# GEP Electron Arm Reconstruction and Exclusivity Constraint on SBS FT Tracking

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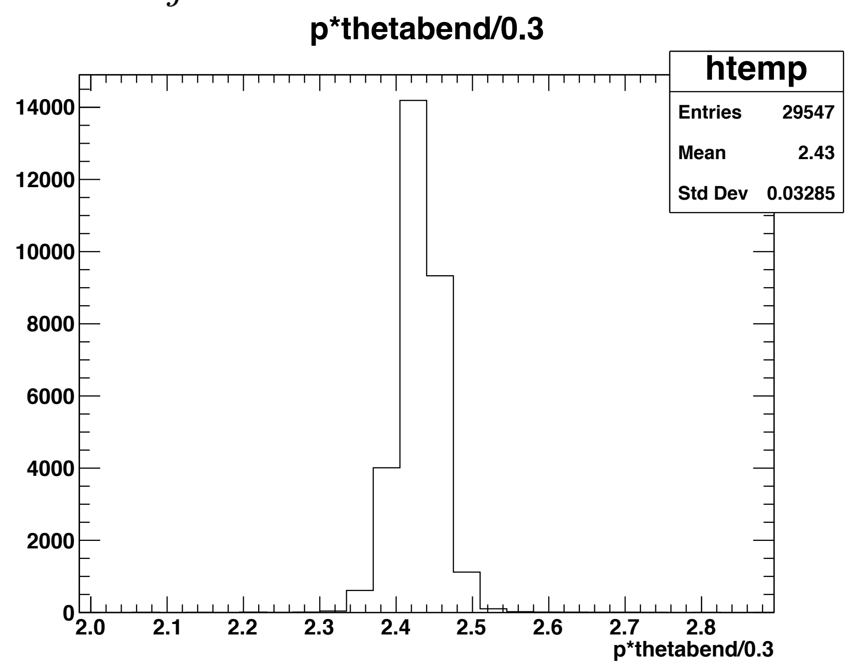
SBS Software Meeting

Jan 28, 2019

# SBS Optics

$$\begin{bmatrix} x'_{tar} \\ y'_{tar} \\ y_{tar} \\ p\theta_{bend} \end{bmatrix} = \sum_{i,j,k,\ell,m=0}^{i+j+k+\ell+m\leq n} \begin{bmatrix} C^{x'_{tar}}_{ijk\ell m} \\ C^{y'_{tar}}_{ijk\ell m} \\ C^{y_{tar}}_{ijk\ell m} \\ C^{p\theta}_{ijk\ell m} \end{bmatrix} x^i_{fp} y^j_{fp} {x'}^k_{fp} {y'}^\ell_{fp} x^m_{tar}$$

New formalism for momentum reconstruction: Expand the product $p\theta_{bend}$. For non-focusing dipole spectrometer like SBS, with approximately uniform field integral, this quantity is almost constant within the acceptance. Trajectory bend angle $\theta_{bend}$ is easily reconstructed, then $p = \frac{p\theta_{bend}}{\theta_{bend}}$. This expansion converges very rapidly: a 4$^{th}$-order fit gives accuracy well below intrinsic resolution over entire phase space.




$$\theta_{bend} = \frac{0.3 \int B \cdot dL}{p}$$

$$\Rightarrow \frac{p\theta_{bend}}{0.3} = \int B \cdot dL \approx 2.4\ T \cdot m$$

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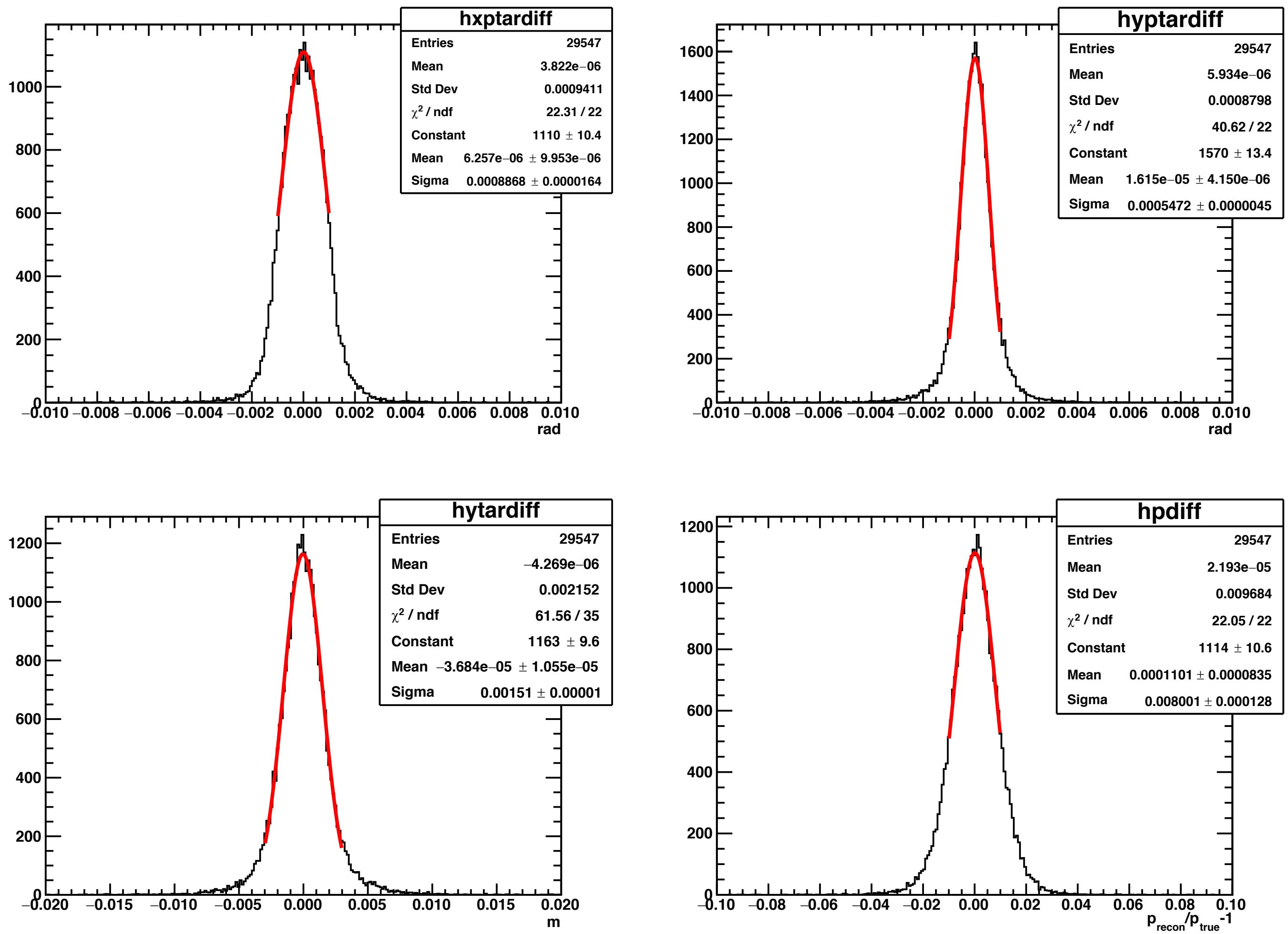
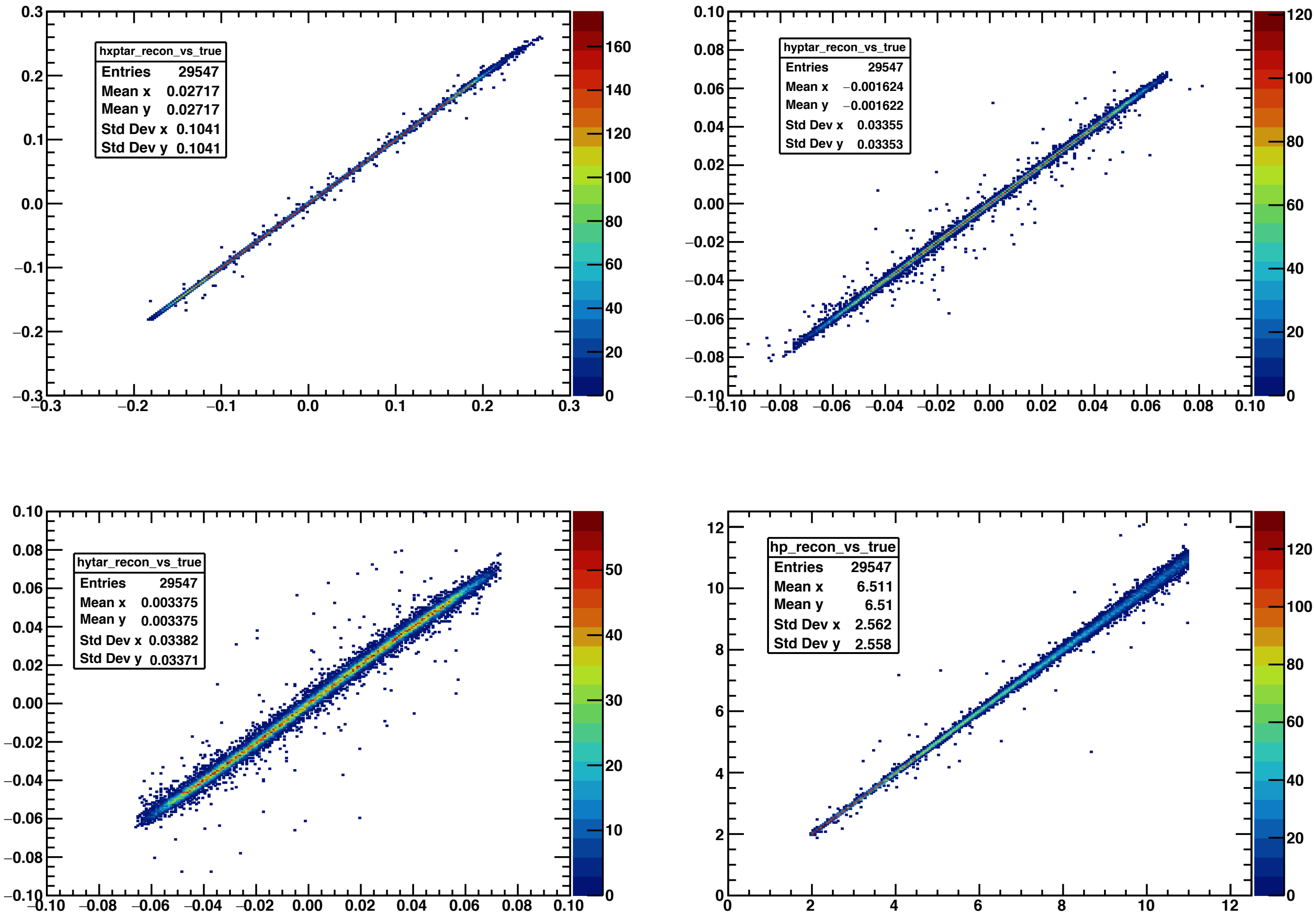
# SBS Optics: Angle, vertex, momentum resolution



# SBS Optics: Correlation between “recon” and “true” quantities

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# SBS forward optics expansion

$$\begin{bmatrix} x_{fp} \\ y_{fp} \\ x'_{fp} \\ y'_{fp} \end{bmatrix} = \sum_{i,j,k,\ell,m=0}^{i+j+k+\ell+m \leq n} \begin{bmatrix} C^{x_{fp}}_{ijk\ell m} \\ C^{y_{fp}}_{ijk\ell m} \\ C^{x'_{fp}}_{ijk\ell m} \\ C^{y'_{fp}}_{ijk\ell m} \end{bmatrix} {x'}^{i}_{tar} {y'}^{j}_{tar} x^{k}_{tar} y^{\ell}_{tar} \left(\frac{1}{p}\right)^{m}$$

- Forward optics also needed to translate electron arm reconstructed track into a search region for elastically scattered protons in the SBS FT

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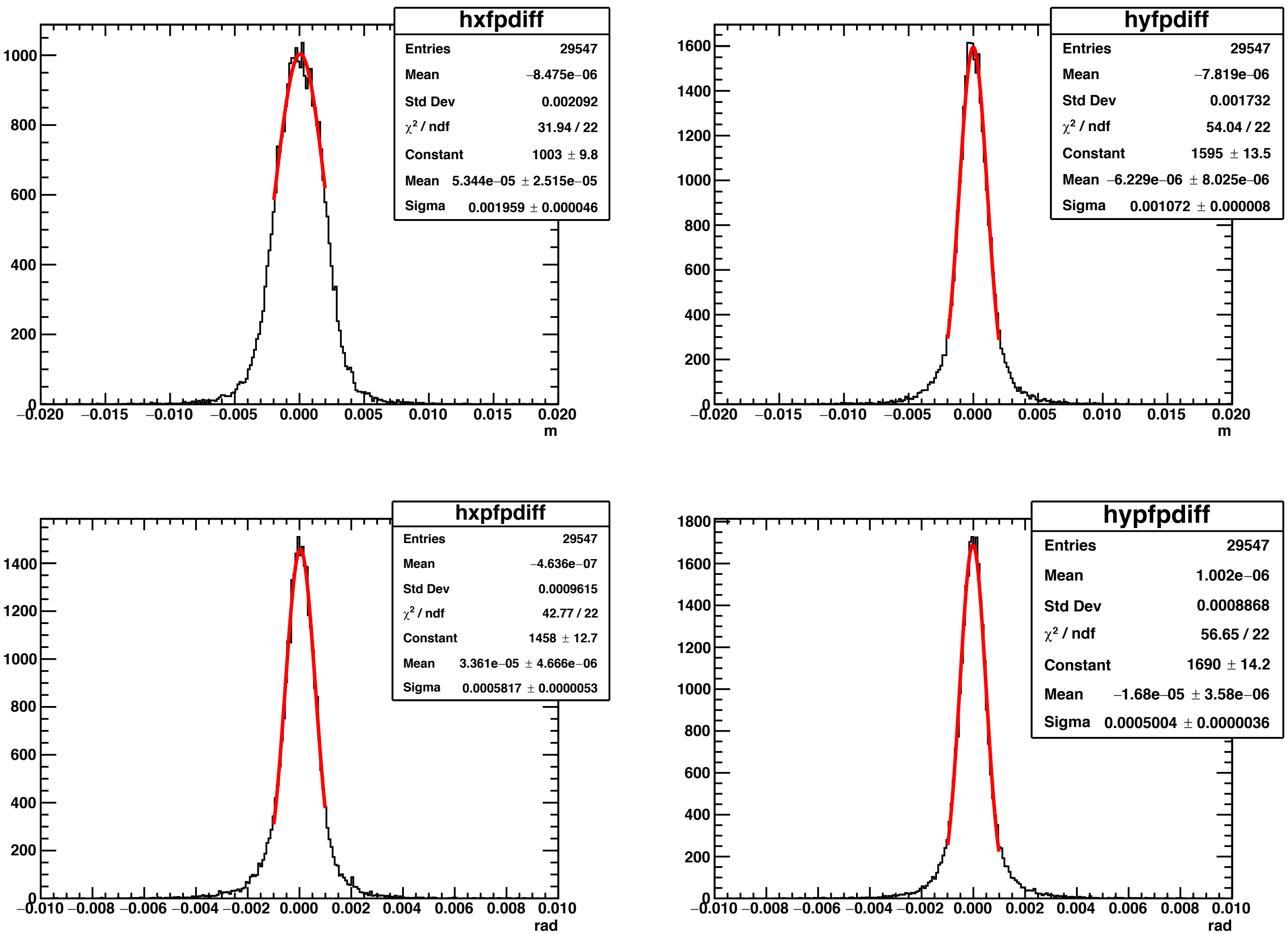
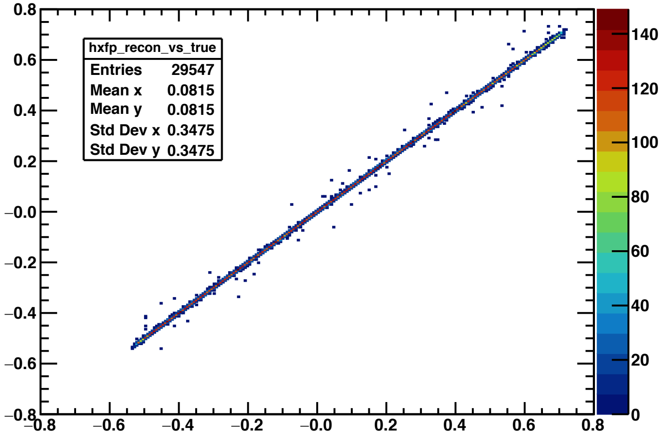
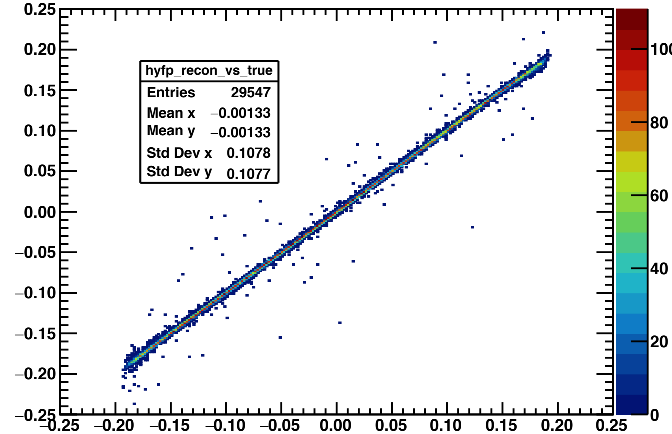
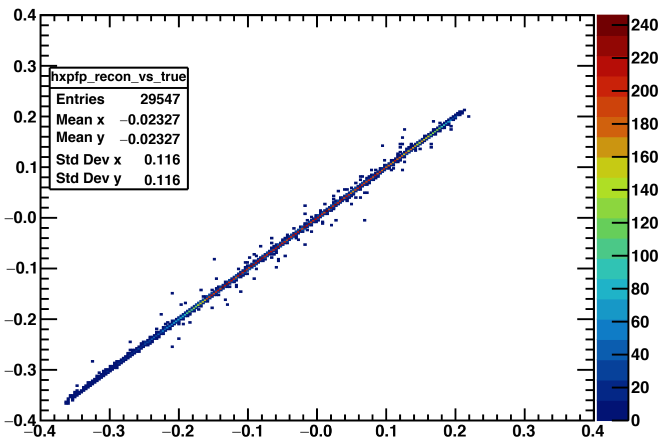
# SBS Forward Optics: resolution of “fp” coordinates and angles

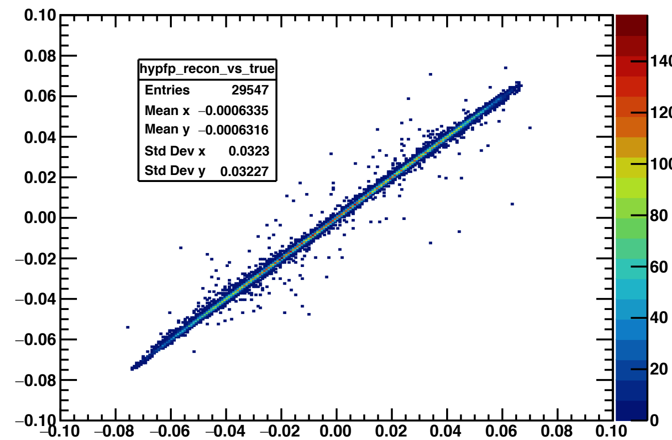


# SBS Forward Optics: Recon. Vs. True

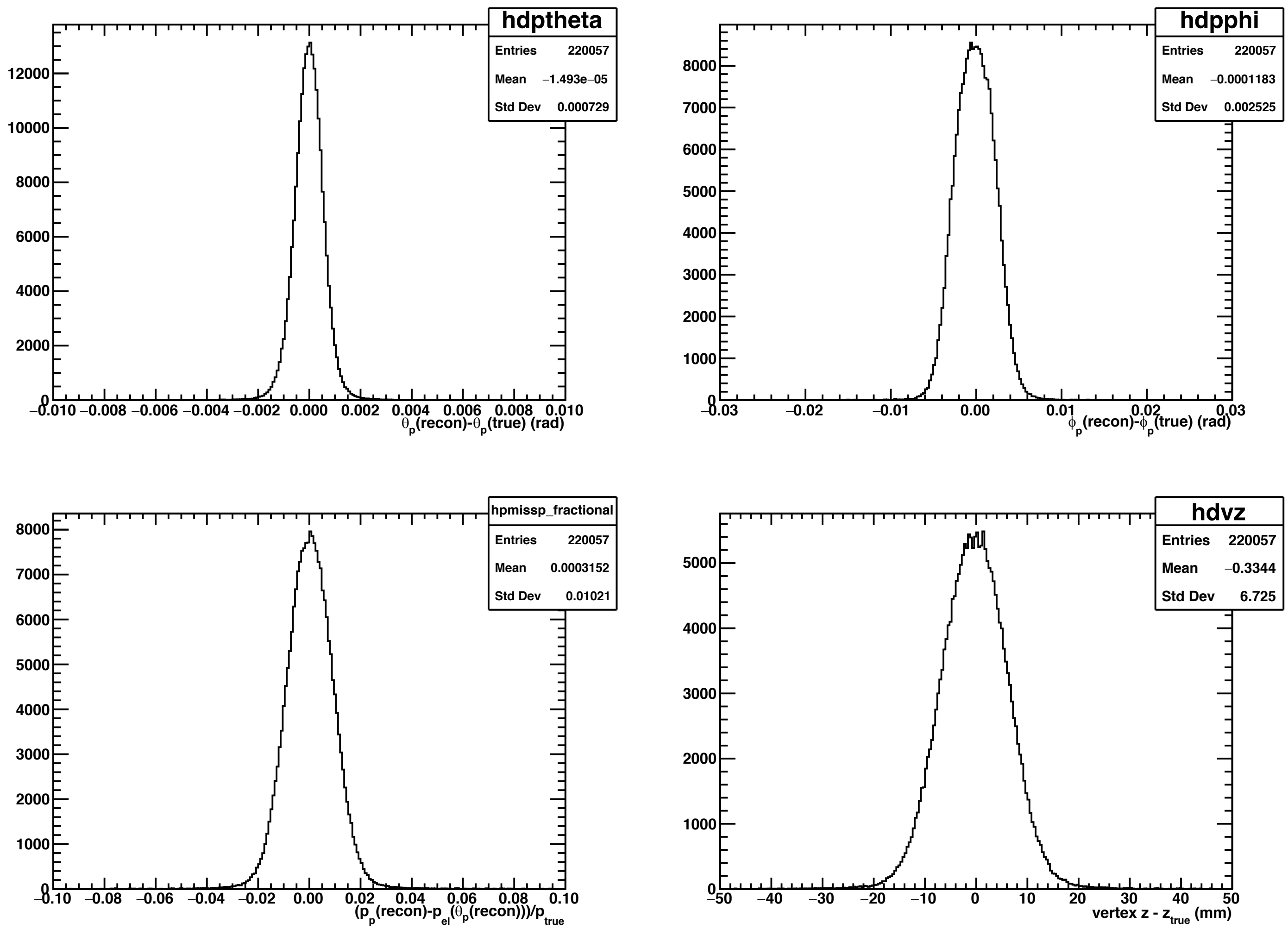


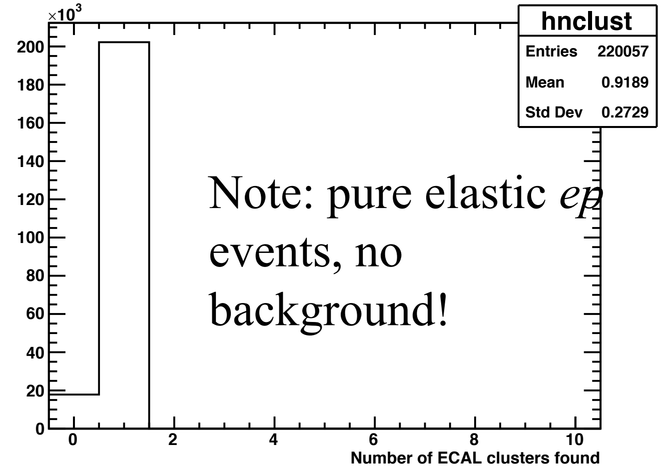



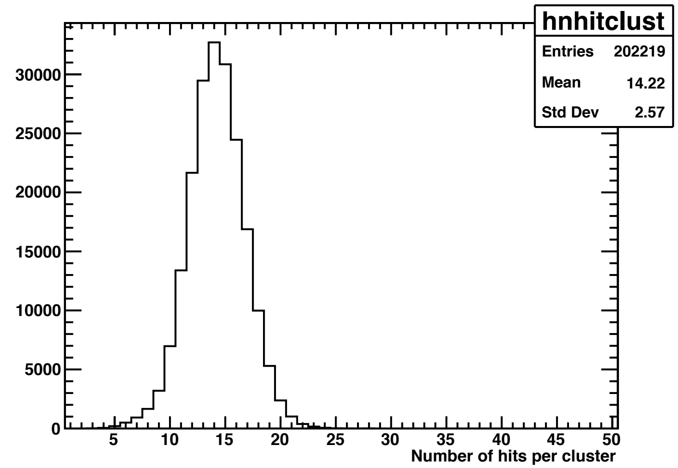
# SBS Optics—"physics angles", proton angle-momentum correlation, etc.

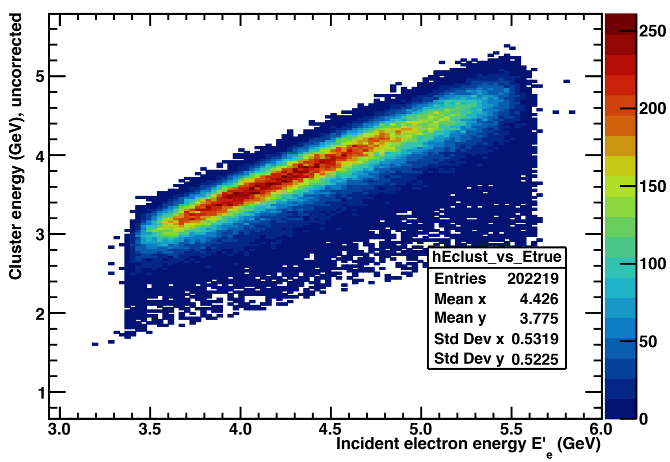


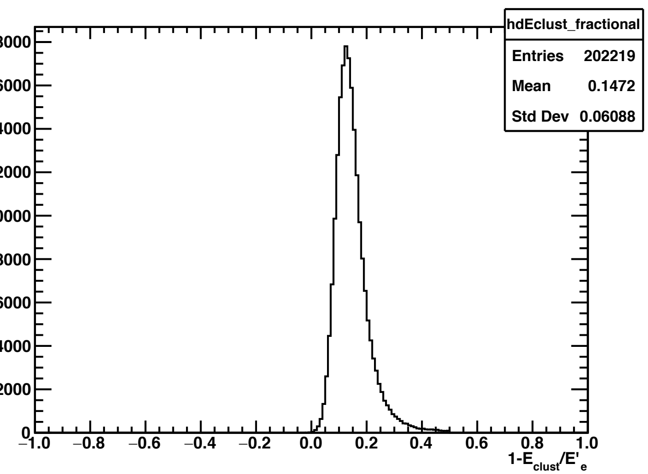
# Electron Arm Reconstruction—ECAL Clustering




Note: pure elastic *ep* events, no background!




Curiously, the "missing" energy fraction is about 15% on average. Where is it going? Resolution still about 6%

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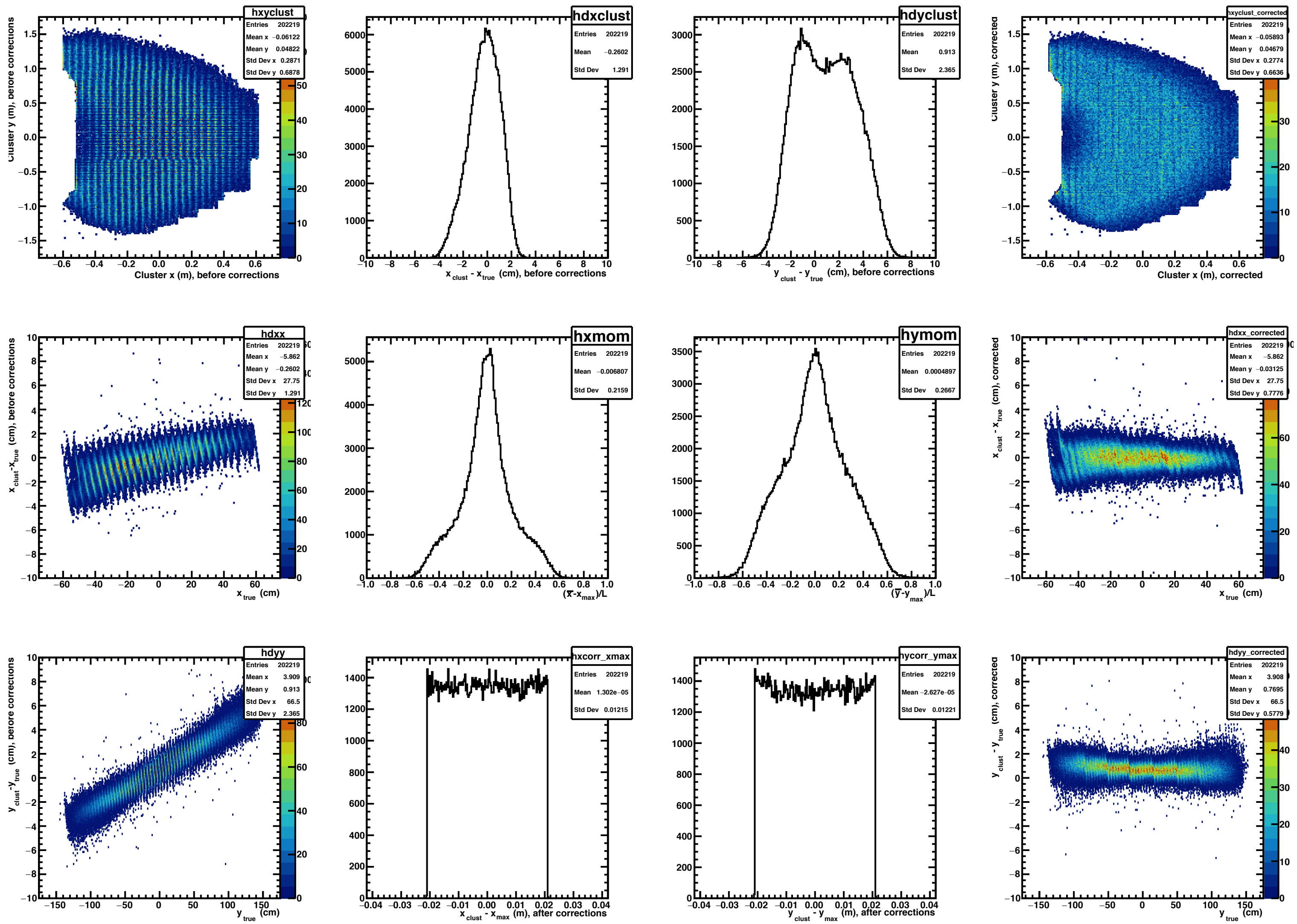
# ECAL—Shower coordinate reconstruction

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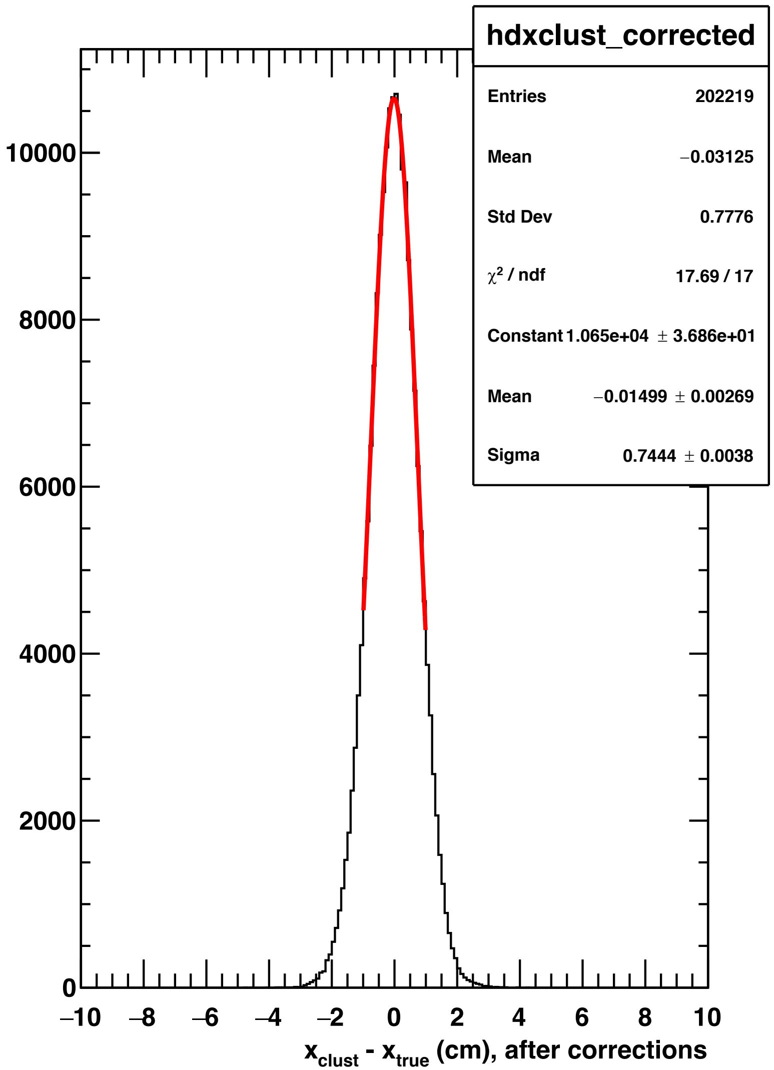
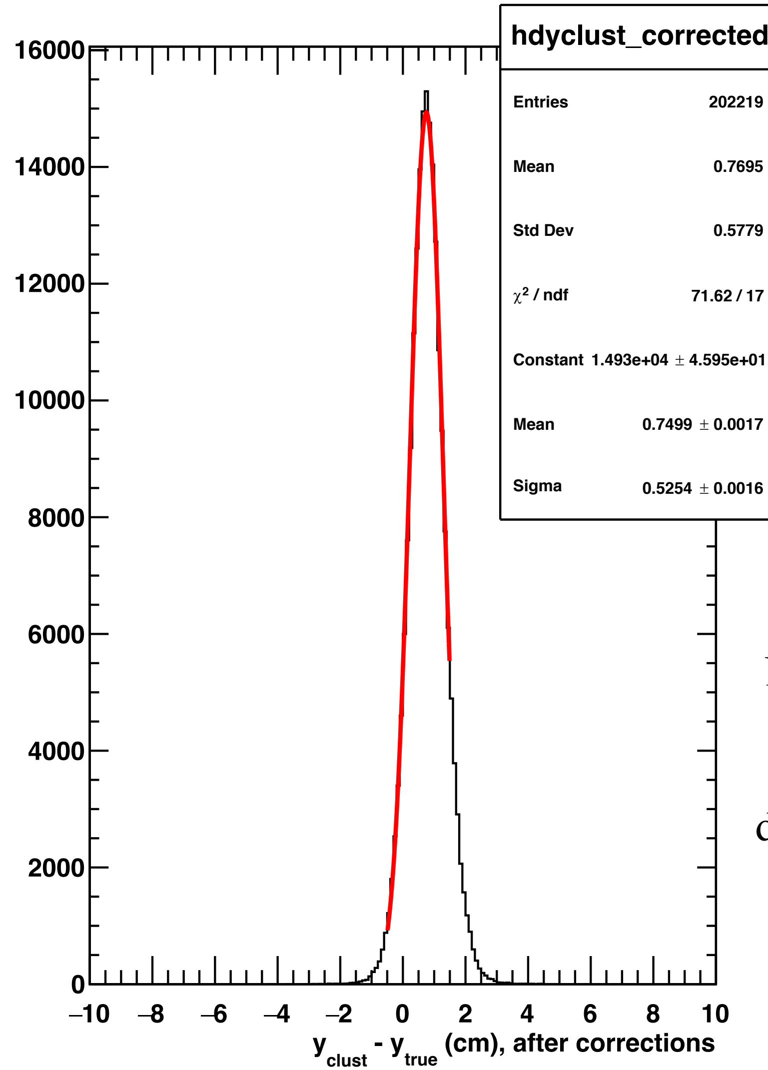
# ECAL final shower coordinate resolution




Note: y offset of ~7.5 mm results from vertical deflection in SBS fringe field

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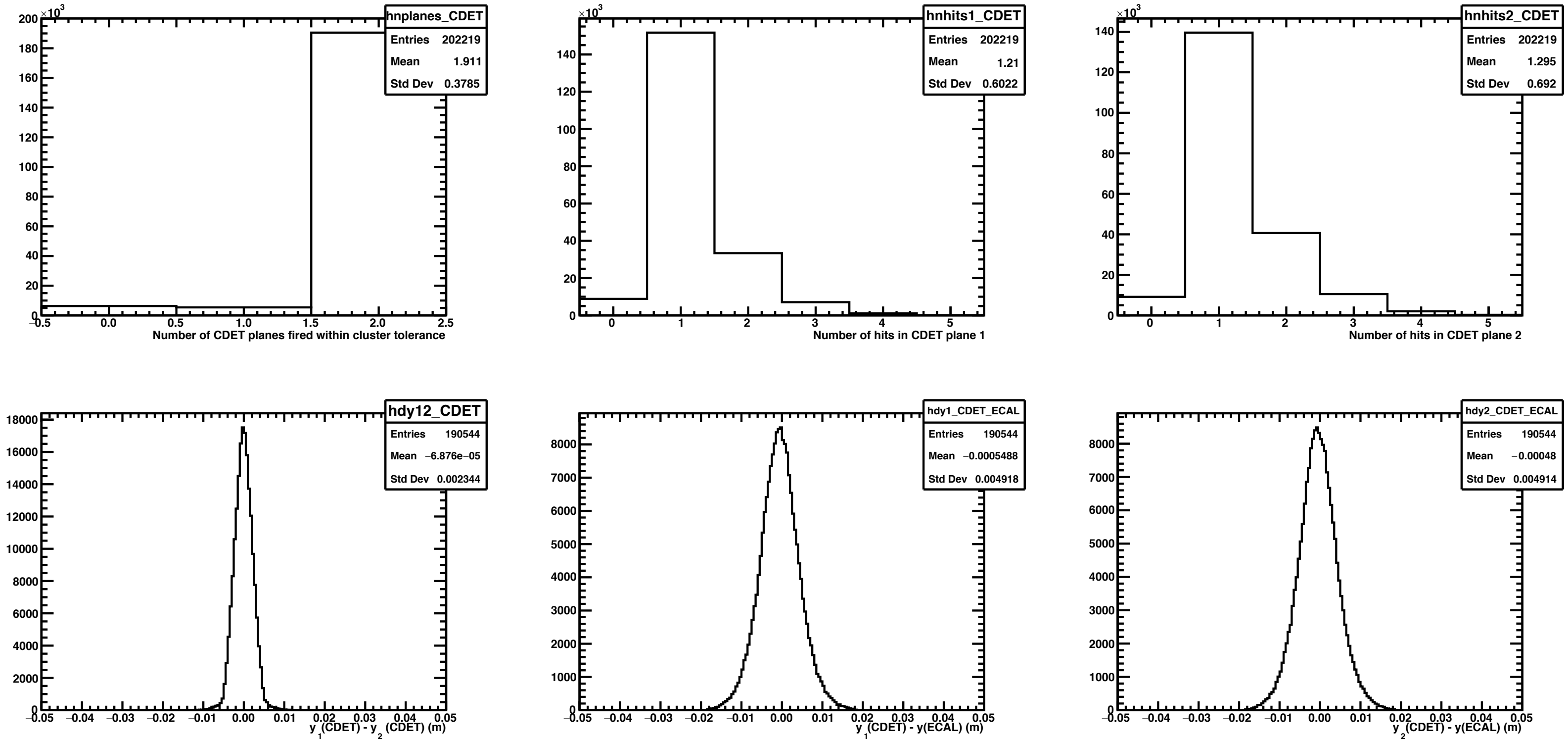
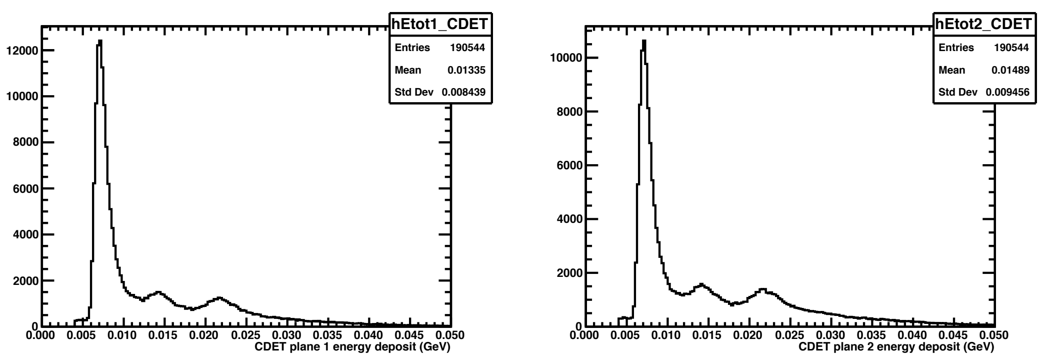
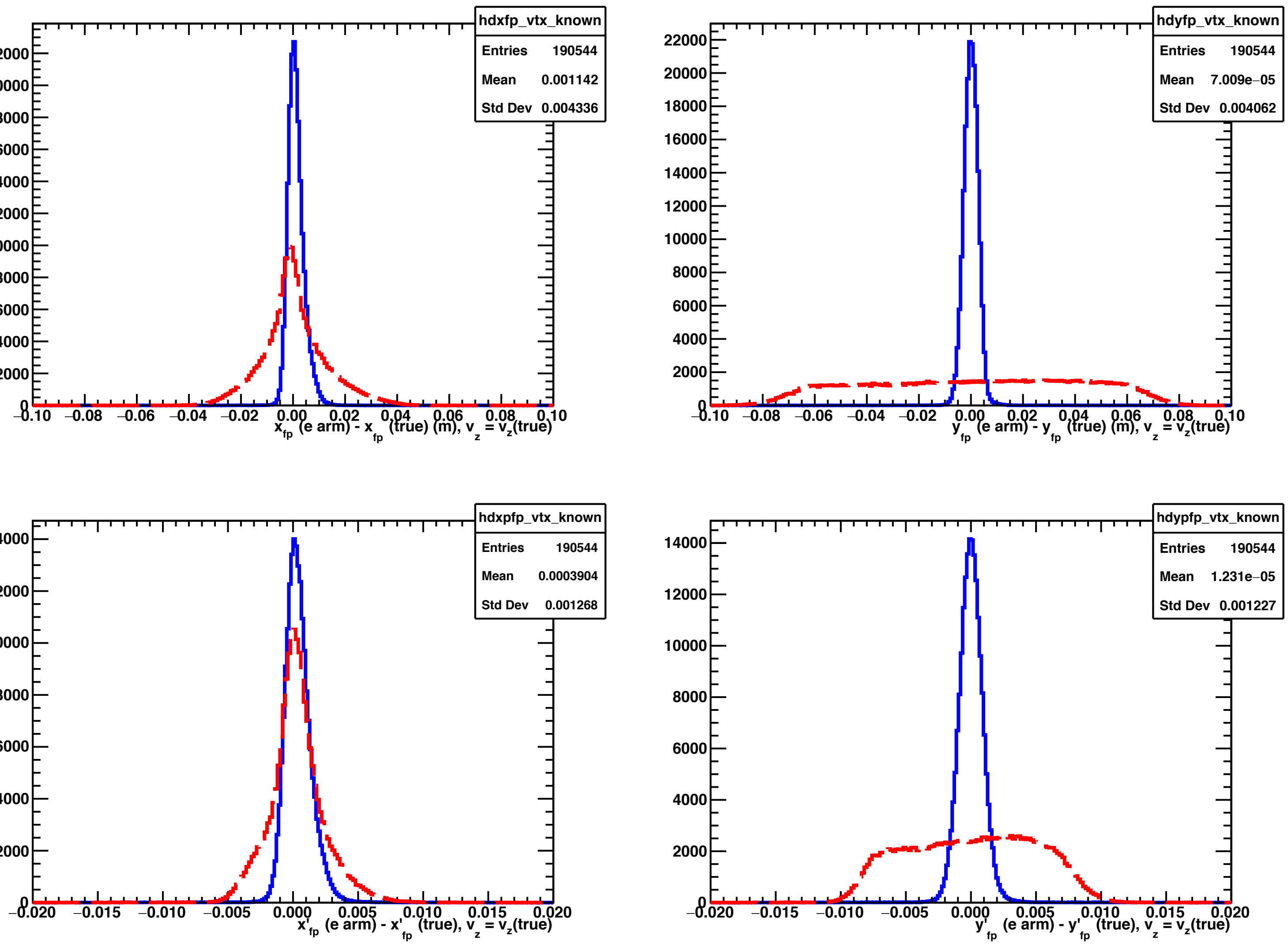
# CDET Reconstruction



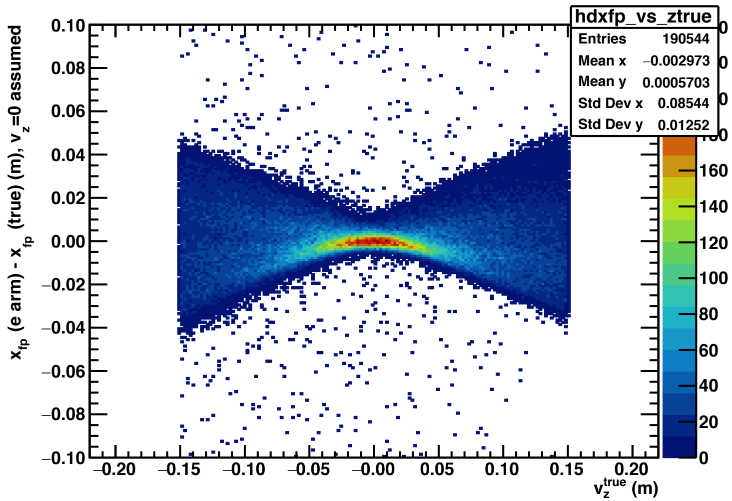

- Search for CDET hits within $|\Delta y| \leq 3\sigma_y^{ECAL}$ of ECAL shower cluster
- Compute y coordinate at each CDET plane from energy deposition-weighted average strip y position

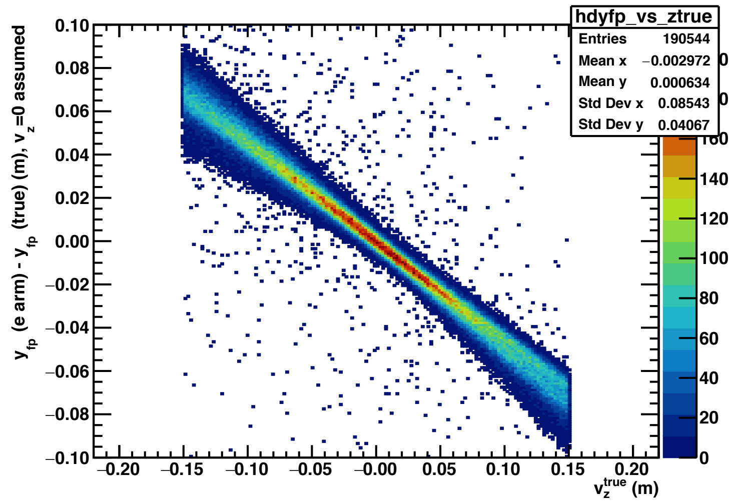
# Projecting expected elastically scattered proton track to SBS FT—with and without vertex information

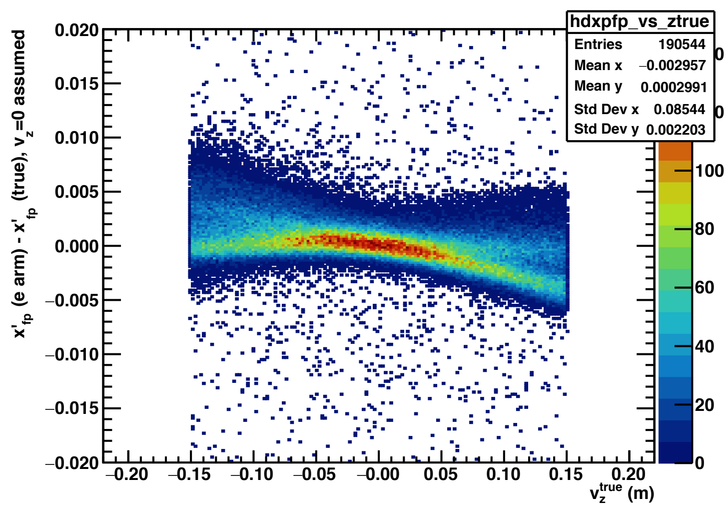


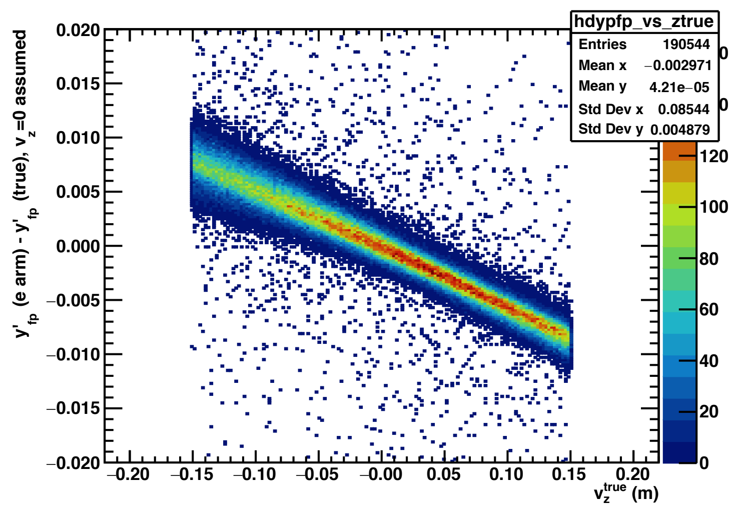
# FT track projections vs. true vertex z position

Electron angles reconstructed from ECAL/CDET assuming $v_z = 0$

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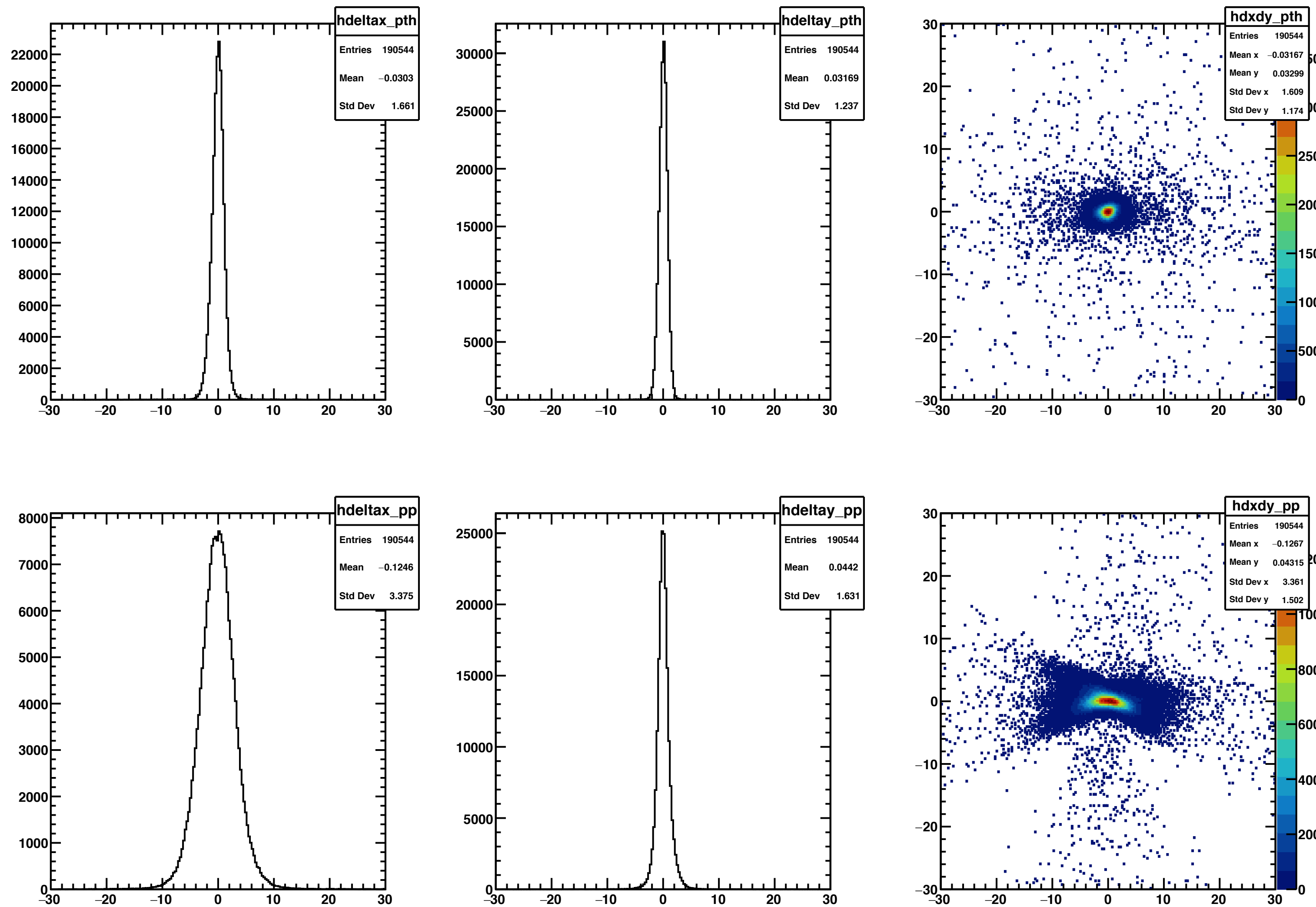
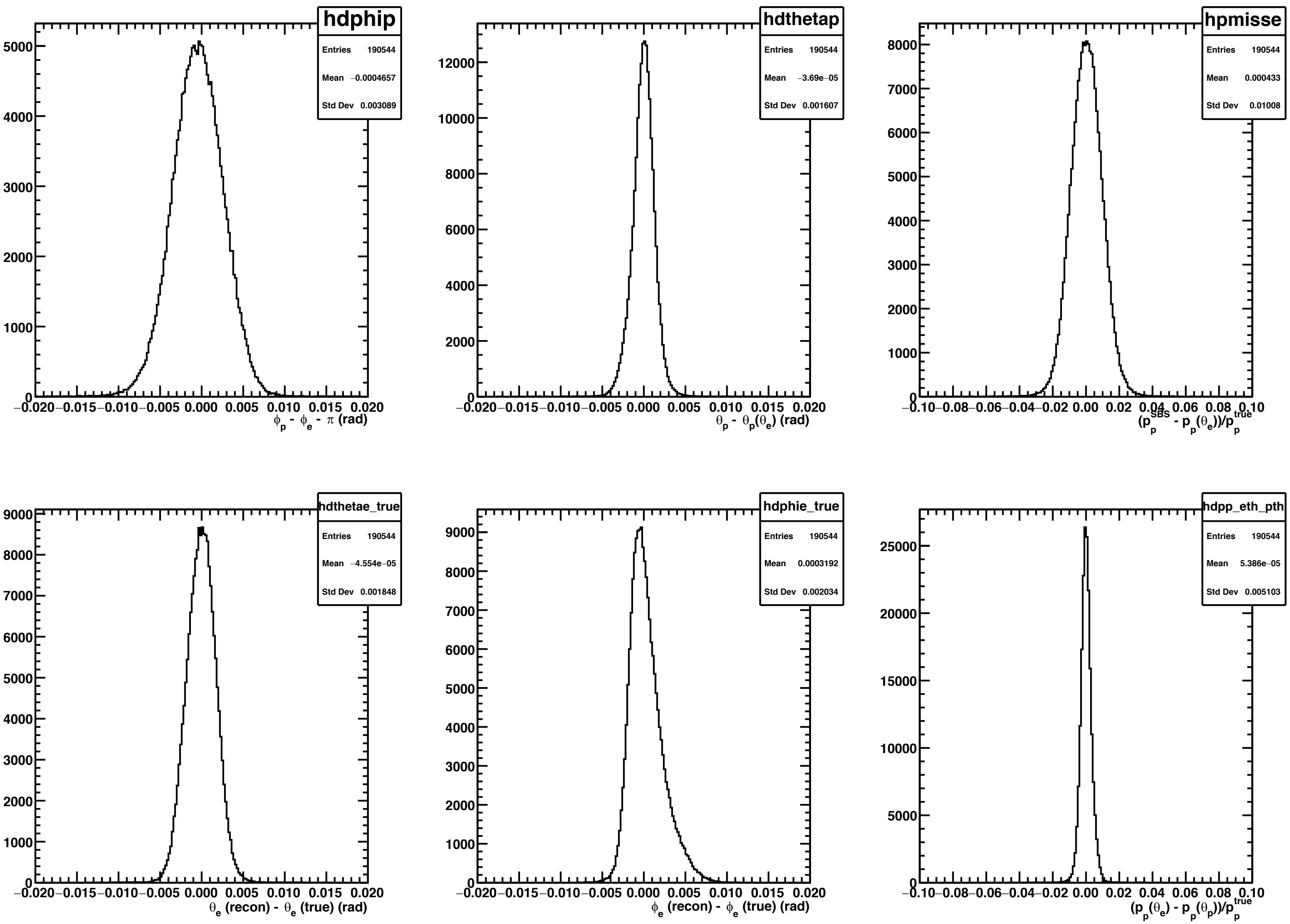
# ECAL shower coordinates—measured vs SBS predicted




Top row: using $\theta_e(\theta_p)$. Bottom row: using $\theta_e(p_p)$

# Miscellaneous Exclusivity Cut variables



# Summary and Conclusions

- SBS forward and backward optics formalism developed, stable
- GEP electron arm basic reconstruction and calibration algorithms written
- Without knowing vertex z coordinate, ECAL+CDET information localizes elastic proton track to within an area of $\pm 4\ cm\ (X) \times \pm 8\ cm\ (Y)$, slopes to within $\pm\ 8\ mrad\ \left(\frac{dx}{dz}\right)$ and $\pm 10\ mrad\ \left(\frac{dy}{dz}\right)$
- GEP electron arm has no sensitivity to the vertex z coordinate, BUT:
  - **Once ECAL shower coordinate is fixed, there is a one-to-one correspondence between vertex z coordinate and electron scattering angle, and therefore also proton scattering angle/momentum/etc.**
- If the vertex coordinate is known, ECAL shower coordinate predicts FT track coordinates to within $\sim \pm 1\ cm$, slopes to within $\sim \pm 3\ mrad$. Area of search region at each plane is of order 1 $cm^2$.
- This suggests a tracking strategy in which we divide the target length into an appropriate number of bins in vertex z coordinate, scan the *assumed* value of vertex z along the length of the target, and search for tracks within the narrow allowed region for elastic protons implied by a particular choice of vertex z. This should minimize the combinatorics and speed up tracking, and lead to cleaner results.
- For each bin in vertex z, we record the number of "good" FT 2D hits/planes/track candidates found, and then we do target reconstruction, perhaps some kind of kinematic fitting to choose "best" quantities.
- Use tight chi^2 cuts, requirements on agreement with exclusivity requirements, etc.