OLYMPUS GEM Luminosity Monitors

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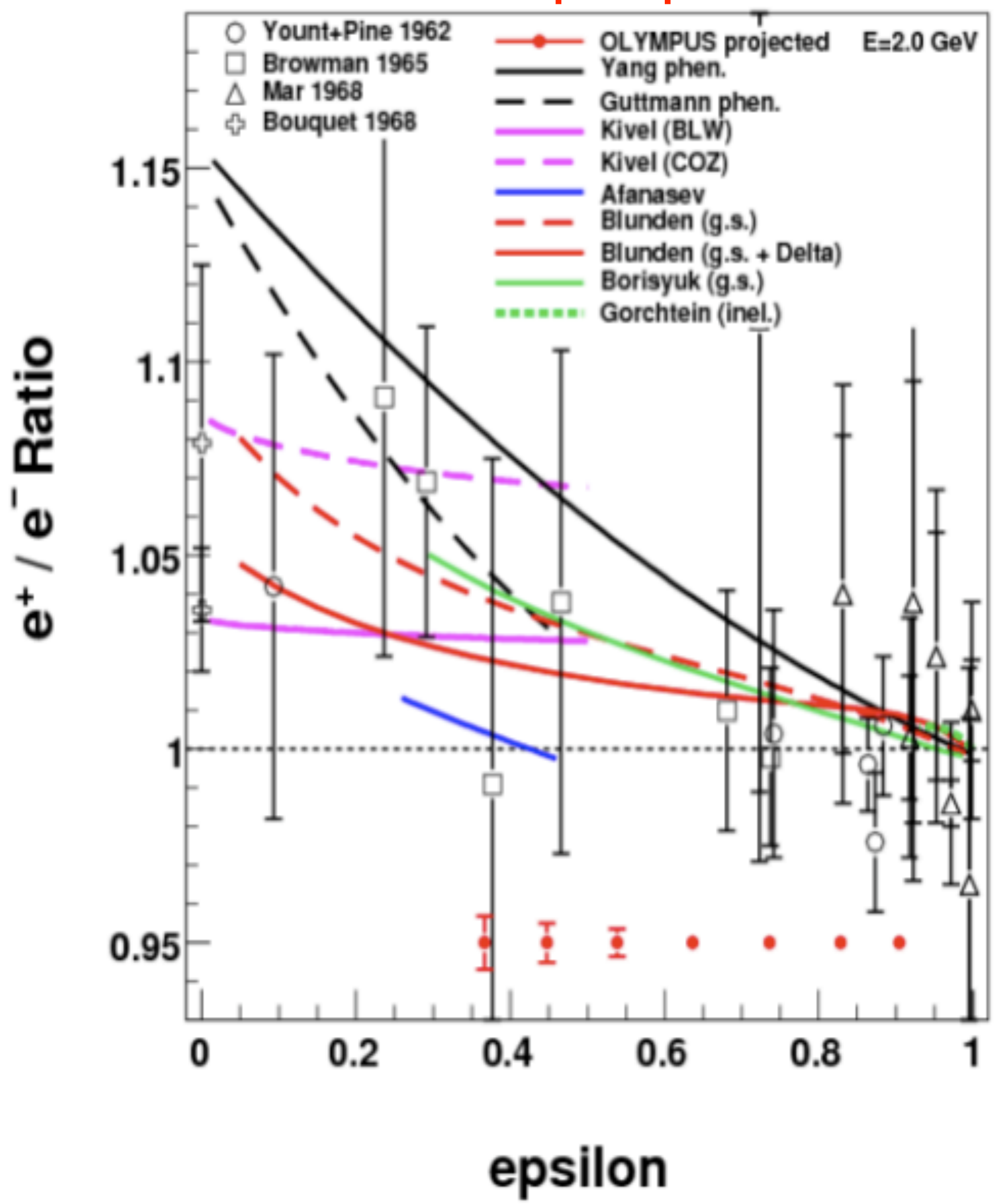
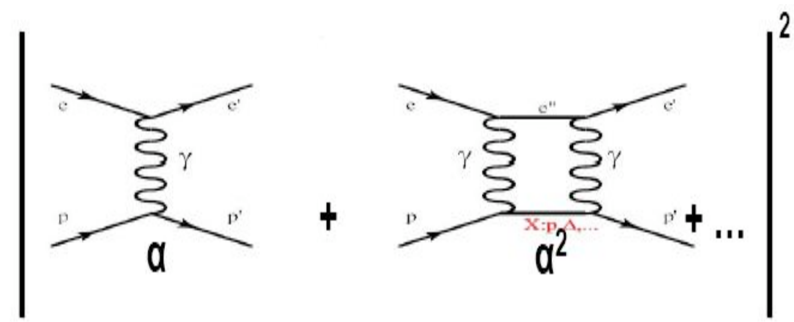
- The OLYMPUS Experiment
- 12-degree GEM Luminosity Measurements
- Detector Performance: Resolutions and Efficiencies
- Trigger Efficiencies of the 12-degree Lumi System
- 2D Comparison Plots: (GEMs vs MWPCs) and (Protons vs Leptons)

The Motivation of The OLYMPUS Experiment

Elastic e^+-p /e^--p Ratio



Two-photon exchange theoretically suggested :
Interference of one- and two-photon amplitudes



$$\sigma = (1\gamma)^2\alpha^2 + (1\gamma)(2\gamma)\alpha^3 + ...$$

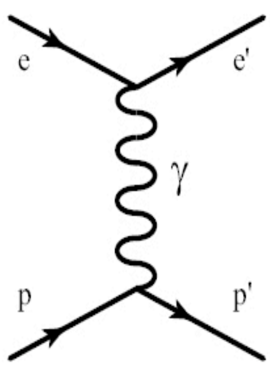
$$e^- \Longleftrightarrow e^+ \Rightarrow \alpha \Longleftrightarrow -\alpha$$

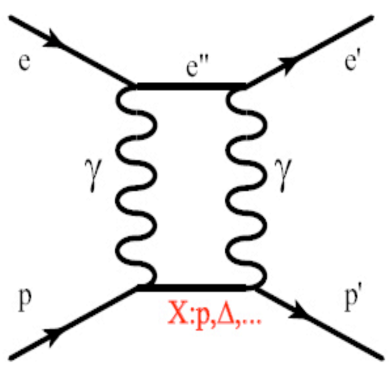
→ Measure ratio of positron-proton to electron-proton unpolarized elastic scattering to 1% Precision!! in stat.+sys.

The OLYMPUS Experiment at DESY

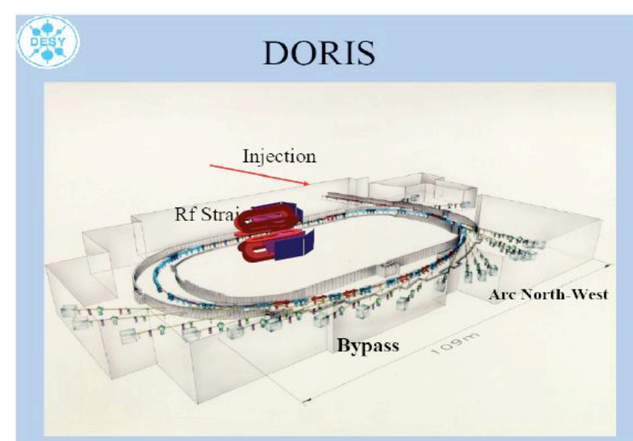
- Electrons/positrons (100mA) in multi-GeV storage ring
  DORIS at DESY, Hamburg, Germany
- OLYMPUS prepared at DORIS/DESY since 2010.
- Took full data set in 2012 with two periods.
- Comparison of $e^{+}p$ and $e^{-}p$ elastic scattering

  to study the effect of “Two Photon Exchange”.

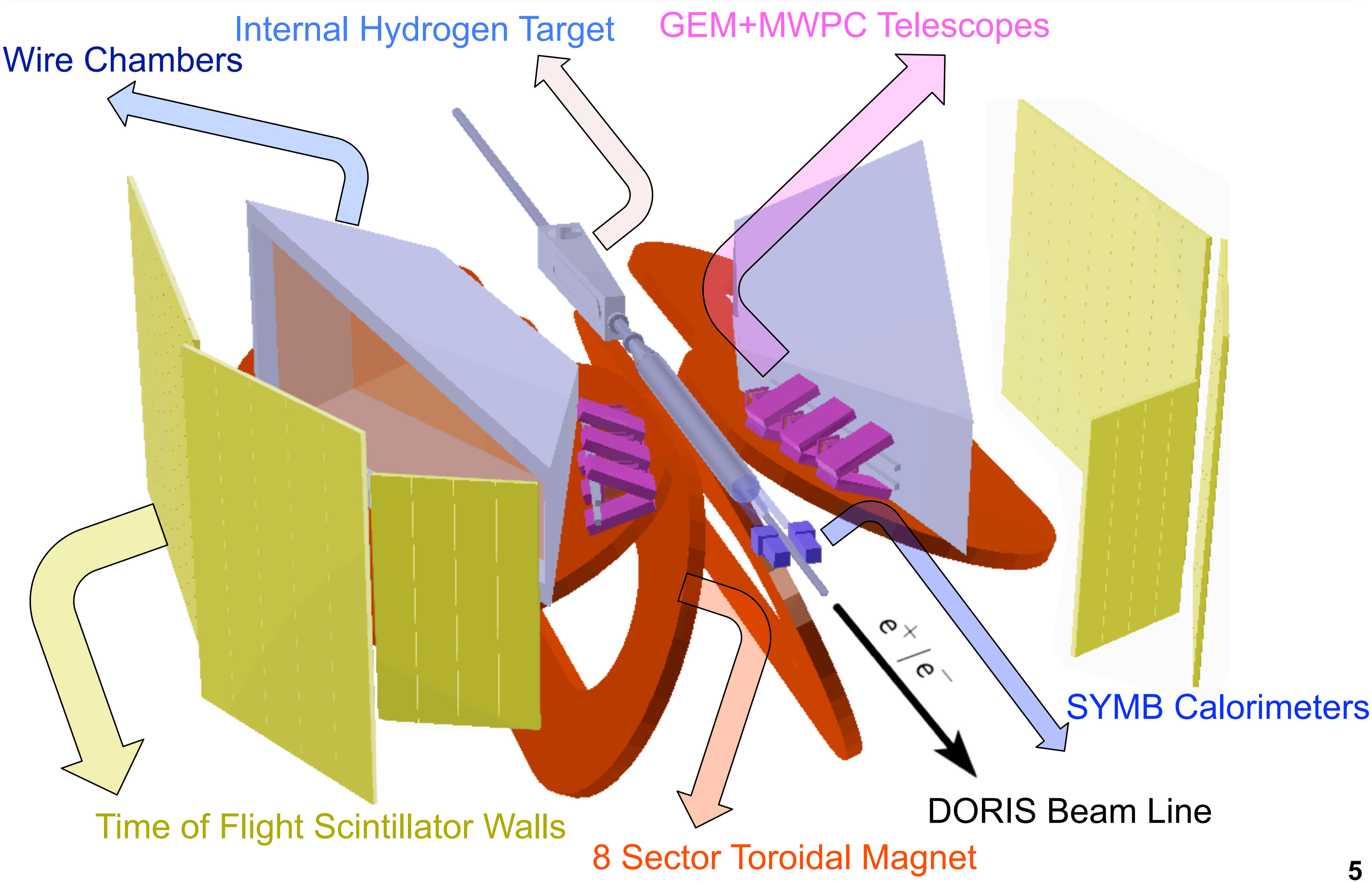




DORIS Electron/Positron Storage Ring



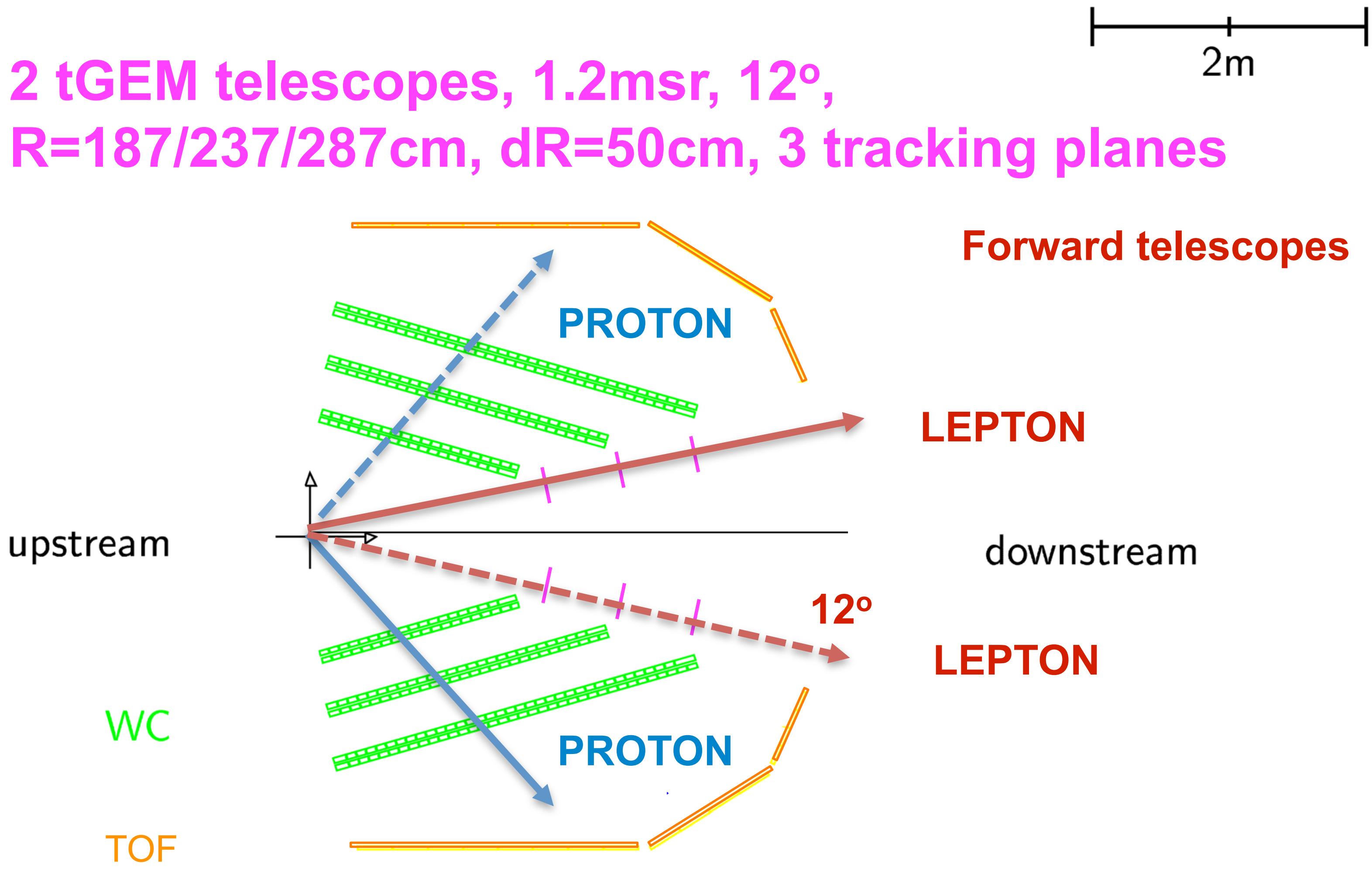
The OLYMPUS Experiment

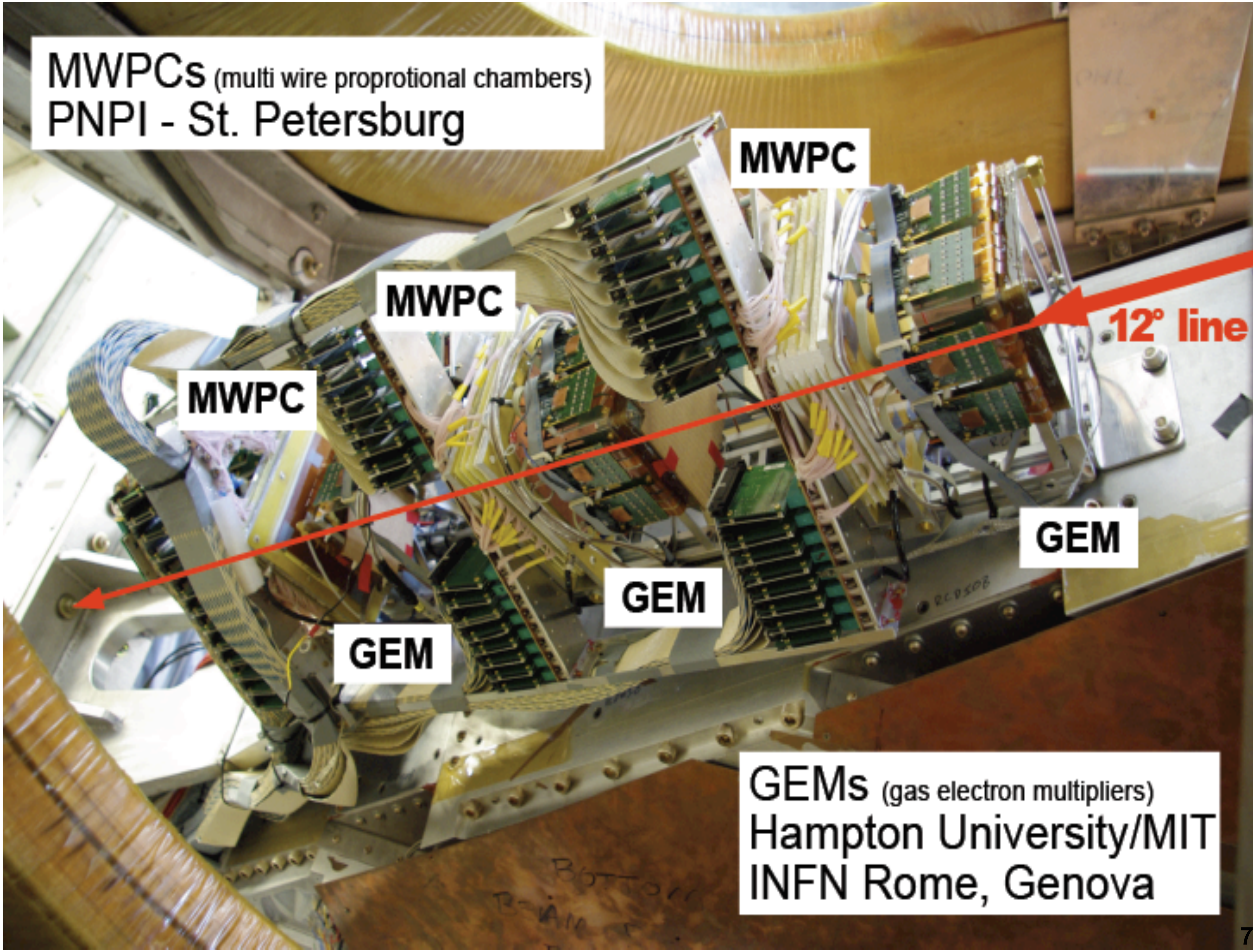


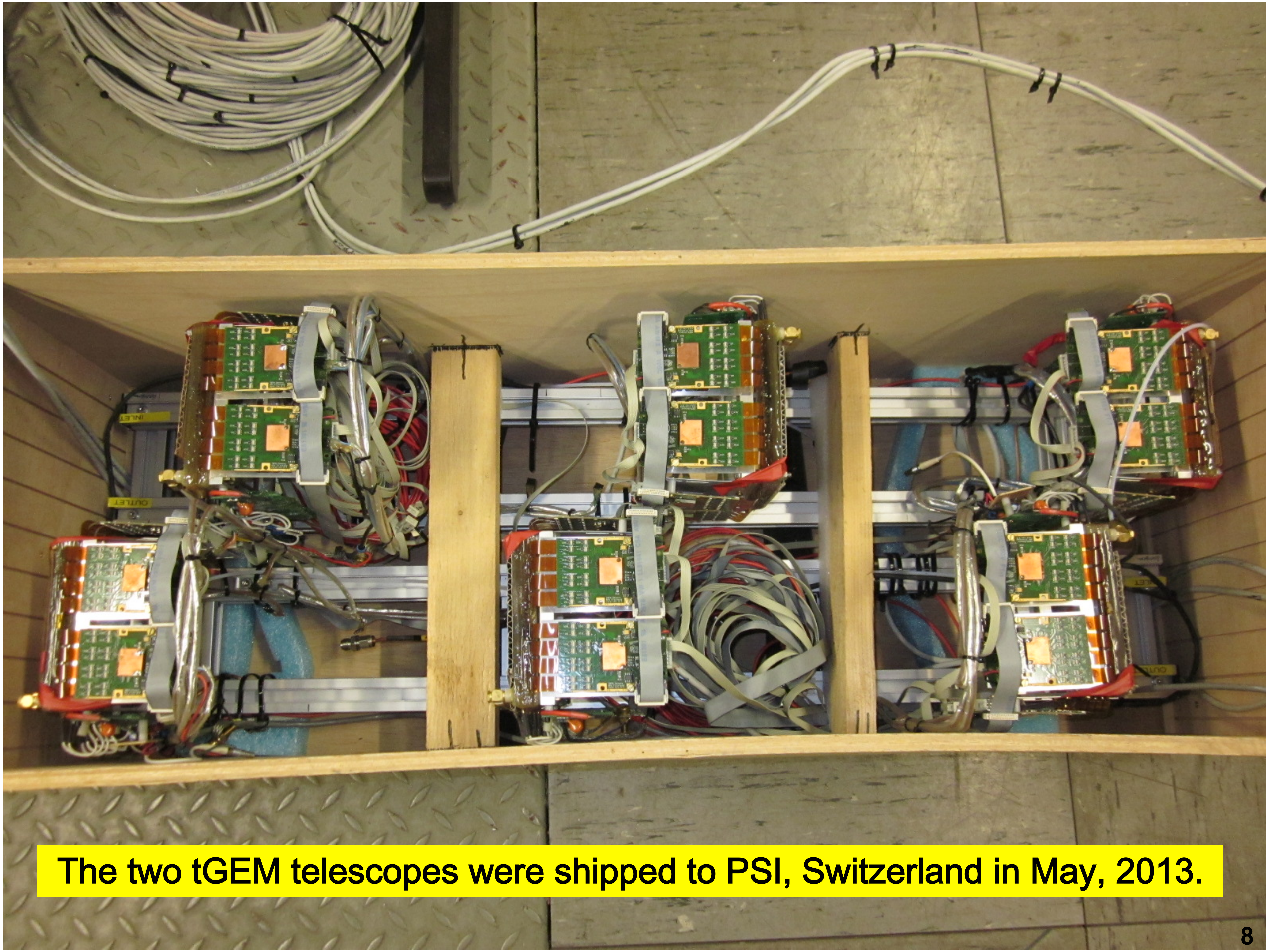
GEM LUMINOSITY MONITORS

"Luminosity monitors for LEPTON in coincidence with Recoil PROTON detected in the opposite sector, and vice versa"

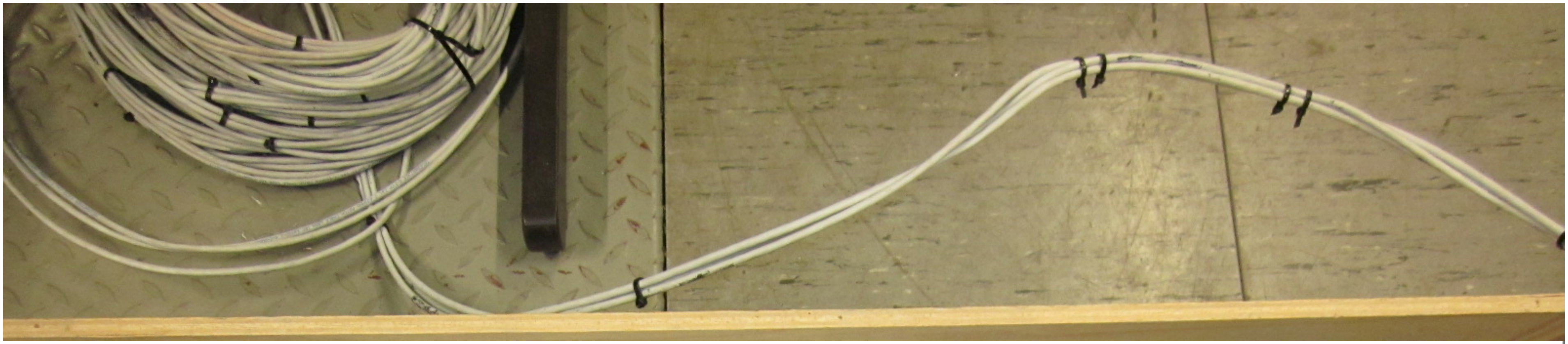
2 tGEM telescopes, 1.2msr, 12°, R=187/237/287cm, dR=50cm, 3 tracking planes



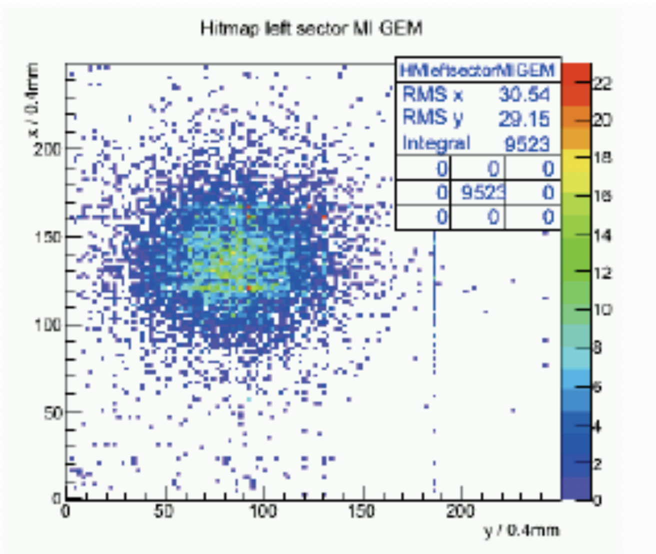

MWPCs (multi wire proprotional chambers)
PNPI - St. Petersburg
MWPC
MWPC
MWPC
12° line
GEM
GEM
GEM
GEMs (gas electron multipliers)
Hampton University/MIT
INFN Rome, Genova

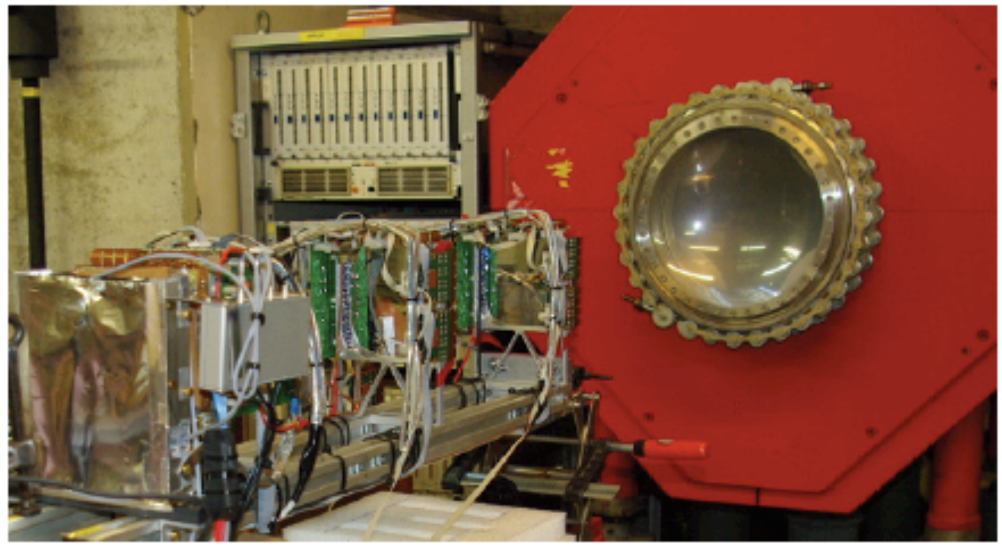


The two tGEM telescopes were shipped to PSI, Switzerland in May, 2013.



Beam spot with GEM telescope – May 20, 2013 (!) at PSI





They are being used for beam particle trajectories.

Luminosity Monitoring

Triple Ratio:

Run the Experiment for the 2 beam particles: e^- and e^+

Frequent switching between e+ and e- to reduce systematics

$$\frac{\sigma_{e^+}}{\sigma_{e^-}} = \left[\frac{N_{e^+}}{N_{e^-}} \Big/ \left(\frac{L_{e^+}}{L_{e^-}} \cdot \frac{A_{e^+}}{A_{e^-}} \right) \right]$$

Ratio of counts

Ratio of luminosities

Ratio of acceptances

- Forward-angle (high-epsilon, low-Q) elastic scattering means that the effect of two-photon exchange is minimal, hence cross sections: ($\sigma_{e+} \approx \sigma_{e-}$)
- Two Telescopes: Left-right symmetry = Redundancy

Extracting 12-degree Luminosity

STEP 1
(Acceptance integrated differential cross-sections)

$$\sigma_{\exp(e^{\pm})} = \frac{N_{\exp(e^{\pm})}}{L_{sc(e^{\pm})}} \qquad \sigma_{MC(e^{\pm})} = \frac{N_{MC(e^{\pm})}}{L_{sc(e^{\pm})}}$$

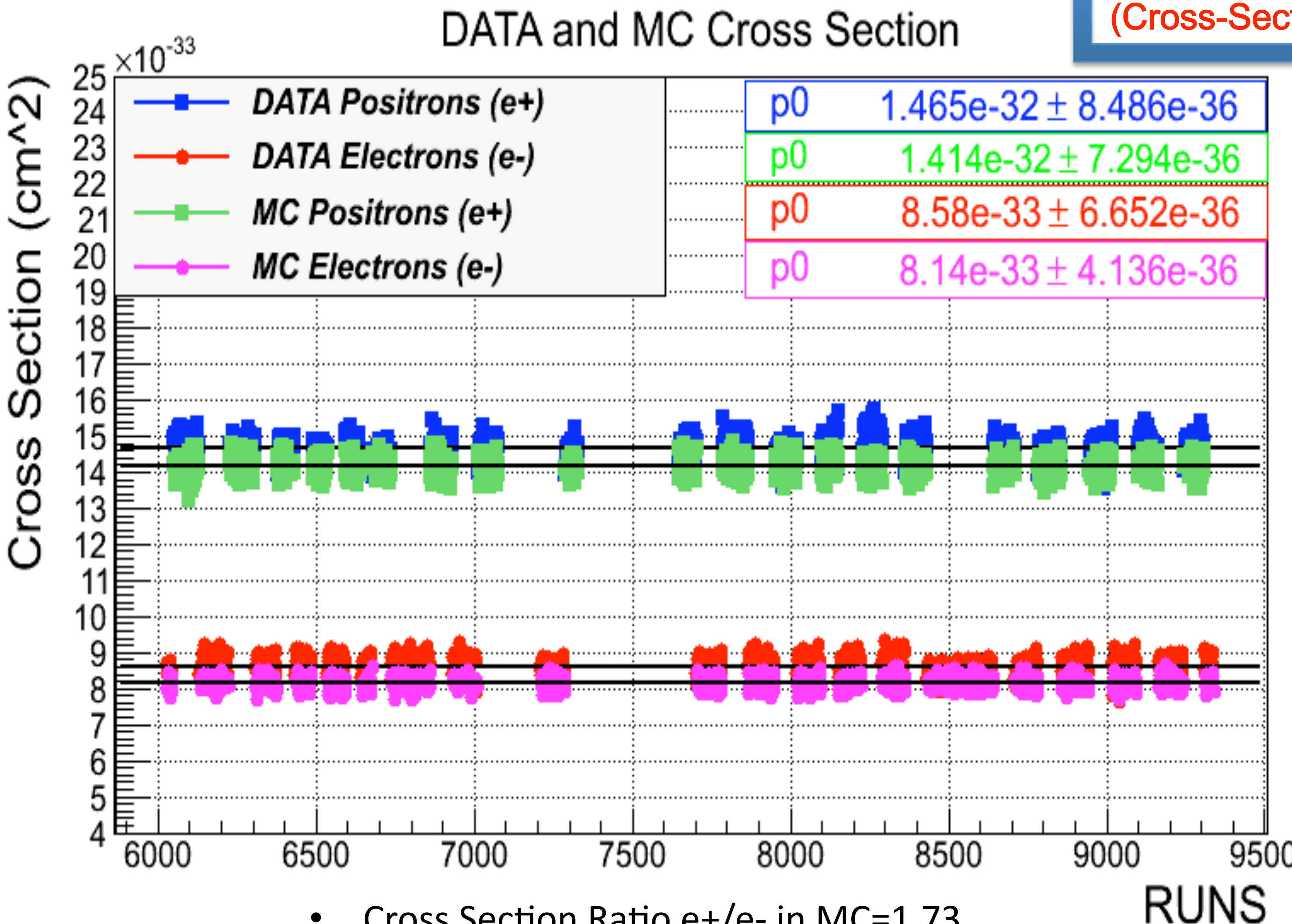
STEP 2
(Luminosity)

$$L_{\exp(e^{\pm})} = \frac{N_{\exp(e^{\pm})}}{\sigma_{MC(e^{\pm})}}$$

STEP 3
(Comparing luminosity or accepted cross-sections)

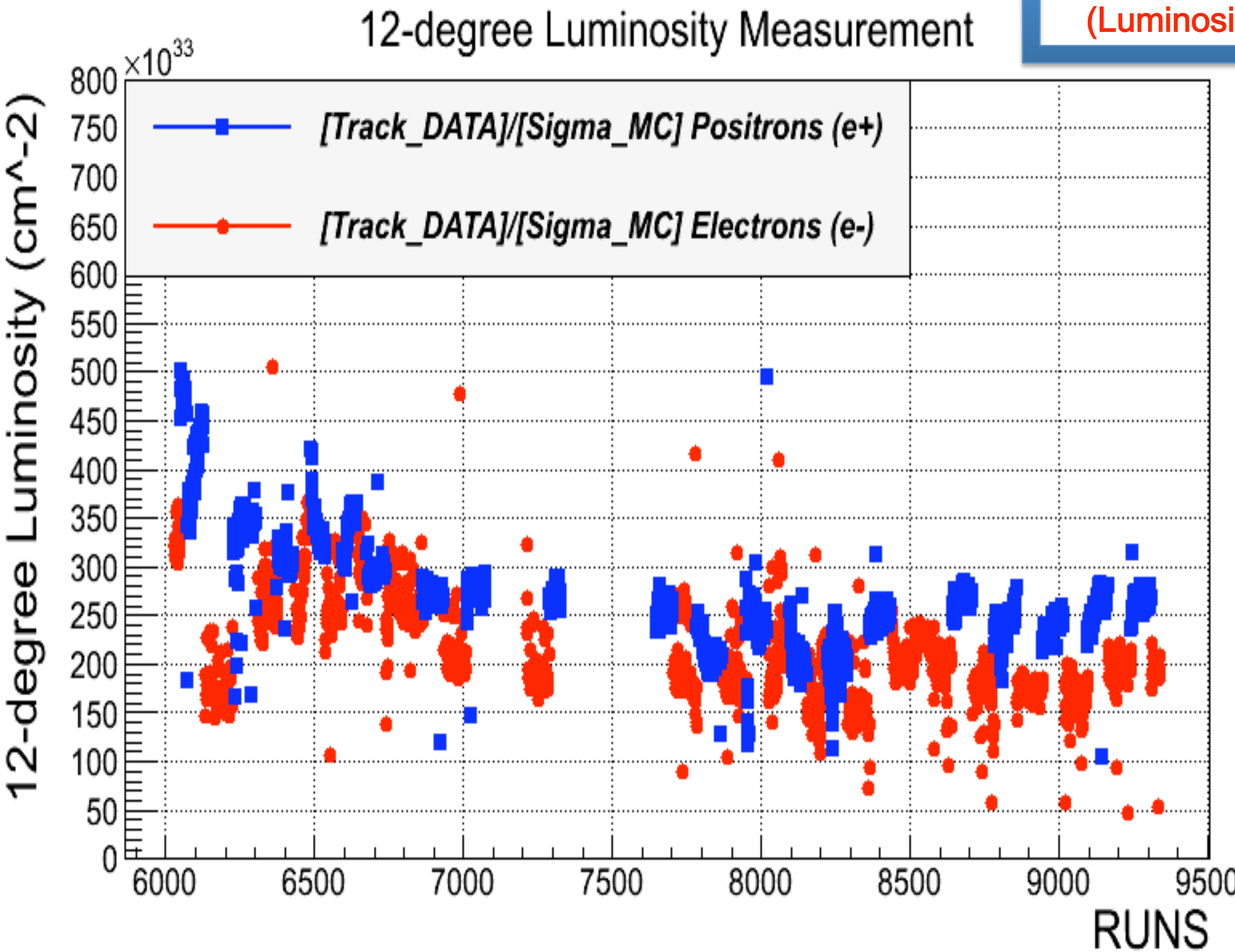
$$\frac{L_{\exp(e^{\pm})}}{L_{SC(e^{\pm})}} = \frac{\sigma_{\exp(e^{\pm})}}{\sigma_{MC(e^{\pm})}} = \frac{\left(N_{\exp(e^{\pm})}/L_{SC(e^{\pm})}\right)}{\sigma_{MC(e^{\pm})}} = \frac{N_{\exp(e^{\pm})}}{\left(\sigma_{MC(e^{\pm})}/L_{SC(e^{\pm})}\right)} = \frac{N_{\exp(e^{\pm})}}{N_{MC(e^{\pm})}}$$

STEP 1
(Cross-Sections)

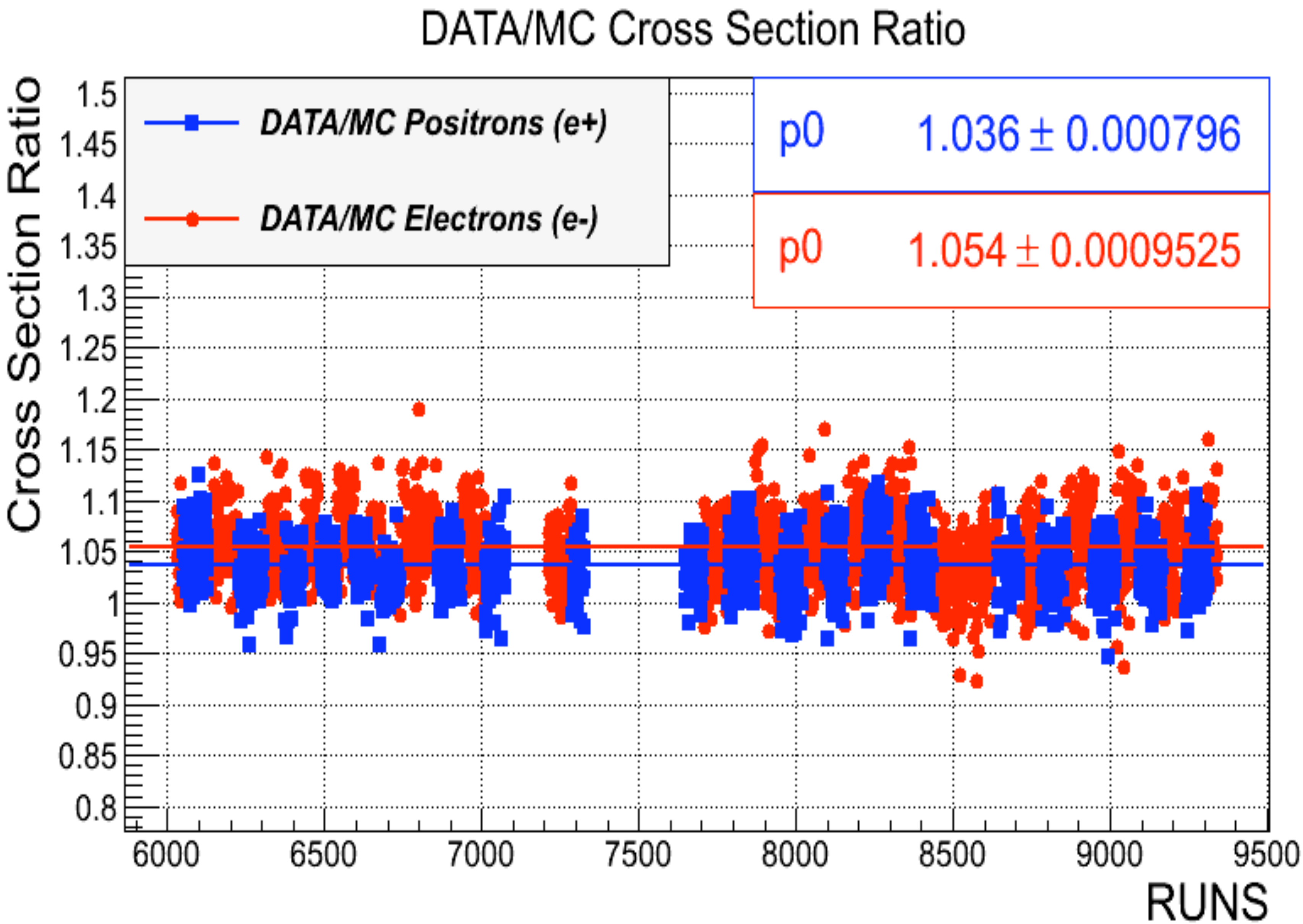


- Cross Section Ratio e+/e- in MC=1.73
- Cross Section Ratio e+/e- in DATA=1.70

STEP 2
(Luminosity)



STEP 3 ★
(Comparing Cross Sections)



The Method For Efficiencies

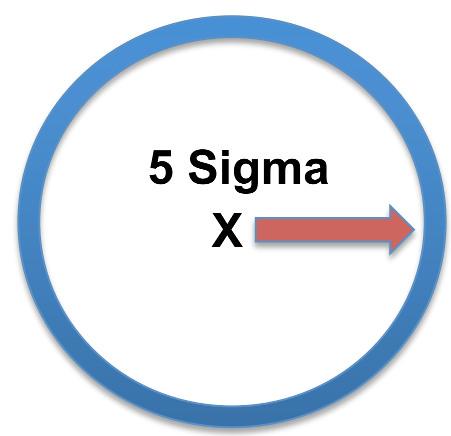
- Fitting 5 out of 6 elements together with MWPC chambers
- Vicinity search for the testing element within 5 "sigma" radius

if there is hit closer to track projection in the 2D areas.

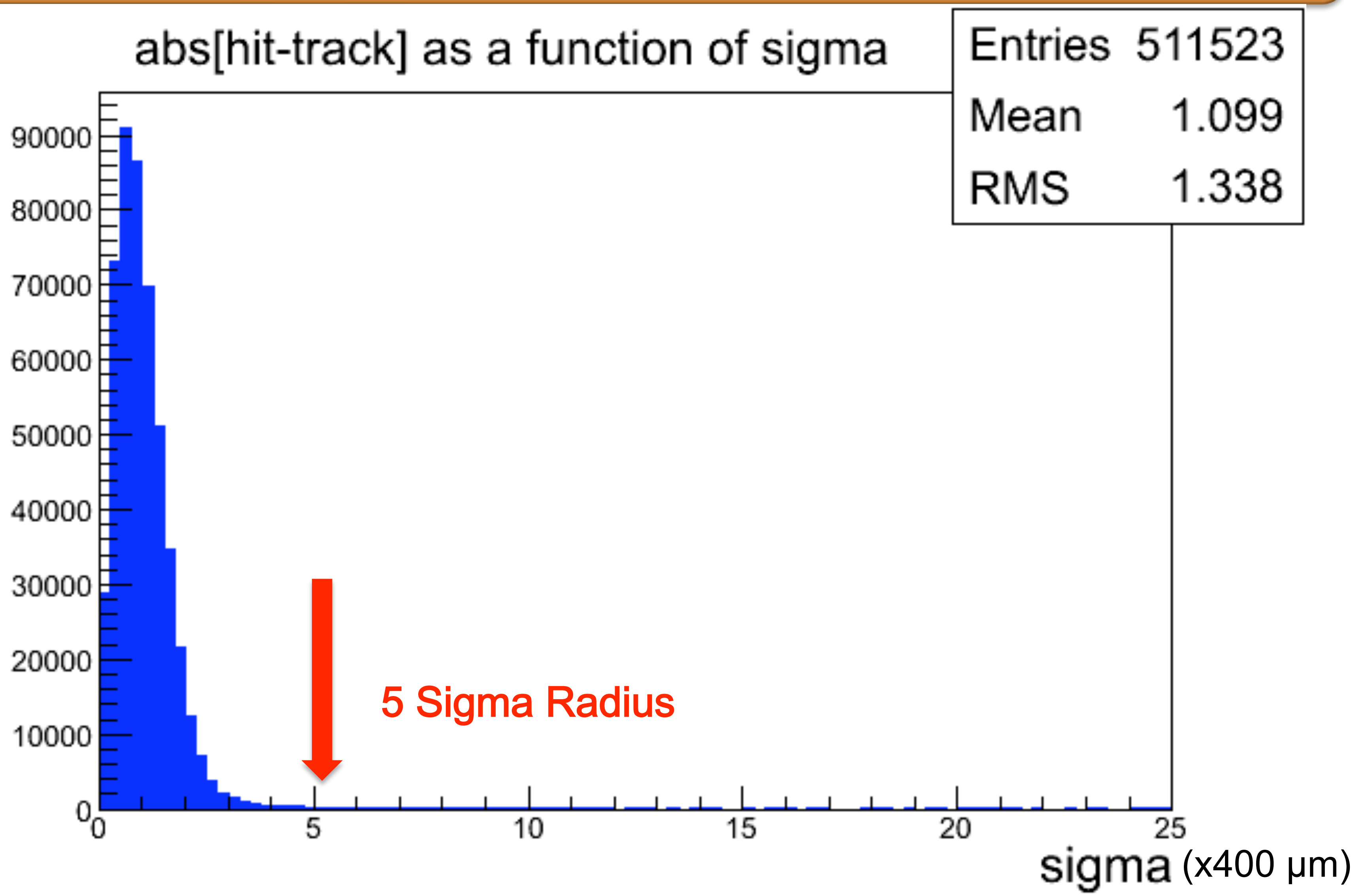
"sigma" = sigma of residual [hit-track]
about 400 μm.

- Binomial Probability

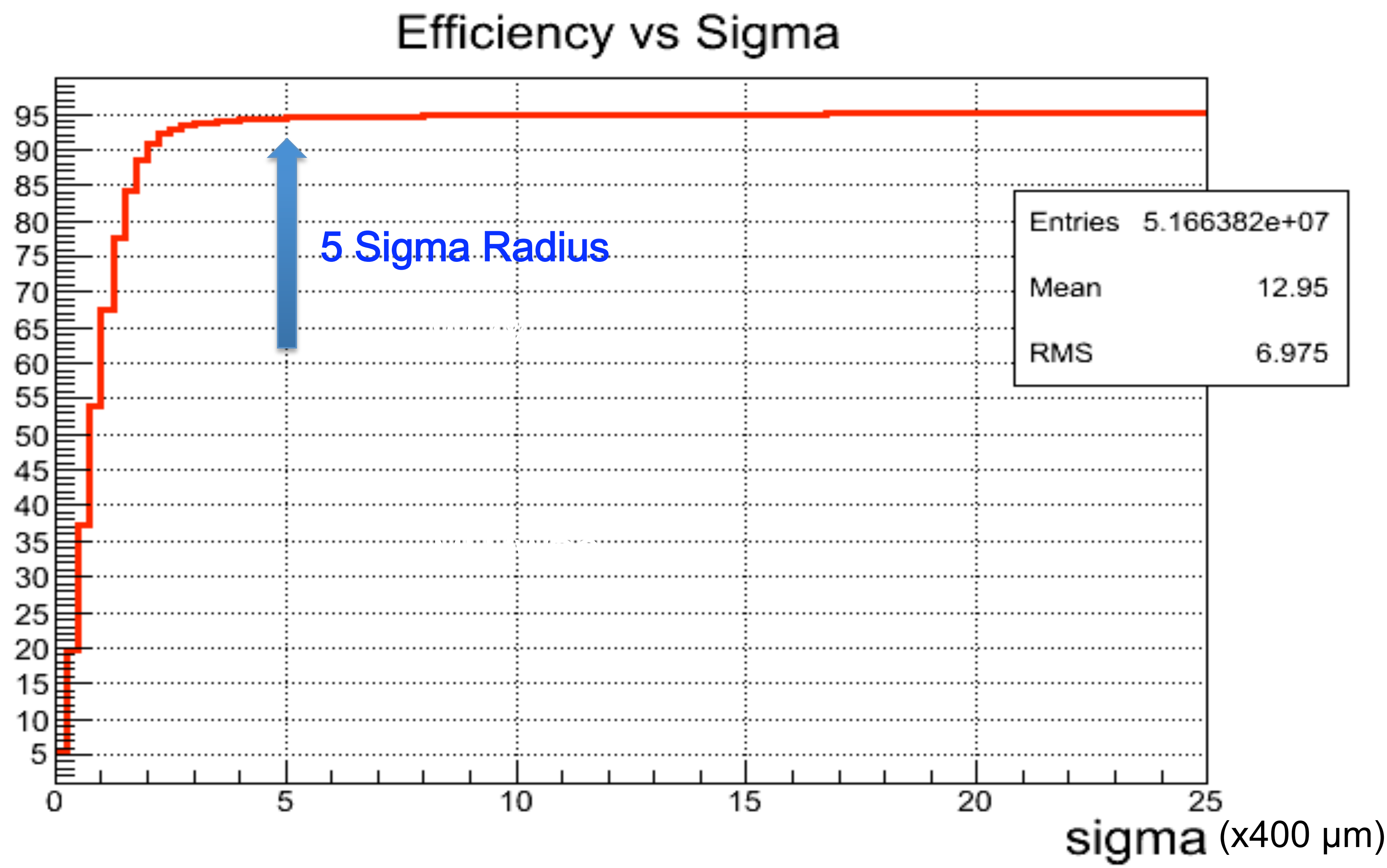
→ If detected (success)
→ If not seen (inefficiency)



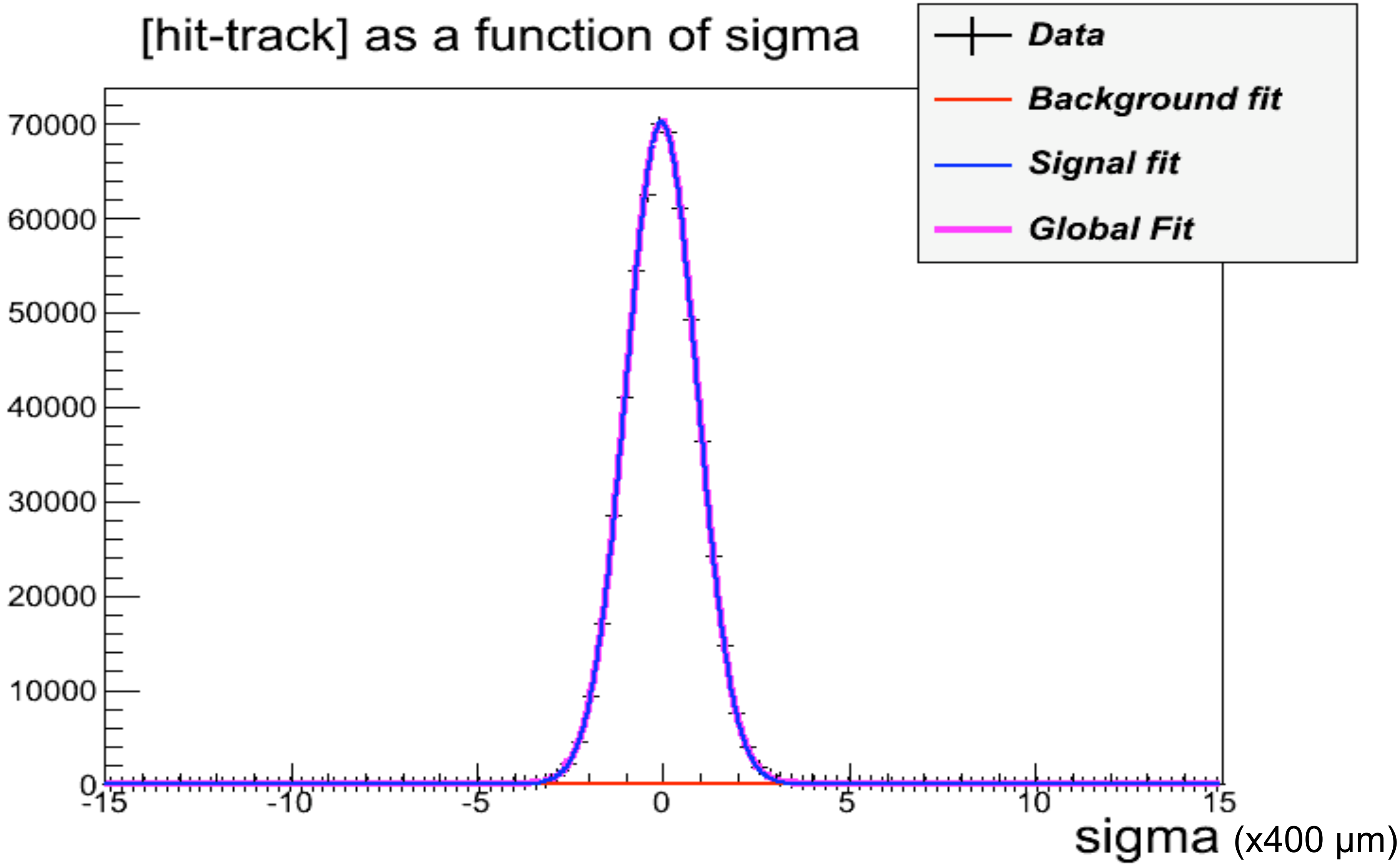
Sigma Radius (US GEM)



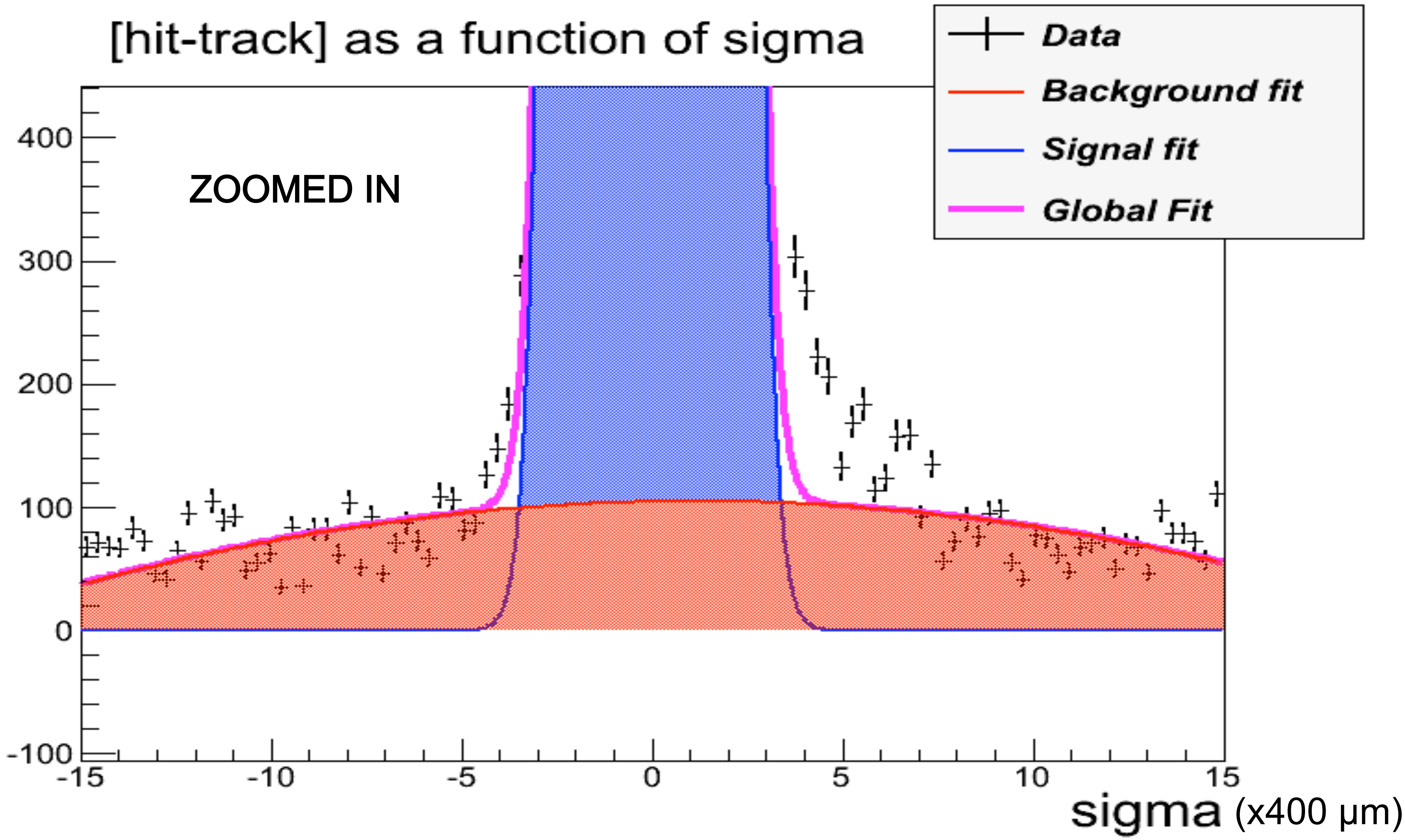
Observed Efficiency 95.8% (US GEM)



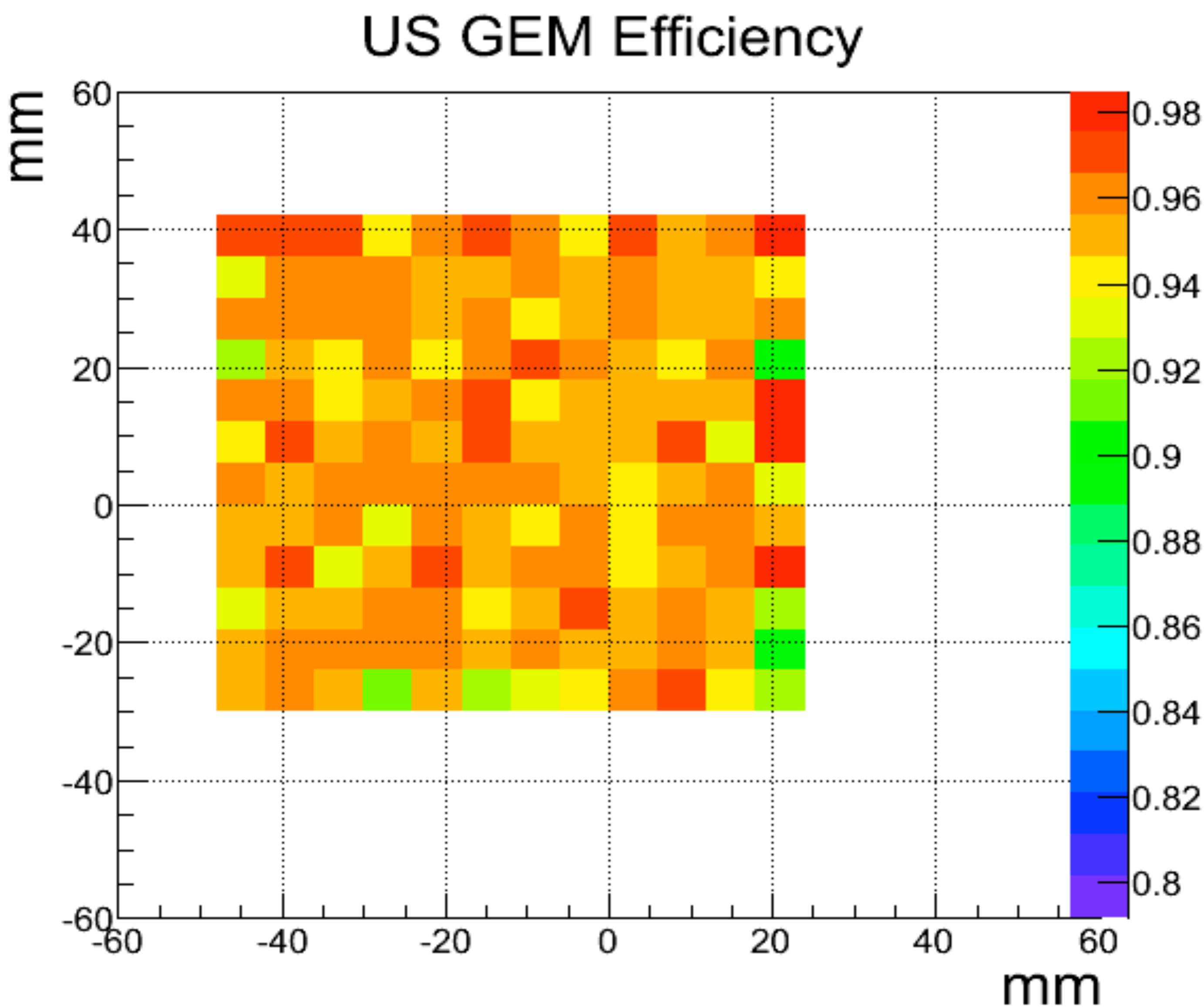
Residual [hit-track] of testing US GEM



Background corrected Efficiency
US GEM 95.5%

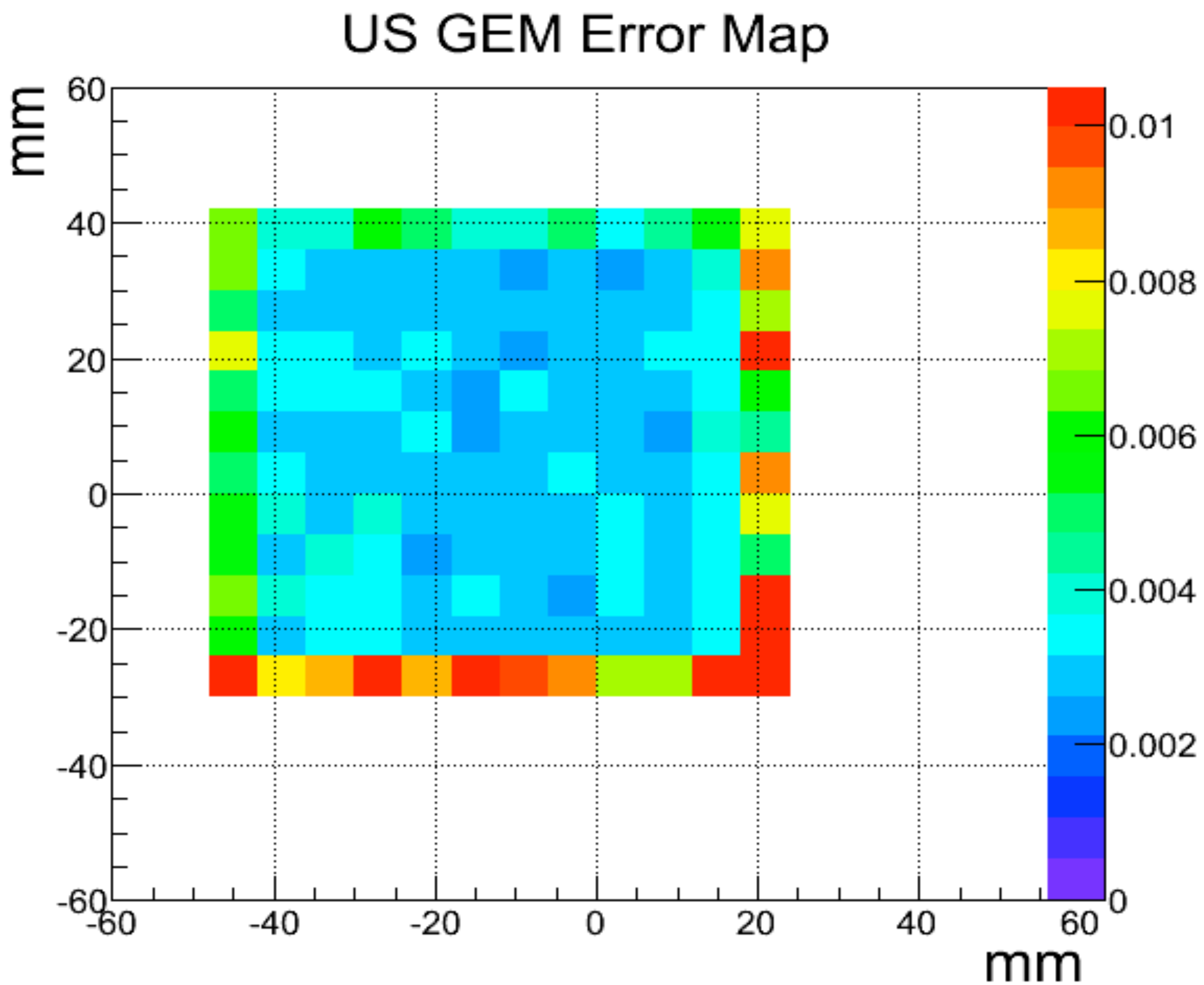


US GEM Efficiency Map 95.5%



Binomial Error corrected US GEM Efficiency

95.5% +/- 0.3%



Resolutions of the GEM and MWPC Detectors

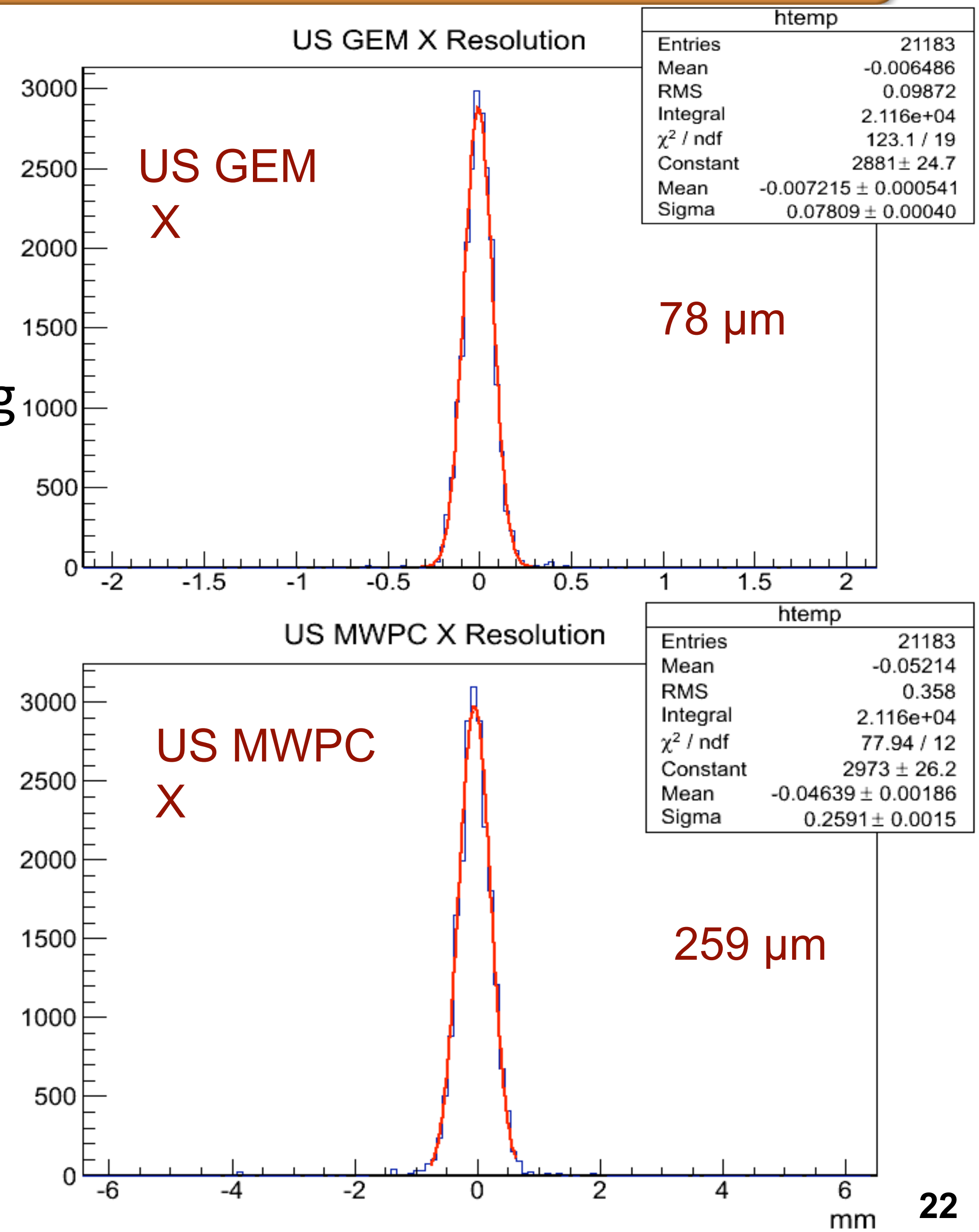
The Iterative Process:

- Fitting 5 out of 6 elements
- Varied the “weights” for tracking
- Used the formula:

$$(\sigma_{resi})^2=(\sigma_{i.reso})^2+(\sigma_{dtr})^2$$

→ resi = residual [hit – track]
→ i.reso = intrinsic resolution
→ dtr = track uncertainty

- The results are stable and similar for the other GEMs and MWPCs.



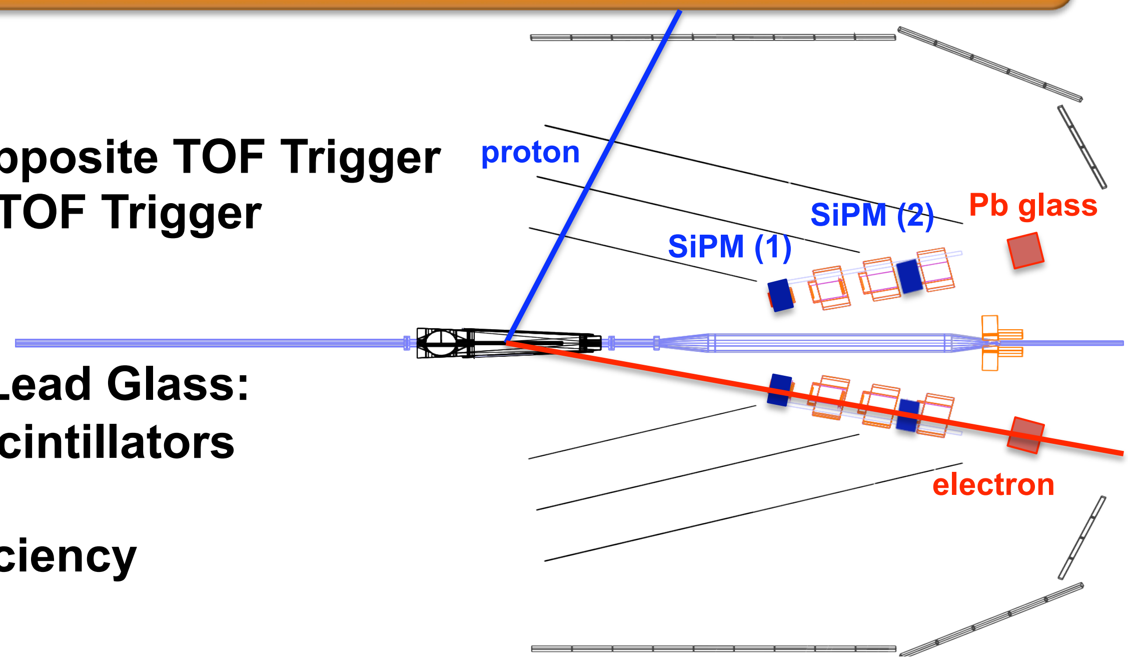
GEM Efficiency and Resolution Table

EFFICIENCIES ('%' percentage)	US GEM	MI GEM	DS GEM
LEFT SECTOR	96.0% +/- 0.3%	94.8% +/- 0.3%	95.8% +/- 0.4%
RIGHT SECTOR	95.5% +/- 0.3%	94.4% +/- 0.4%	96.2% +/- 0.4%

RESOLUTIONS ('µm' micrometer)	US GEM	MI GEM	DS GEM
LEFT SECTOR (X Axis)	76.0 +/- 0.5	78.8+/- 0.5	73.8 +/- 0.4
RIGHT SECTOR (X Axis)	78.0 +/- 0.4	74.4+/- 0.5	72.1+/- 0.3

12-degree Trigger Efficiencies for Right Sector

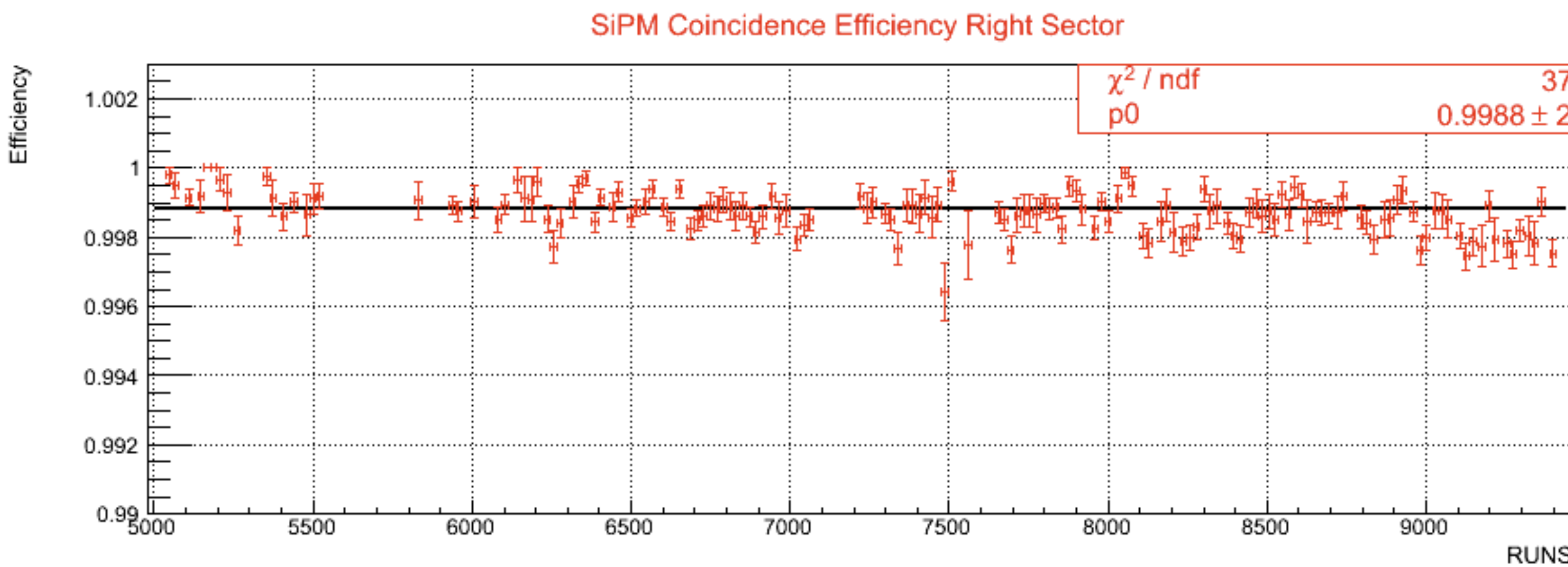
The Two Alternative Lumi Events:
- **Lumi Trigger (Coinc. SiPM) & Opposite TOF Trigger**
- **Lead Glass Trigger & Opposite TOF Trigger**



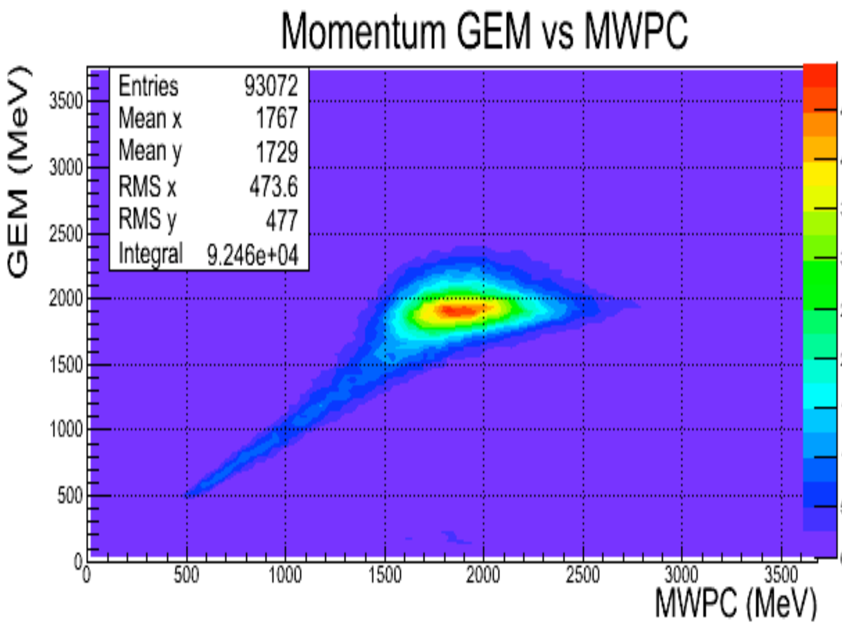
Trigger Efficiency Monitoring by Lead Glass:
- **Project Tracks onto 12-degree Scintillators**

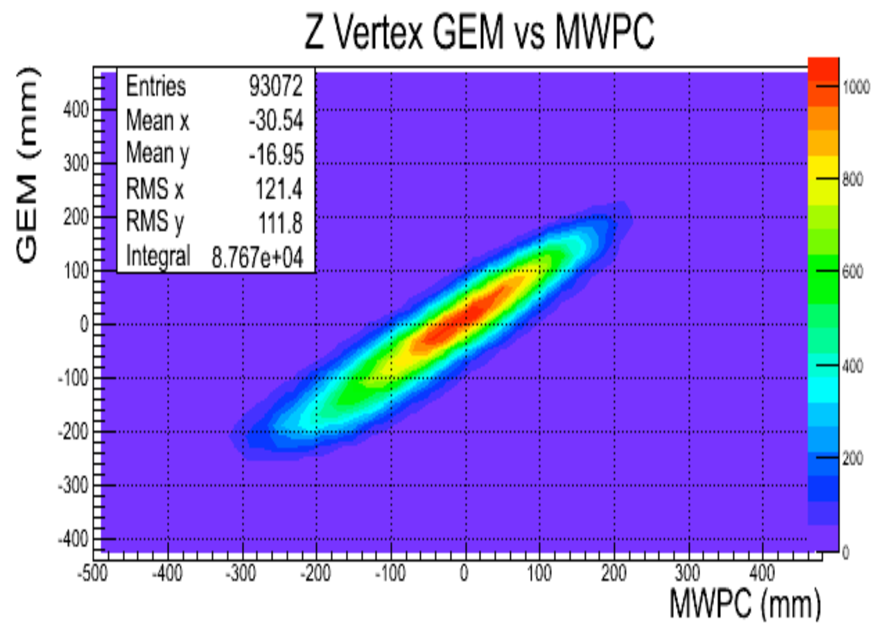
→ Lumi Trigger Fired = Efficiency

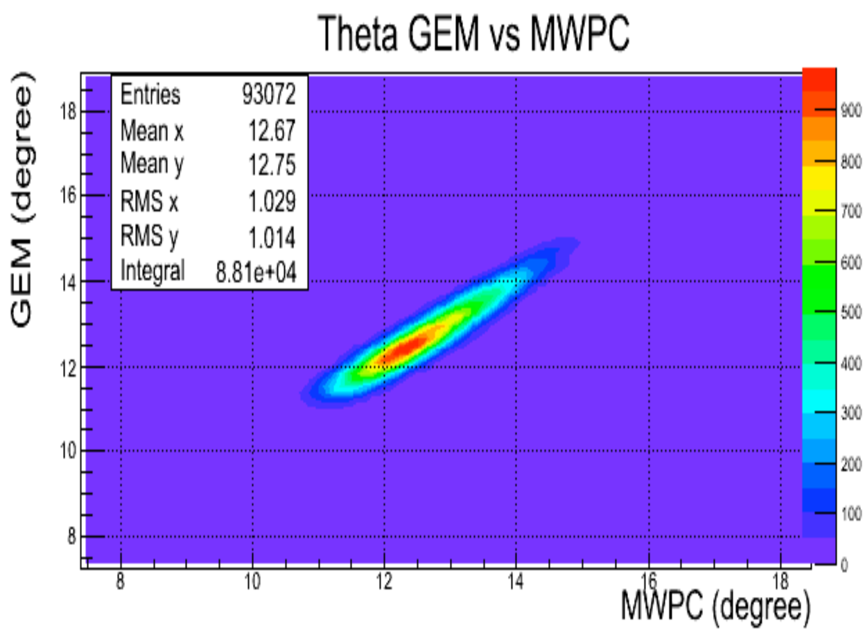
→ If Missing Lumi Trigger = Inefficiency

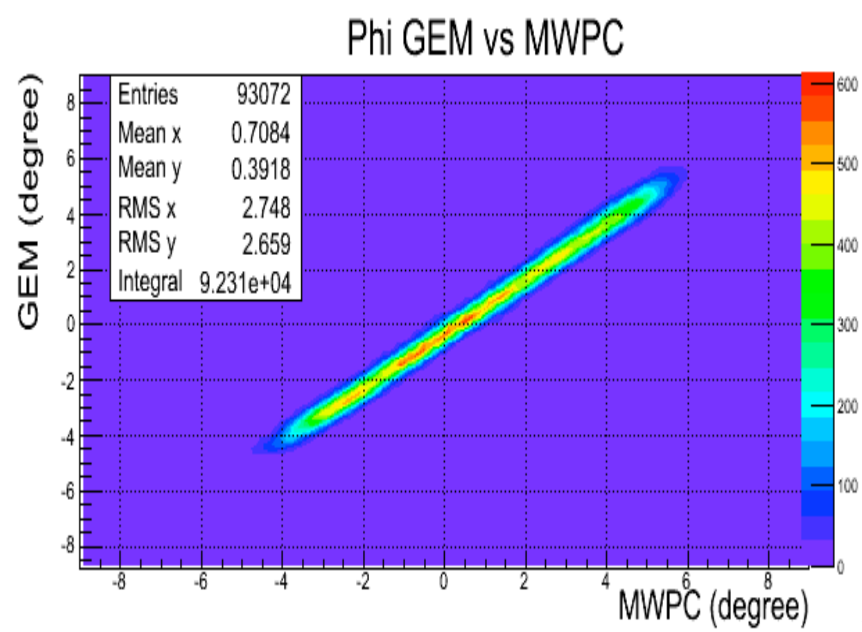


2D Comparison Plots: GEMs vs MWPCs

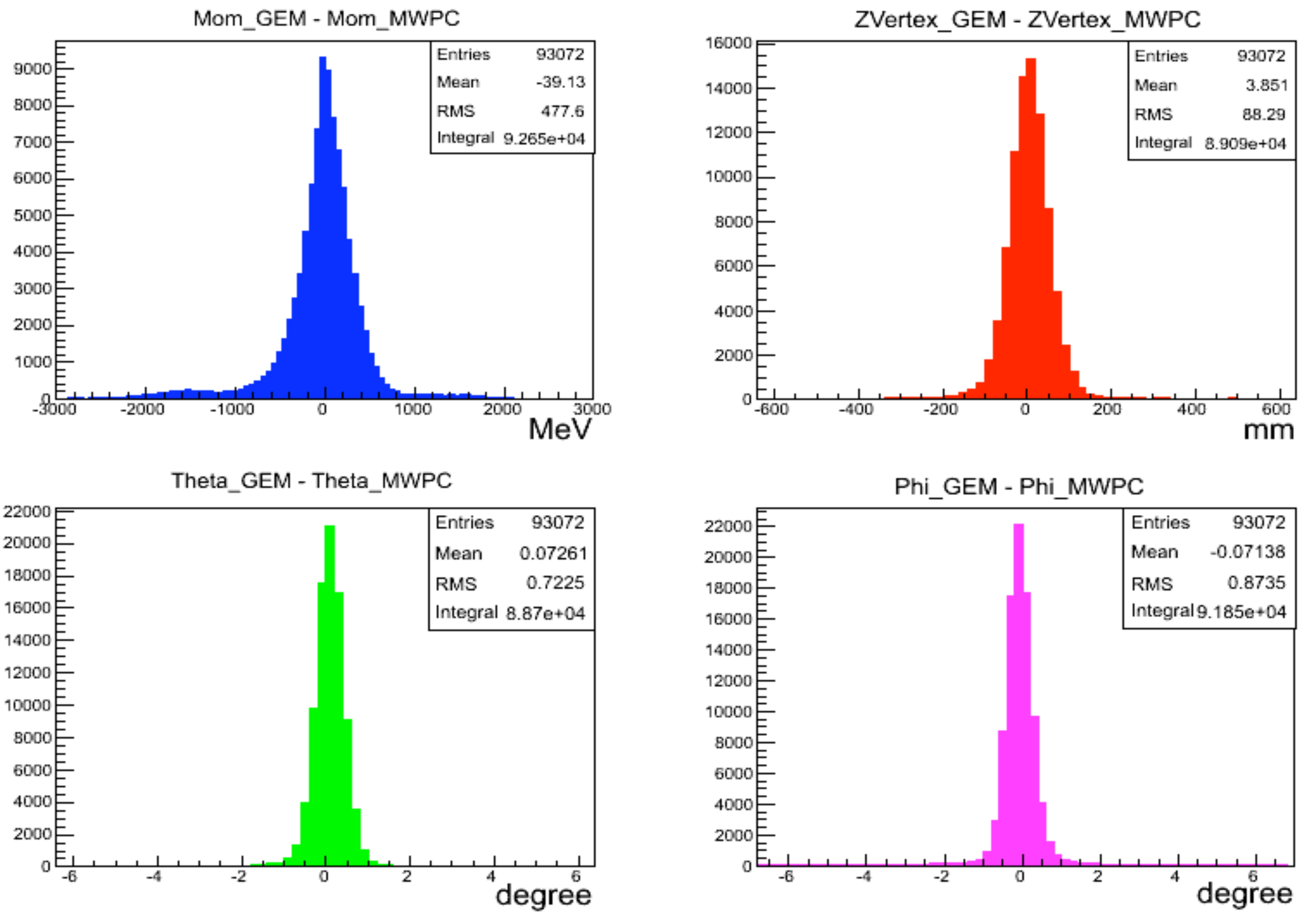




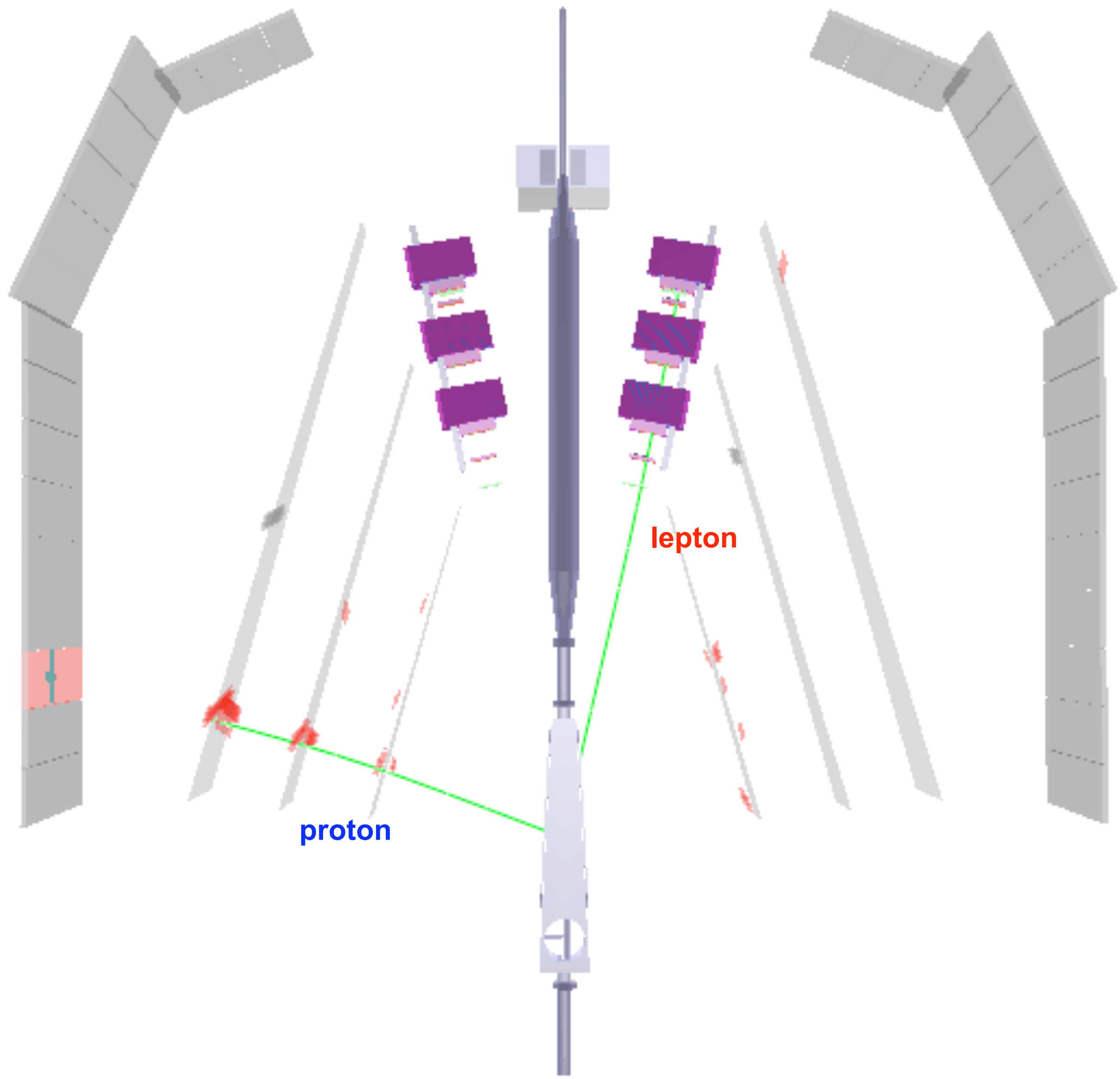




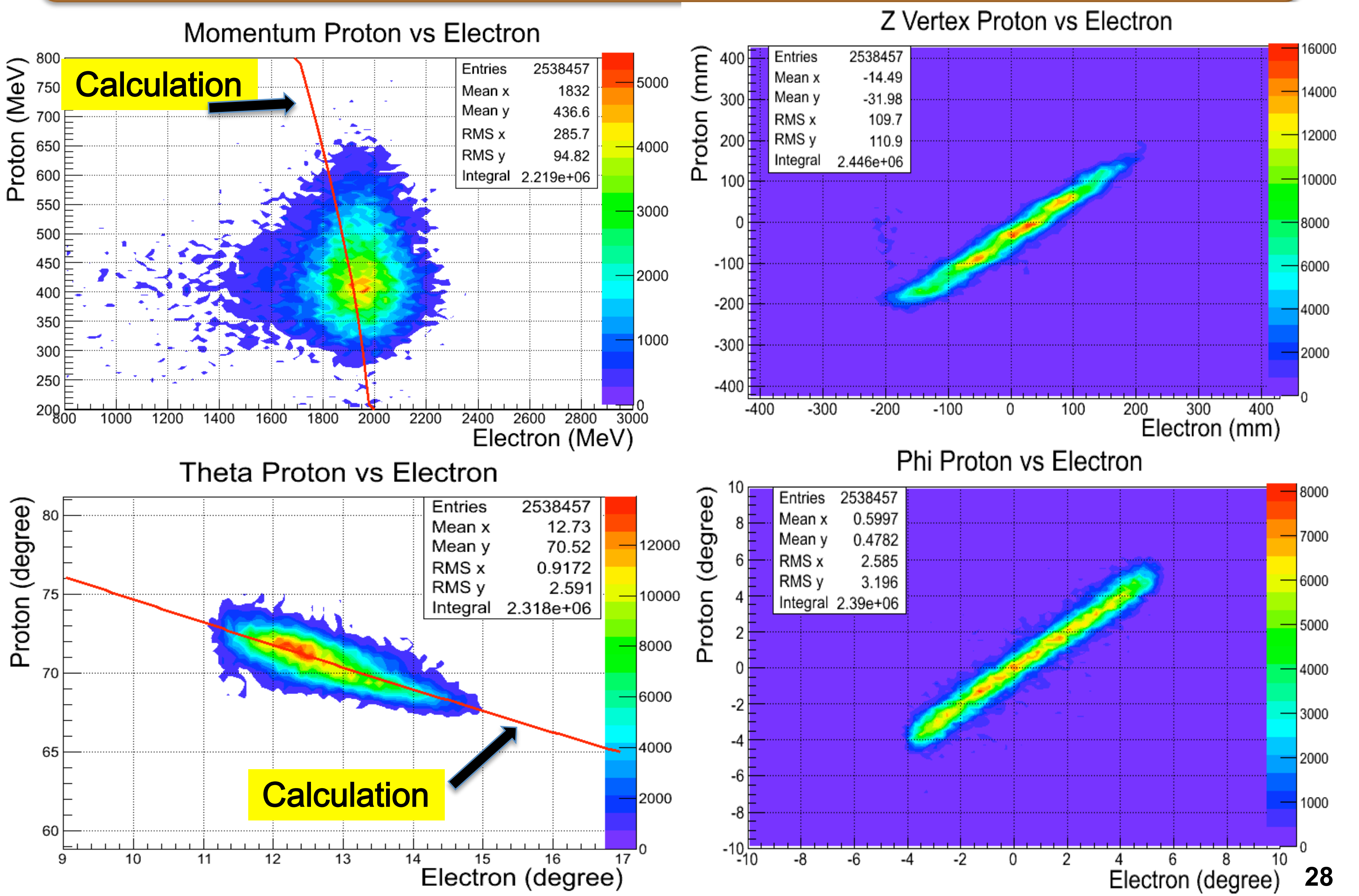
1D Comparison Histograms: GEMs - MWPCs



Elastic ep Events



2D Comparison Plots: Protons vs Electrons



SUMMARY

✓ OLYMPUS collected good data in Feb 2012 and Oct 2012 - Jan 2013.

✓ The 12-degree GEMs and MWPCs have performed very well.

✓ Optical survey was done in order to correct misalignments and geometry issues.

✓ More precise field measurements were done in order to correct magnetic field imperfections.

✓Analysis is underway with 2 alternative tracking codes.

✓ Olympus aims to determine two photon contribution to ep elastic scattering with 1% precision.