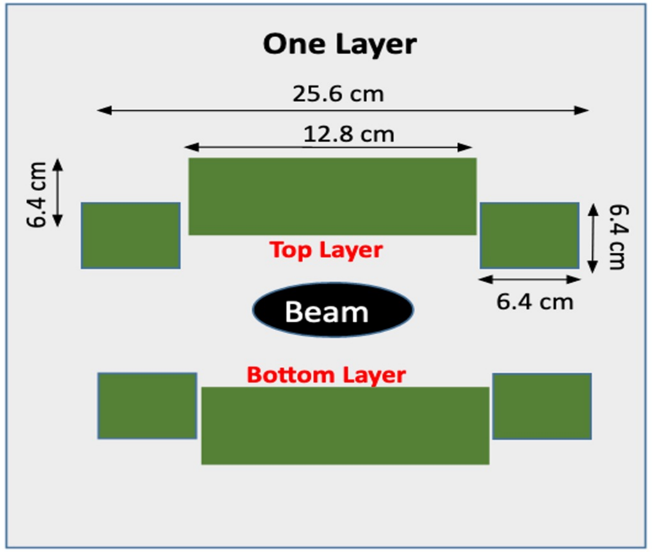
Roman “Pots” @ the EIC



DD4HEP Simulation

$\sigma(z)$ is the Gaussian width of the beam, $\beta(z)$ is the RMS transverse beam size, ε is the beam emittance, and D is the momentum dispersion.

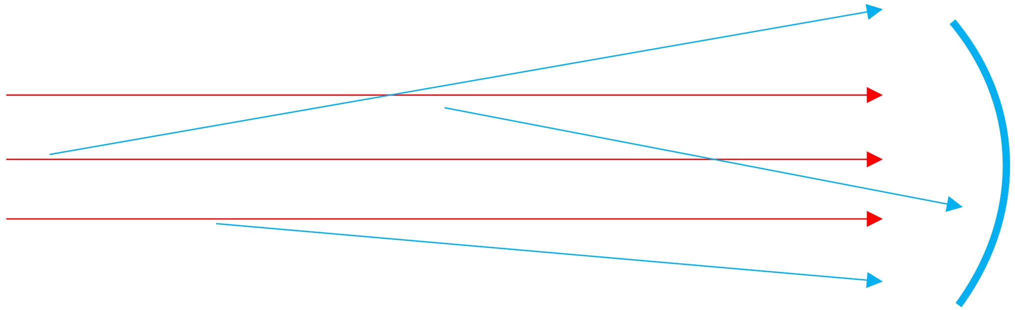
$$\sigma_{x,y} = \sqrt{\beta(z)_{x,y}\epsilon_{x,y} + \left(D_{x,y}\frac{\Delta p}{p}\right)^2}$$



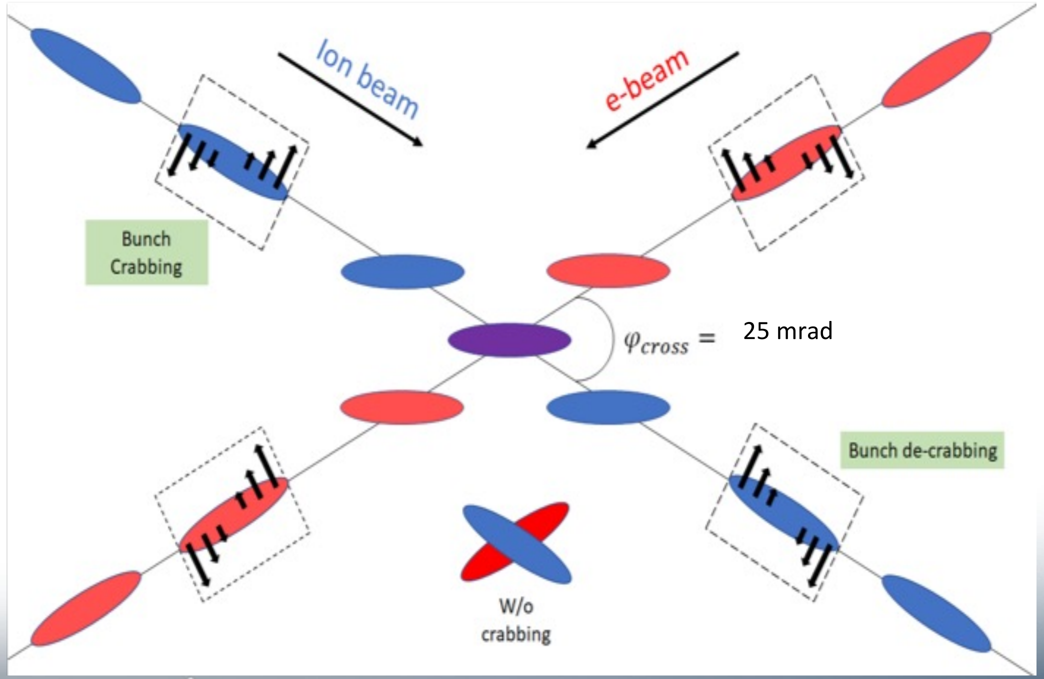
- **<u>Low-pT cutoff determined by beam optics.</u>**
  - **The safe distance is ~10σ from the beam center.**
  - **1σ ~ 1mm**
- **These optics choices change with energy, but can also be changed within a single energy to maximize *either acceptance at the RP, or the luminosity.***

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.



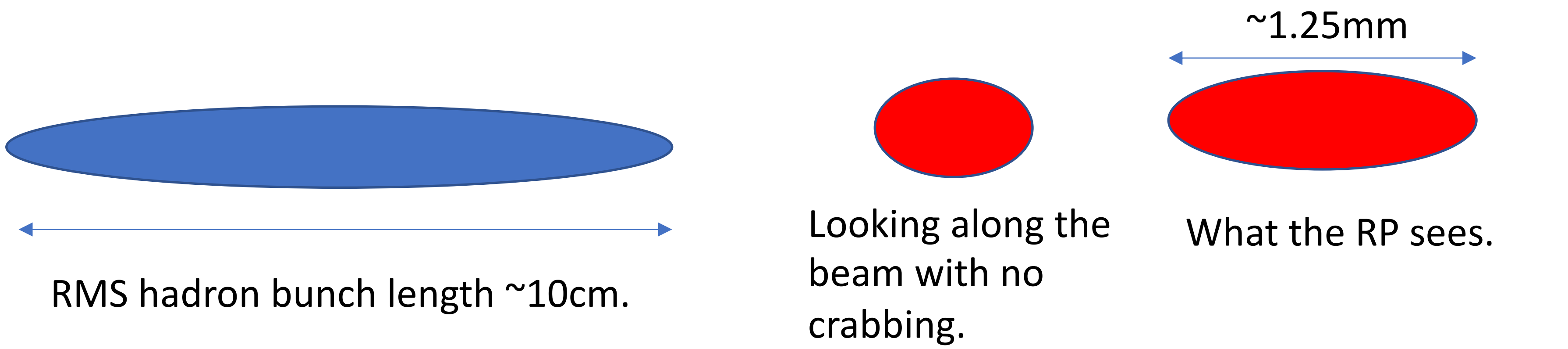
- Crab cavity rotation
  - Can perform rotations of the beam bunches in 2D.
  - Used to account for the luminosity drop due to the crossing angle – allows for head-on collisions to still take place.



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

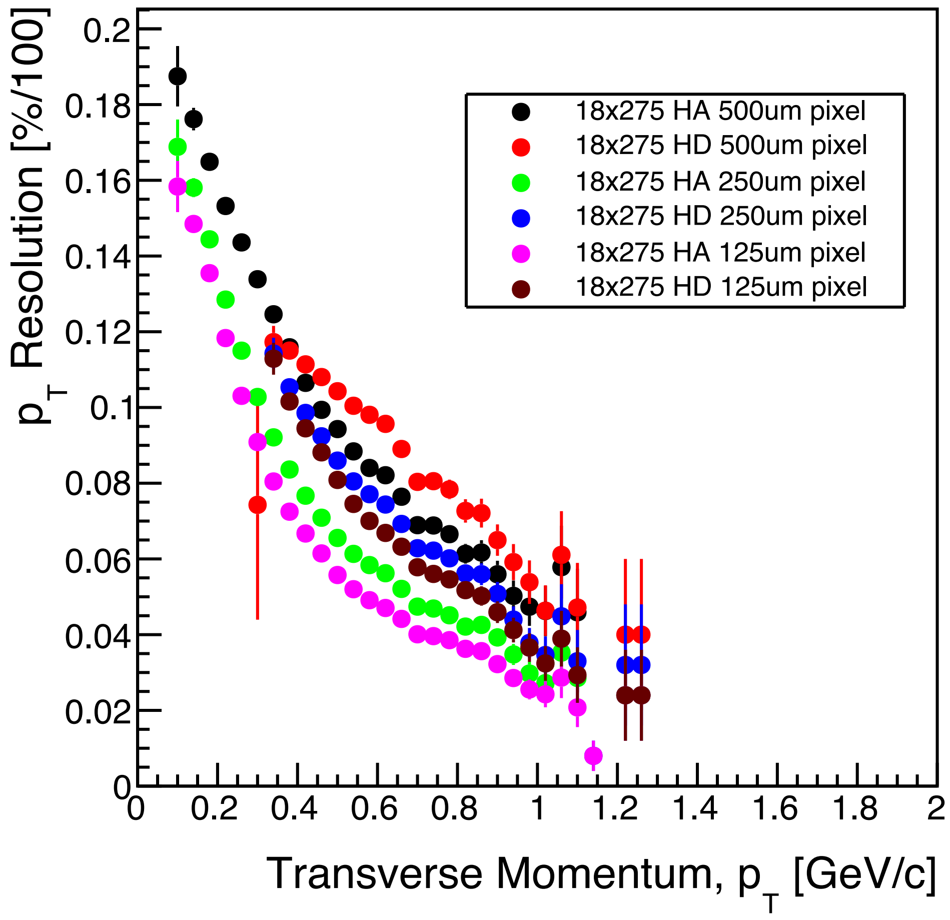
Primary vertex smearing from crab cavity rotation.

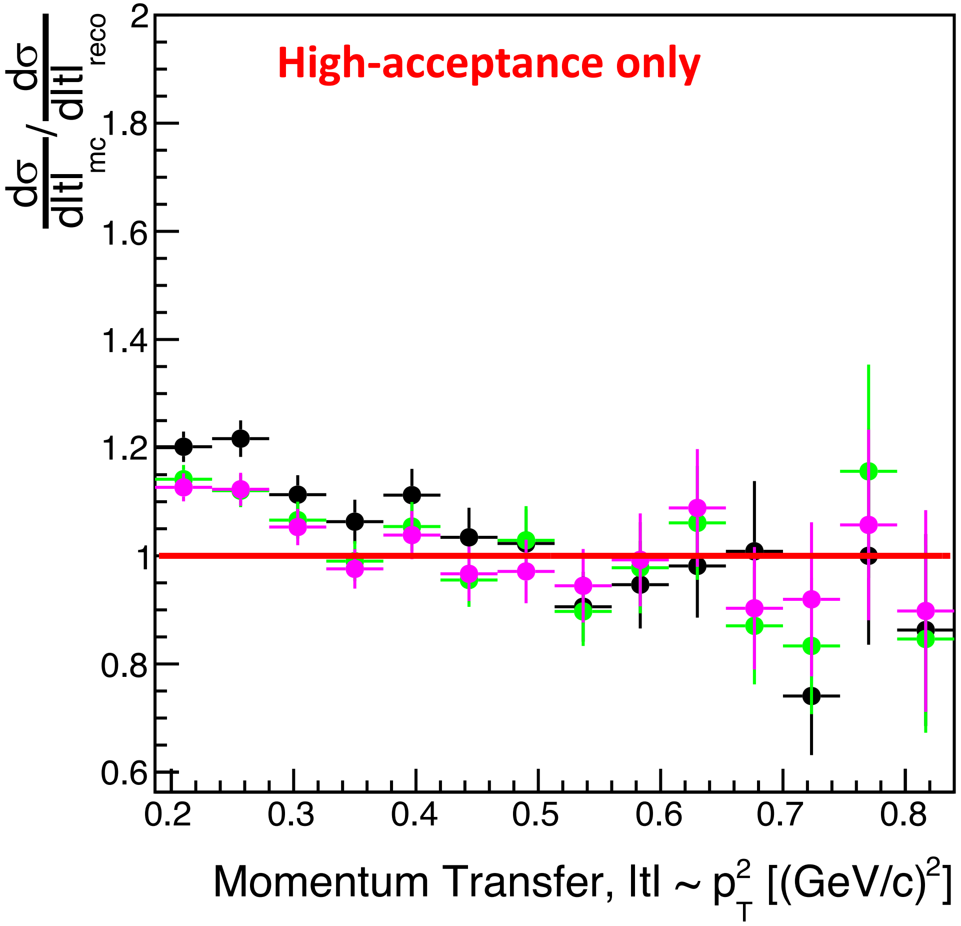
Smearing from finite pixel size.

	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

Detailed RP Momentum Resolution - 18x275 GeV



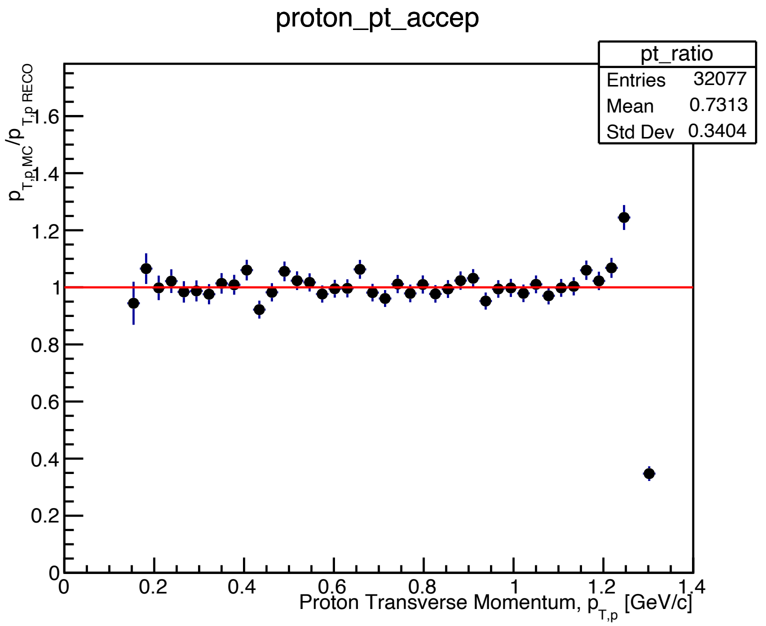


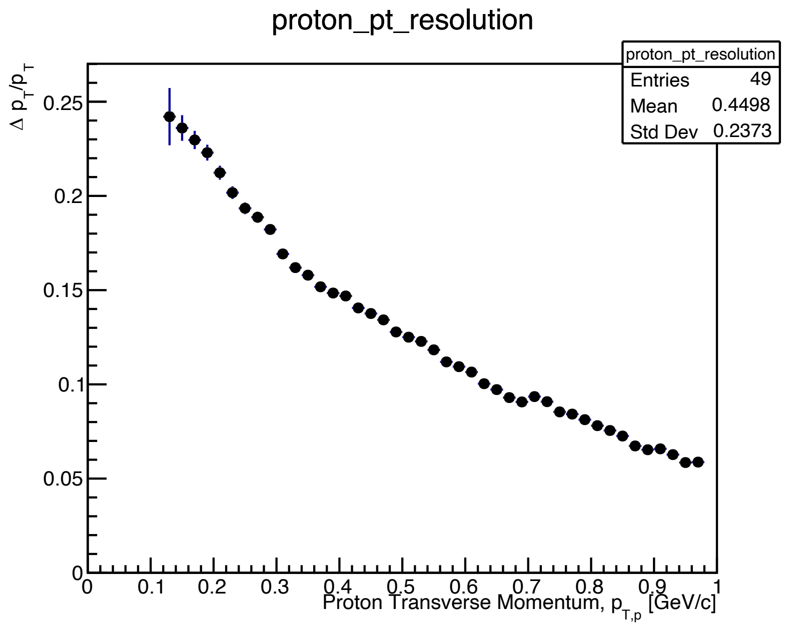
- 500um = no charge sharing
- 250um = charge sharing, x2 improvement
- 125um = charge sharing, x4 improvement

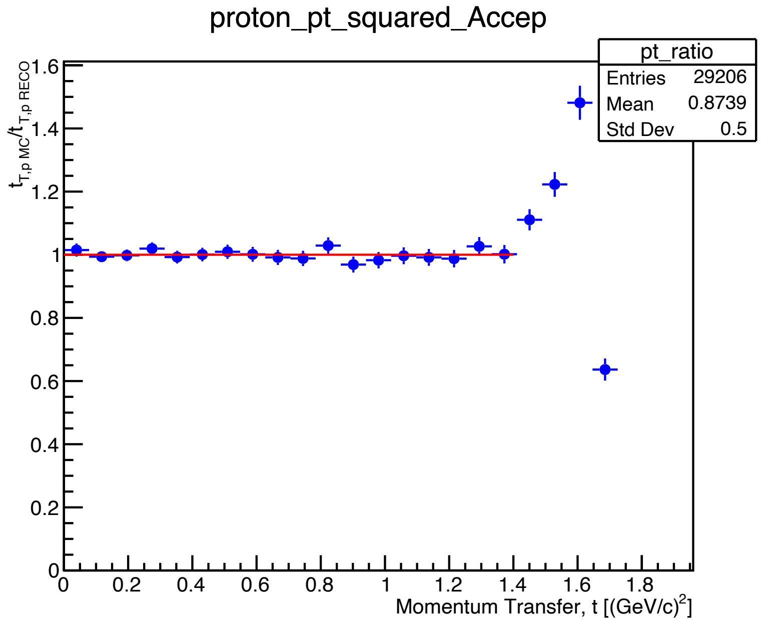
- Each case includes all beam effects.
- Updated transfer matrix reconstruction compared to eRD24.
- **Material thickness has not been evaluated in detail, but of course additional material will degrade resolution.**

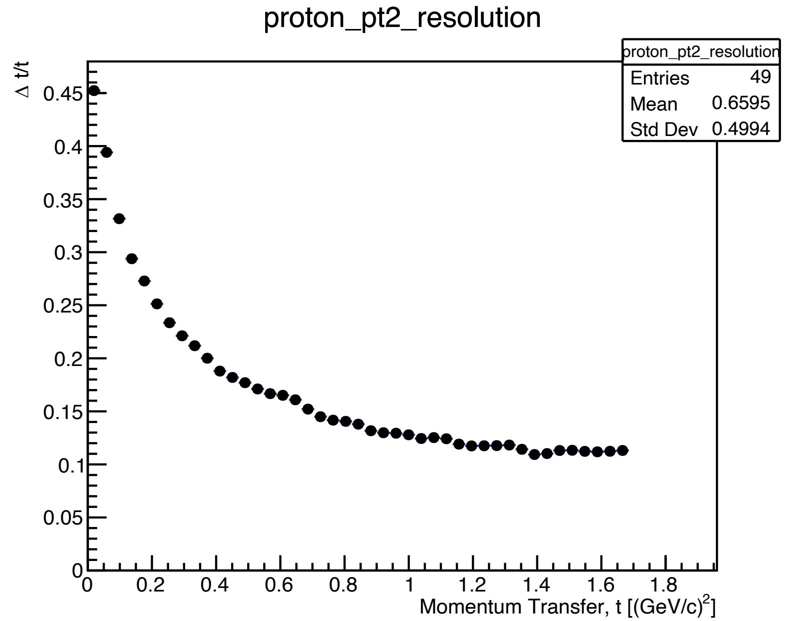
- Goal is to extract slope of t-distribution.
- Ratio indicates expected capability.

Detailed RP Momentum Resolution - 18x275 GeV





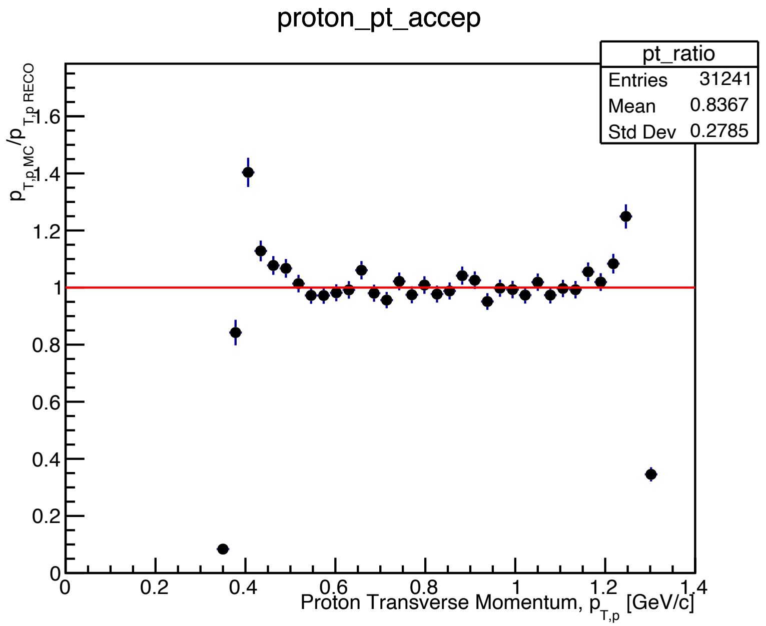


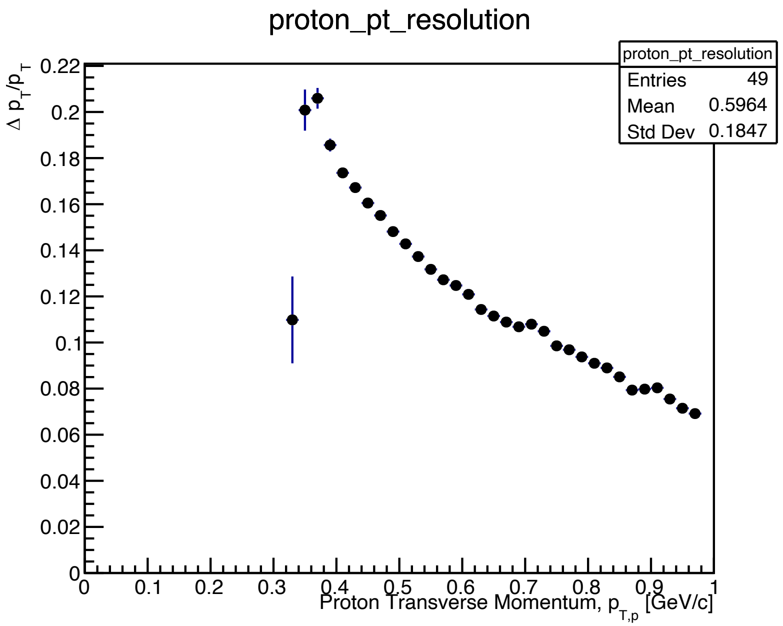


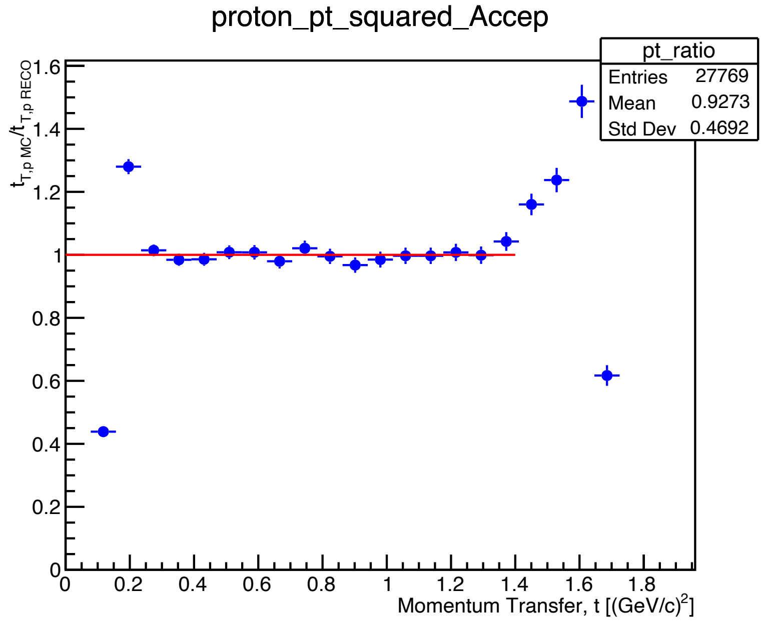
- 275 GeV particle gun with full angular range.
- High acceptance configuration.
- 500um pixels.
- Static matrix reconstruction.

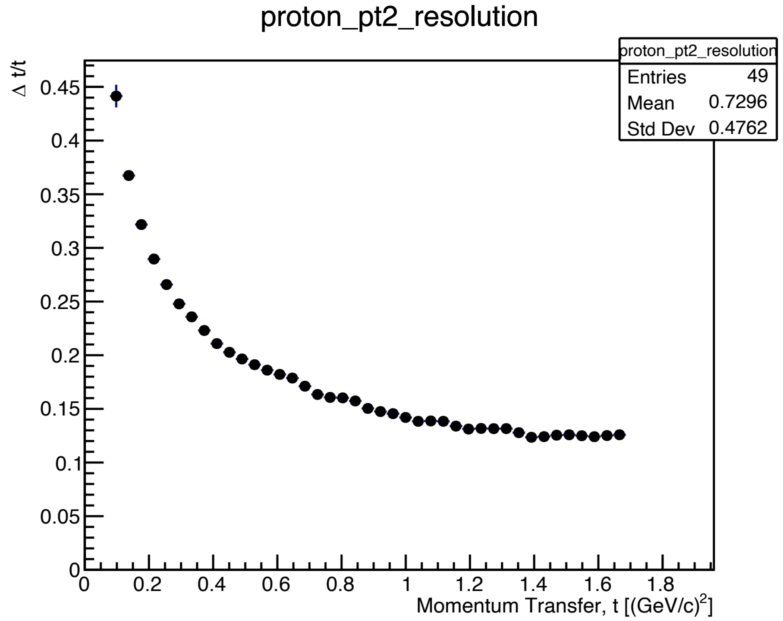
No residual slope observed in pT or t distributions.

Detailed RP Momentum Resolution - 18x275 GeV









- 275 GeV particle gun with full angular range.
- High divergence configuration.
  - Worsens pT acceptance!
- 500um pixels.
- Static matrix reconstruction.

No residual slope observed in pT or t distributions, except at acceptance edges.

Cannot achieve physics goals with only this configuration.

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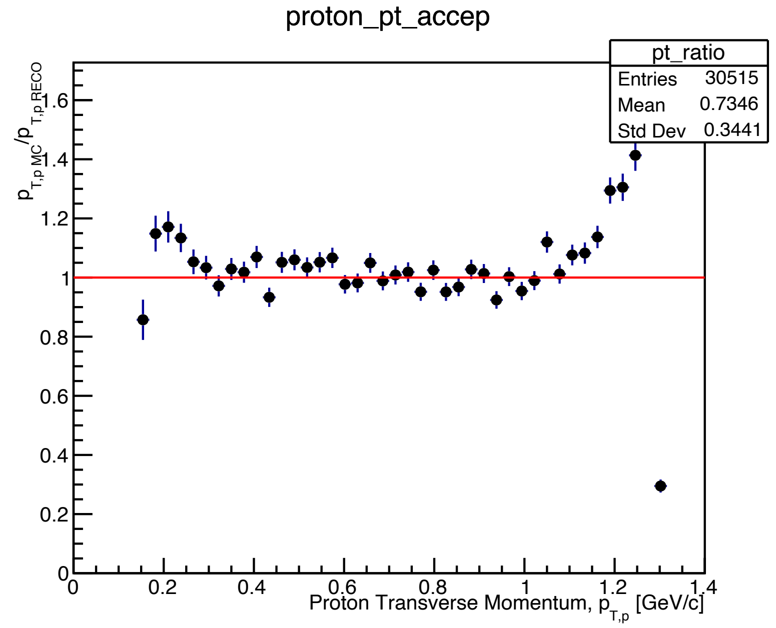
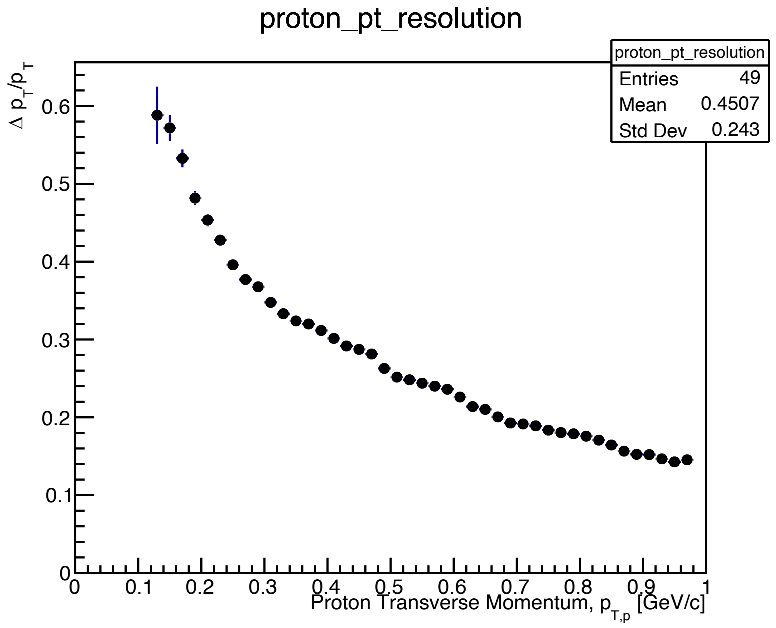
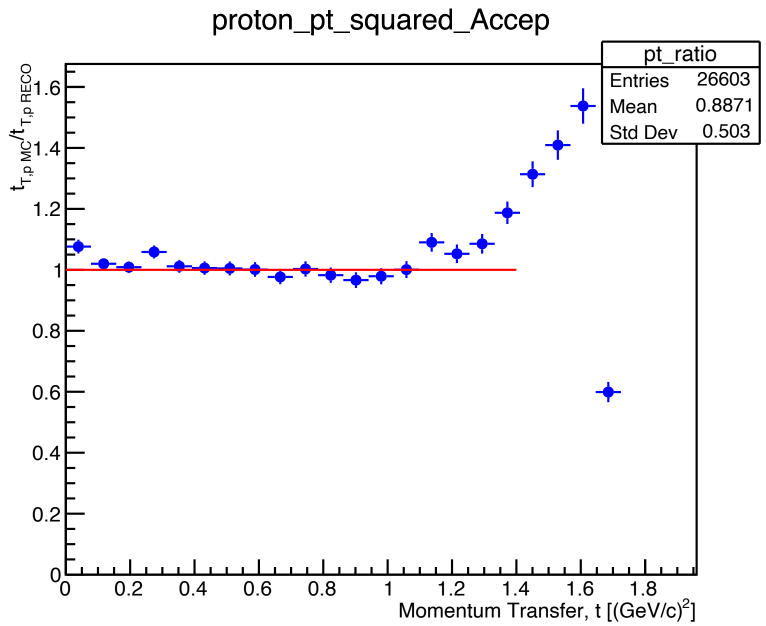
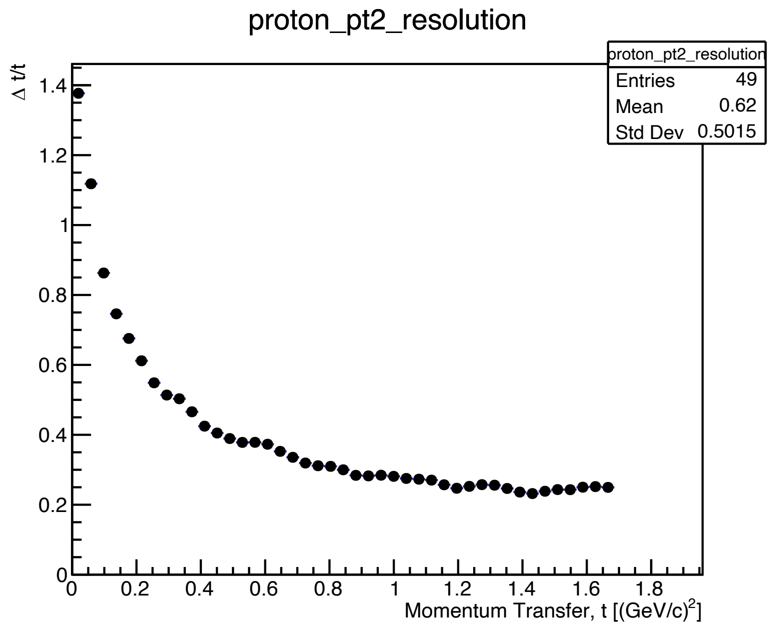








- 275 GeV particle gun with full angular range.
- High divergence configuration.
  - Worsens pT acceptance!
- **1300um pixels.**
- Static matrix reconstruction.

No residual slope observed in pT or t distributions, except at acceptance edges.

Cannot achieve physics goals with only this configuration.

Top-level Summary of Requirements

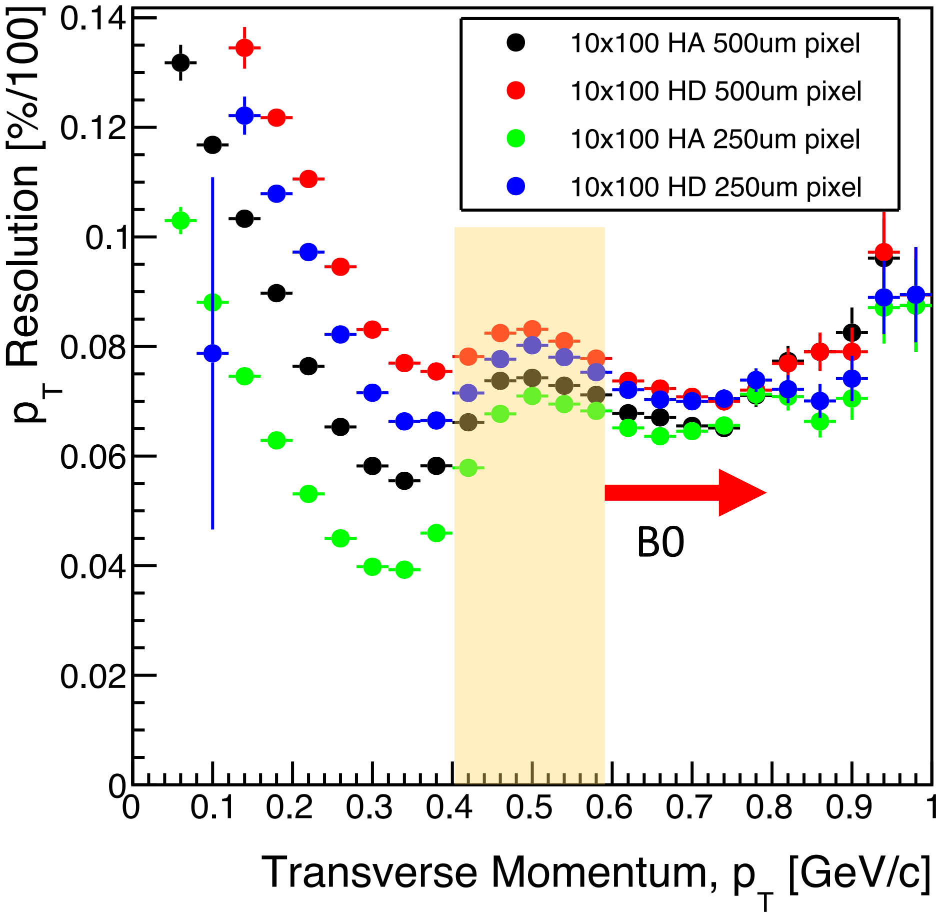
Physics process	Final State particles (for RP/OMD)	Required resolutions	Acceptance	Notes
Spectator tagged e+d breakup	Protons	$\frac{\Delta p_T}{p_T} < 10\ \%\ @\ p_T \sim 1\ GeV/c$	$p_T > 0.0\ GeV/c$	https://arxiv.org/pdf/2005.14706.pdf https://arxiv.org/abs/2108.08314
Deeply Virtual Compton Scattering	Protons	$\frac{\Delta p_T}{p_T} < 10\ \%\ @\ p_T \sim 1\ GeV/c$	$p_T > 0.18\ GeV/c$	
Incoherent vetoing of e+A events	Protons	N/A	N/A	https://arxiv.org/abs/2108.01694
Spin asymmetries in He3	Protons	$\frac{\Delta p_T}{p_T} < 10\ \%\ @\ p_T \sim 1\ GeV/c$	$p_T > 0.0\ GeV/c$	https://arxiv.org/pdf/2106.08805

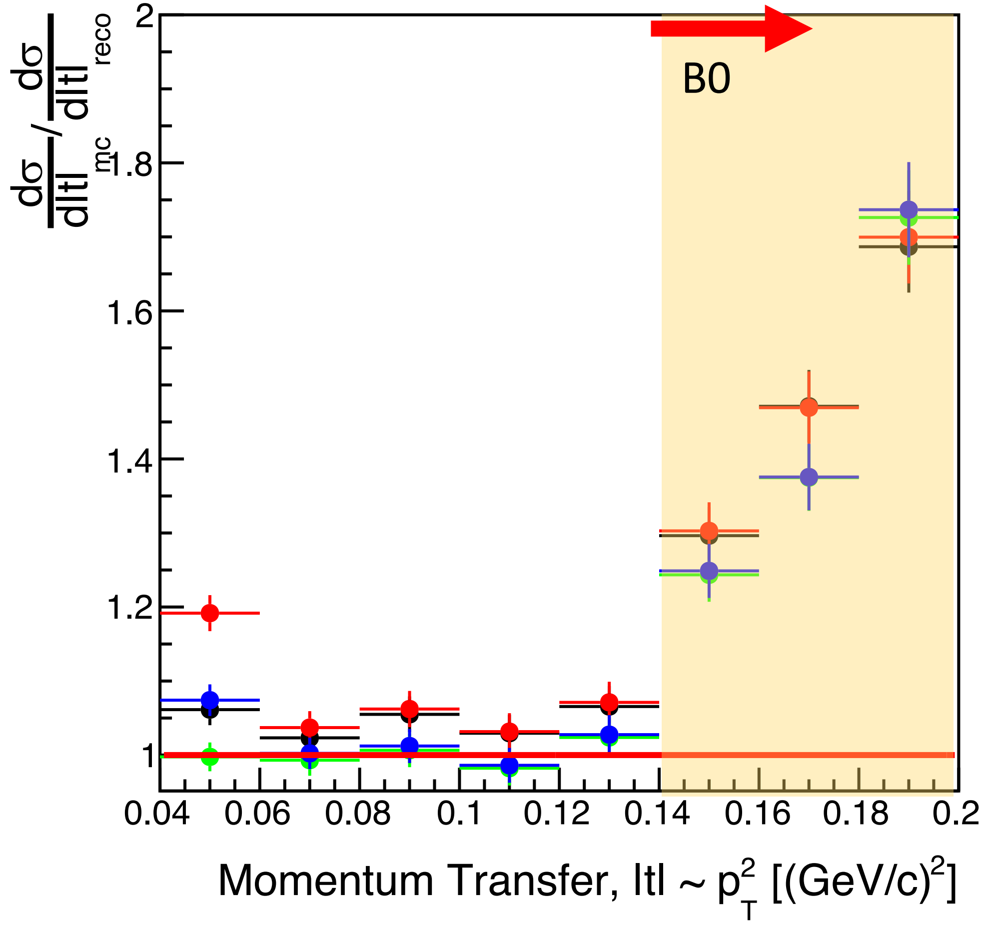
- **To achieve the above resolutions, the sensors must meet the following requirements:**
  - Spatial resolution (x and y) < 140 um.
  - Timing resolution ~ 35ps.
  - Material budget ~ 5% X0, or less.

Next Steps

- **This week:**
  - Look into the same study using DD4HEP setup with beam effects in initial files.
  - Use postburner to remove beam effects for TrueMC + Reco comparison.
  - Summarize final set of requirements and upload to Wiki.

Detailed Momentum Resolution - 10x100 GeV



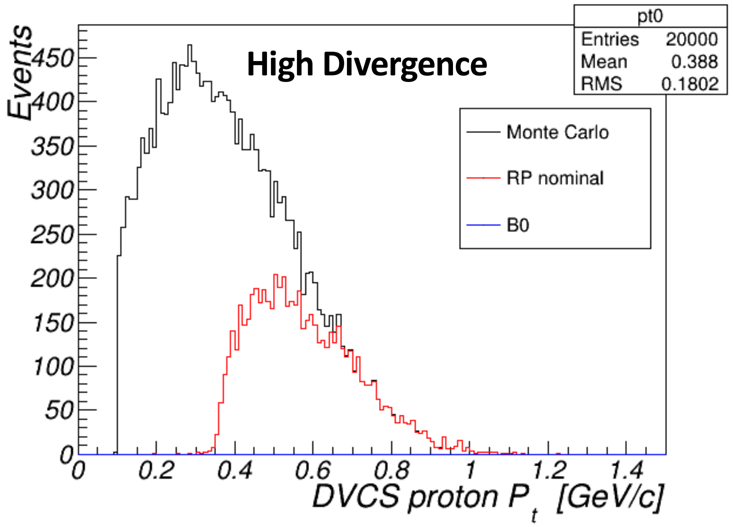


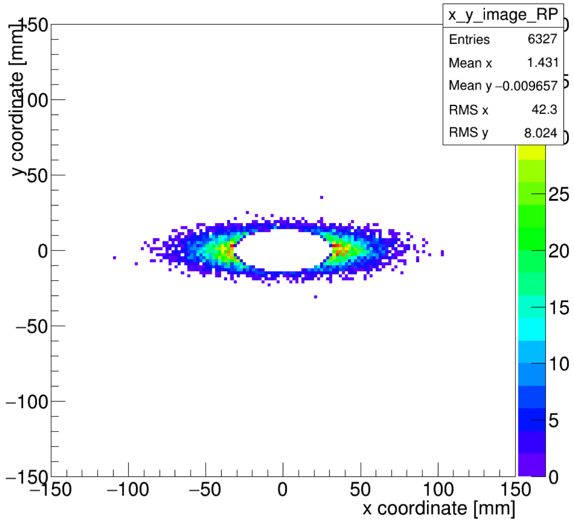
- **Yellow shaded area** is the acceptance gap between the RP and B0 detectors.
- No acceptance correction is applied here.

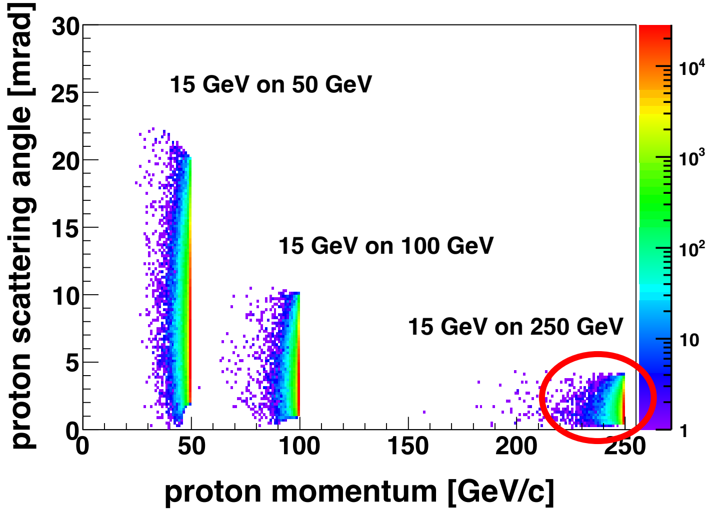
- Zoom-in to relevant RP range.
- Since angular divergence is smaller in the 100 GeV beam, the spatial resolution has a larger impact.

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

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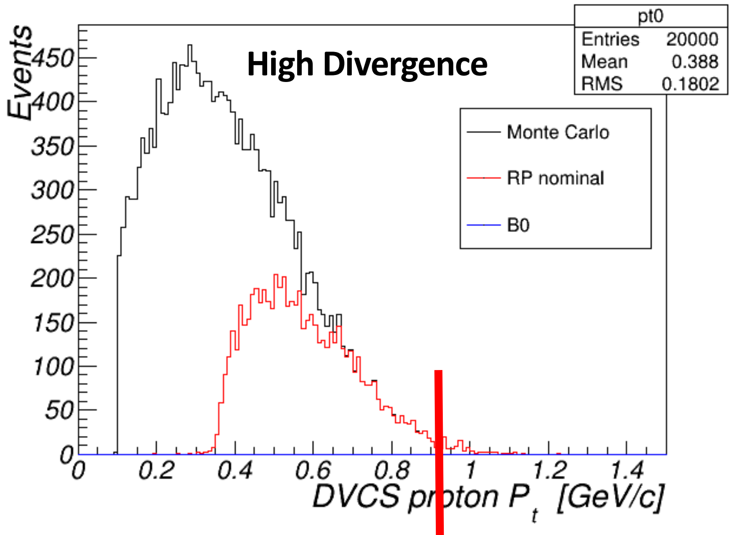
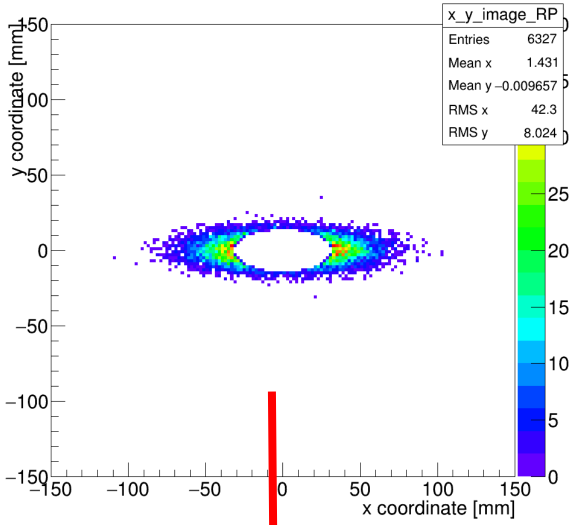
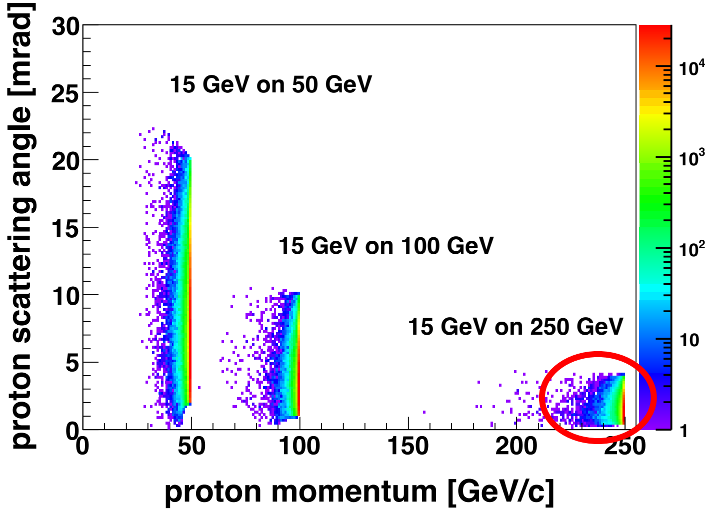
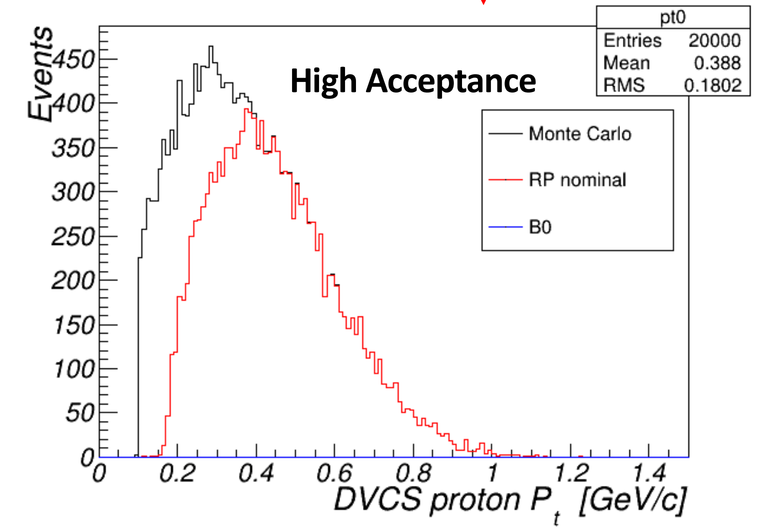
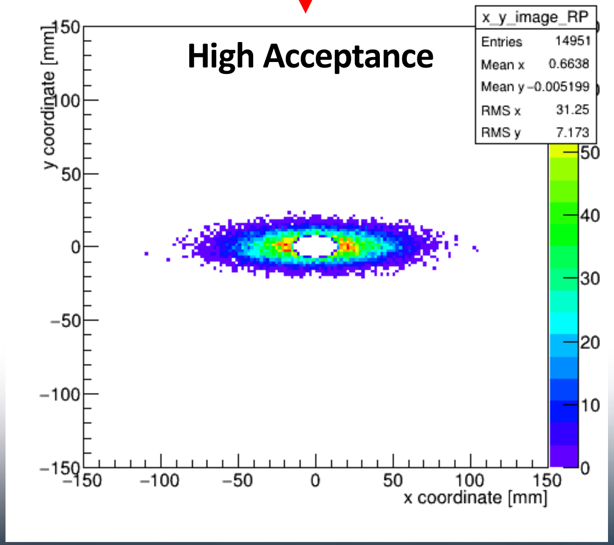








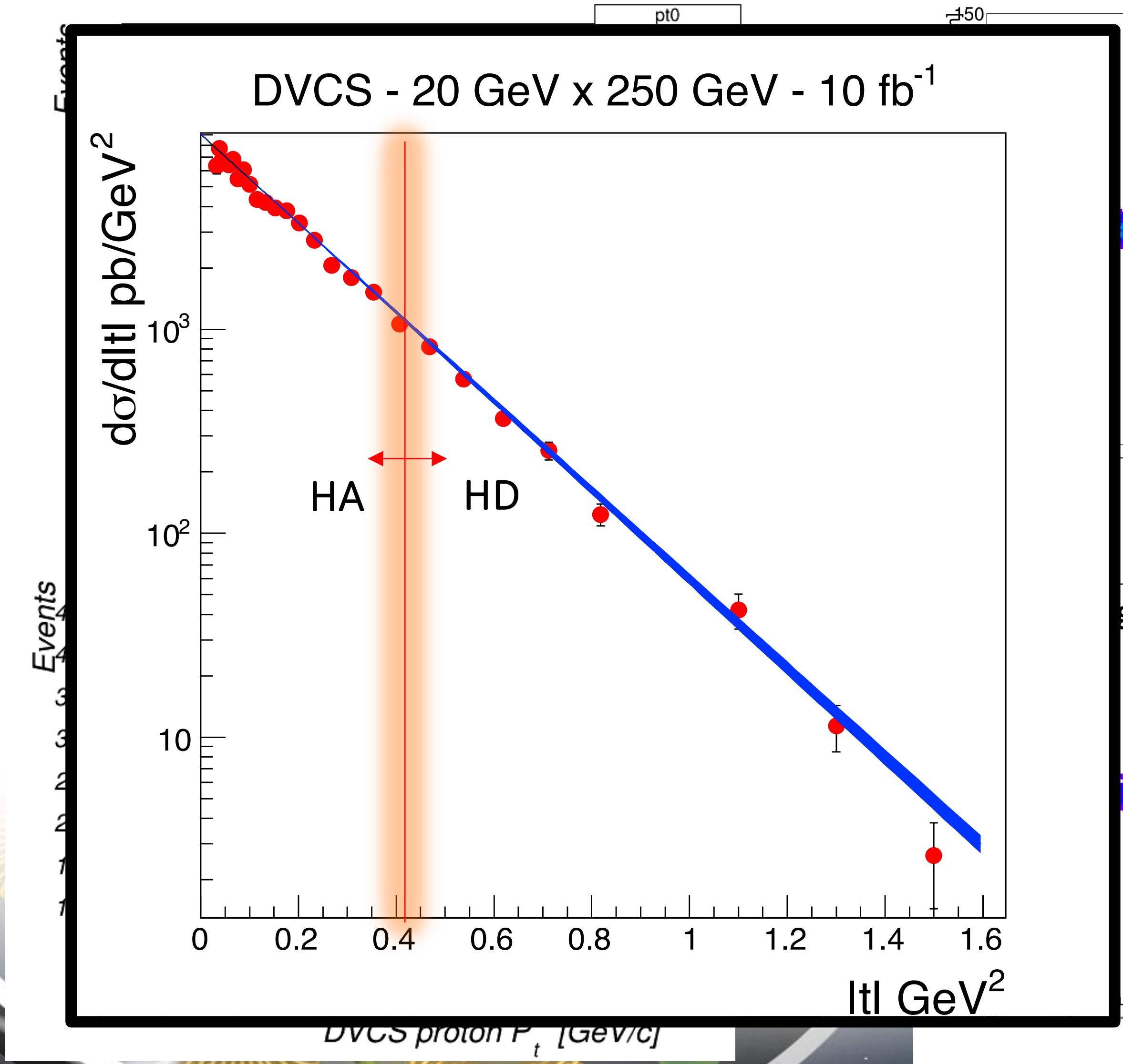


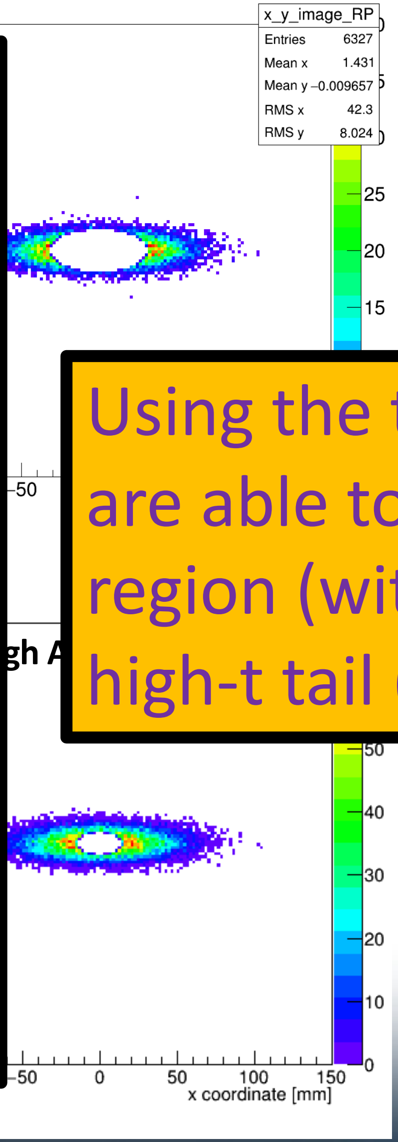
High Divergence: smaller β^* at IP, but bigger $\beta(z = 30m)$ -> higher lumi., larger beam at RP

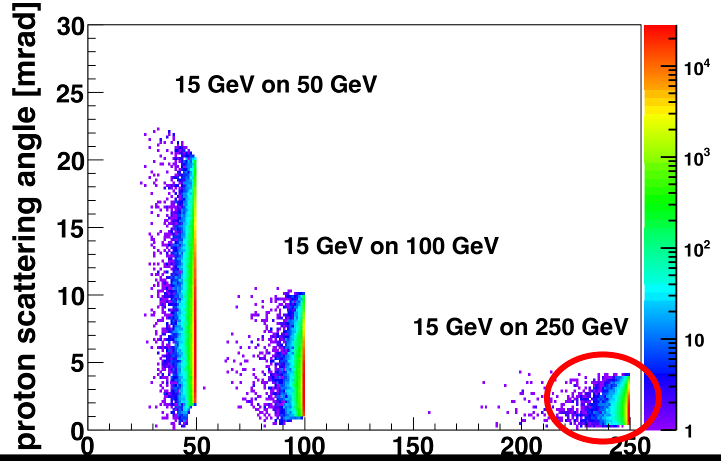
High Acceptance: larger β^* at IP, smaller $\beta(z = 30m)$ -> lower lumi., smaller beam at RP

Digression: Machine Optics

275 GeV DVCS Proton Acceptance





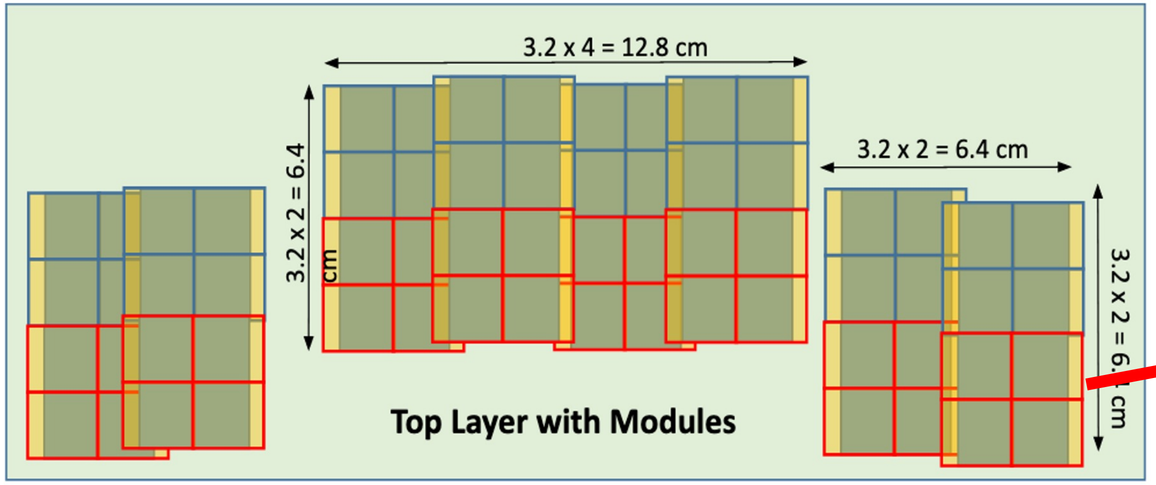


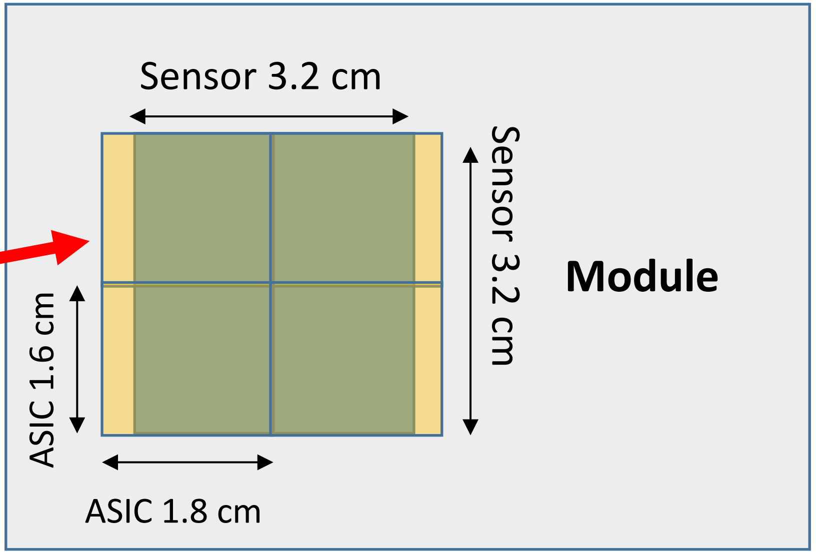
Using the two configurations, we are able to measure the low-t region (with better acceptance) and high-t tail (with higher luminosity).

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

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