Progress report

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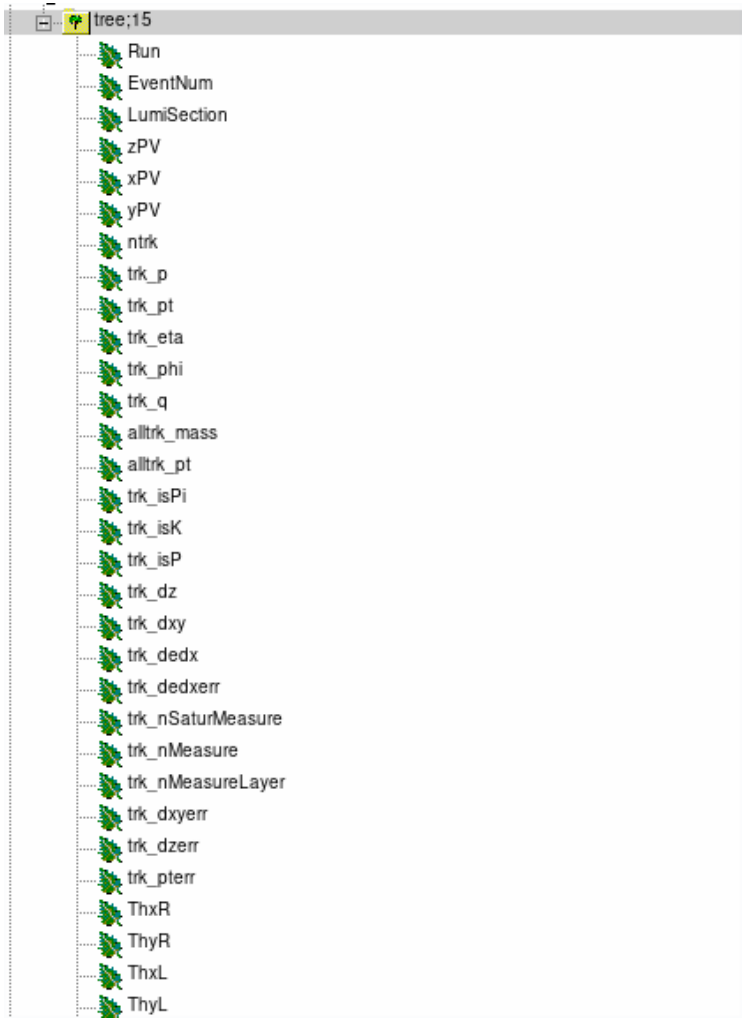
Which data set was used?

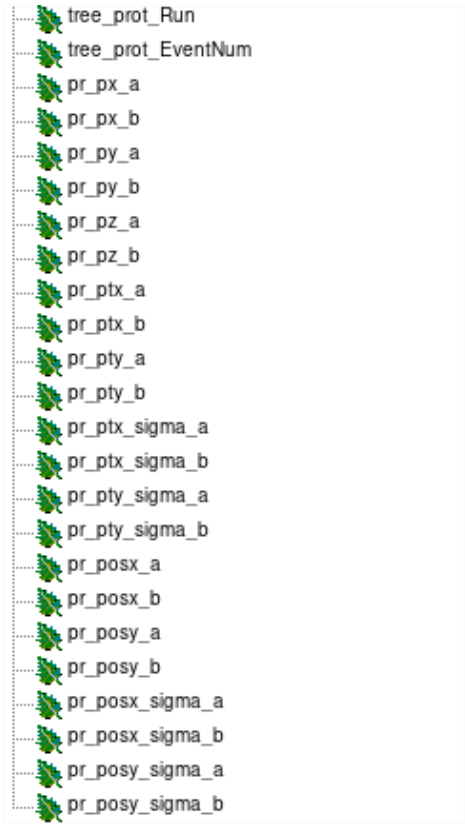
- Original data from: /eos/cms/store/group/phys_diffraction/CMSTotemLowPU2018/YounesNtuples
- Combined all diagonal and parallel data:

$$\text{TOTEM2.root} = \text{TOTEM20.root} + \text{TOTEM21.root} + \text{TOTEM22.root} + \text{TOTEM23.root}$$

$$\text{TOTEM4.root} = \text{TOTEM40.root} + \text{TOTEM41.root} + \text{TOTEM42.root} + \text{TOTEM43.root}$$

Tree structure





Invariant mass analysis

- Cannot use particle identification (unreliable)
- Found no looping tracks
- Focus on 4-track system and demand net charge is zero
- Assume:

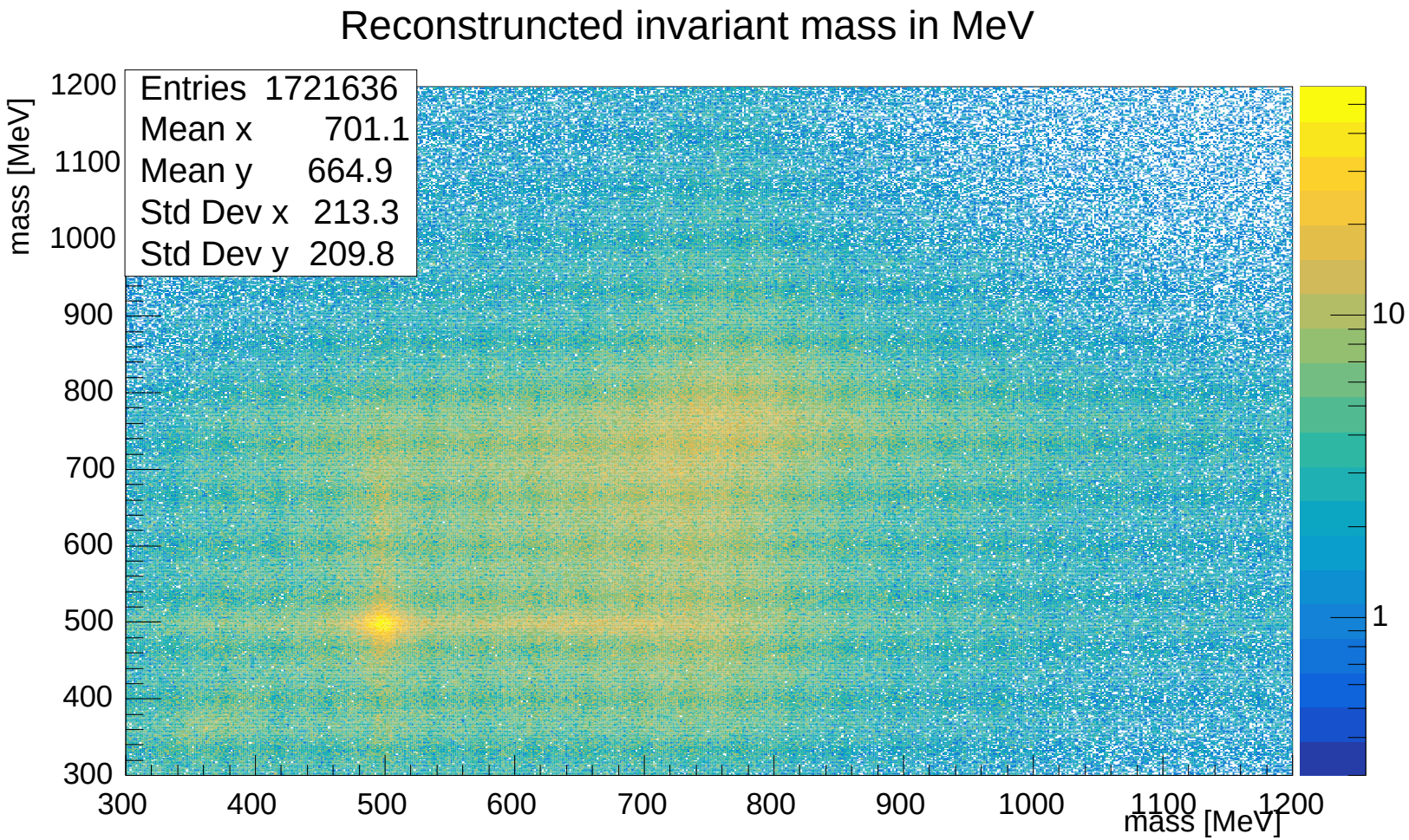
$$X \to \rho\rho \to \pi_1^+\pi_1^-\pi_2^+\pi_2^-$$

- Two ways to form first pion pair:

$$P_1 = \left\{(\pi_1^+, \pi_1^-), (\pi_2^+, \pi_2^-)\right\} \text{ and } P_2 = \left\{(\pi_1^+, \pi_2^-), (\pi_2^+, \pi_1^-)\right\}$$

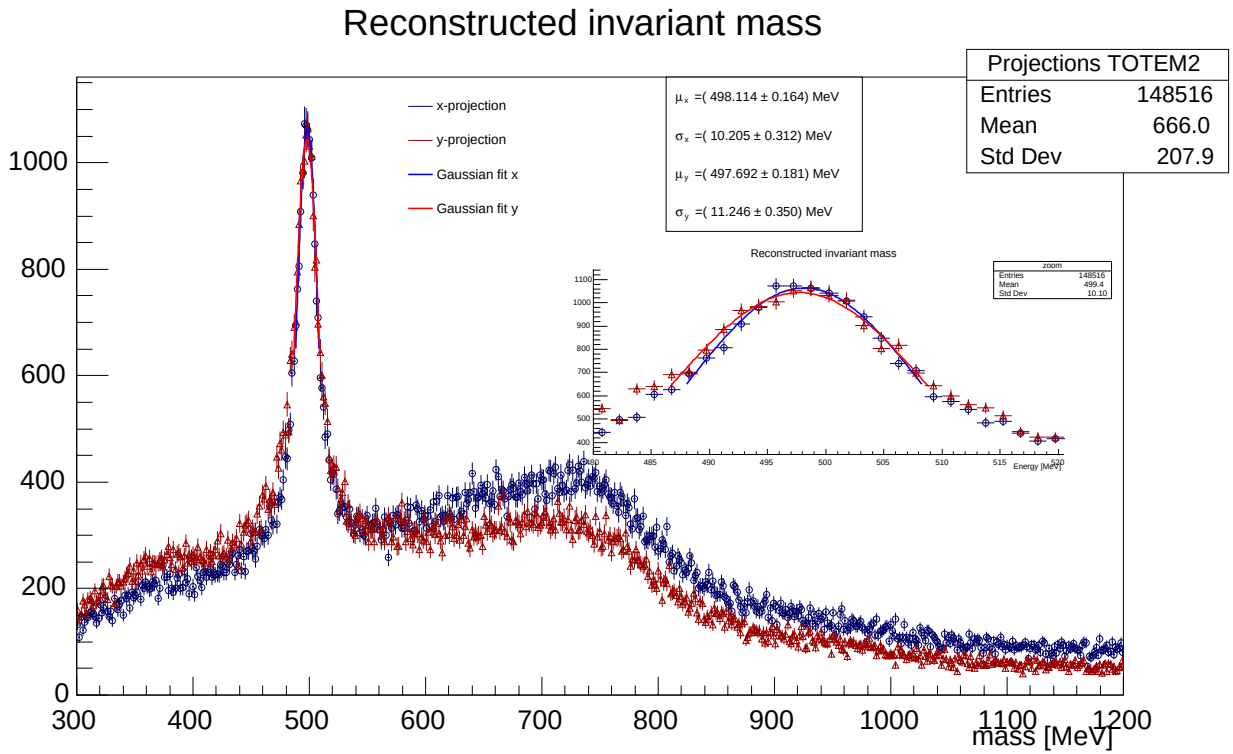
- Add branches *inv_mass_pair1* and *inv_mass_pair2* $\Rightarrow$ Plot invariant mass of both pairs in 2D histogram

2D invariant mass from TOTEM2



Need to remove wrong pairs and Kaon background

Kaon invariant mass analysis TOTEM2



- Used $\pm 3\sigma$ for summation in projection and $\pm 1\sigma$ for fitrange
- PDG value: $m_{K_0} = 497.677(13)\,\text{MeV}$

$$\mu_{\text{avg}} = 497.903(173)\,\text{MeV}$$
$$\sigma_{\text{avg}} = 10.725(331)\,\text{MeV}$$

Conclusion

Background events at $\approx 500\,\text{MeV}$ are indeed Kaons

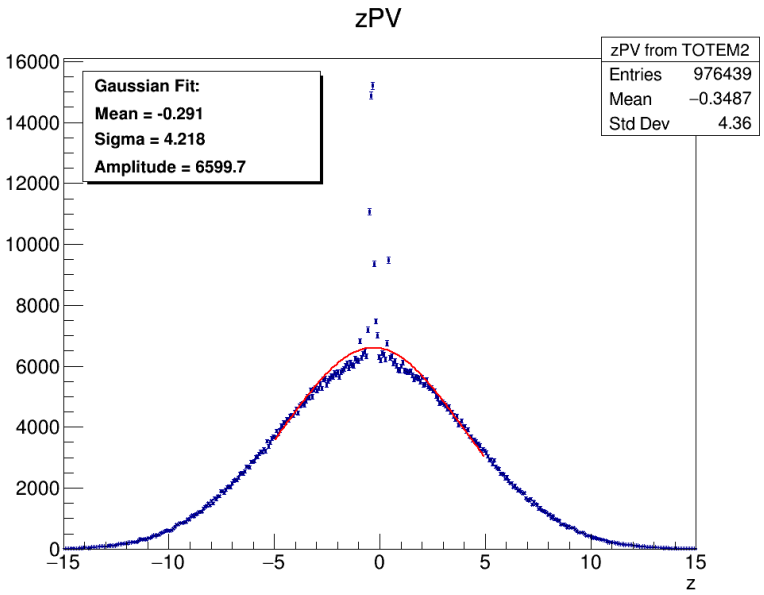
Introduction χ^2-like variable

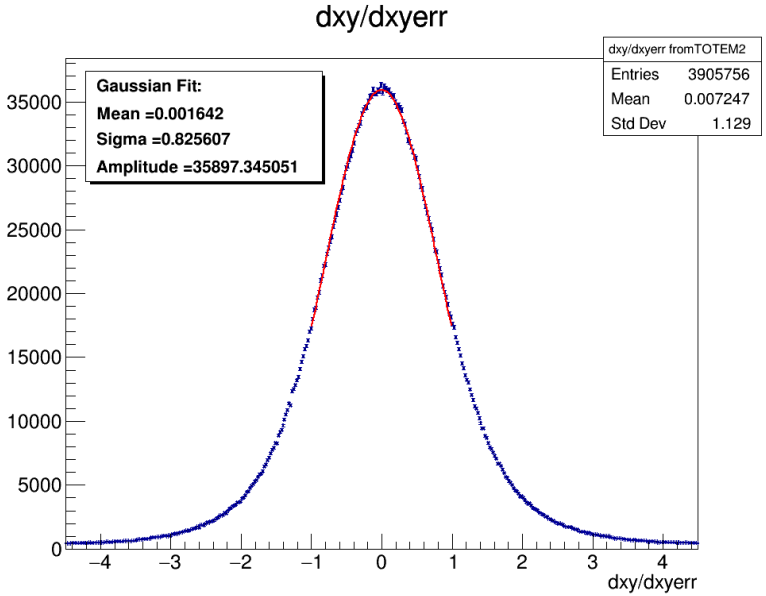
- Define new variable

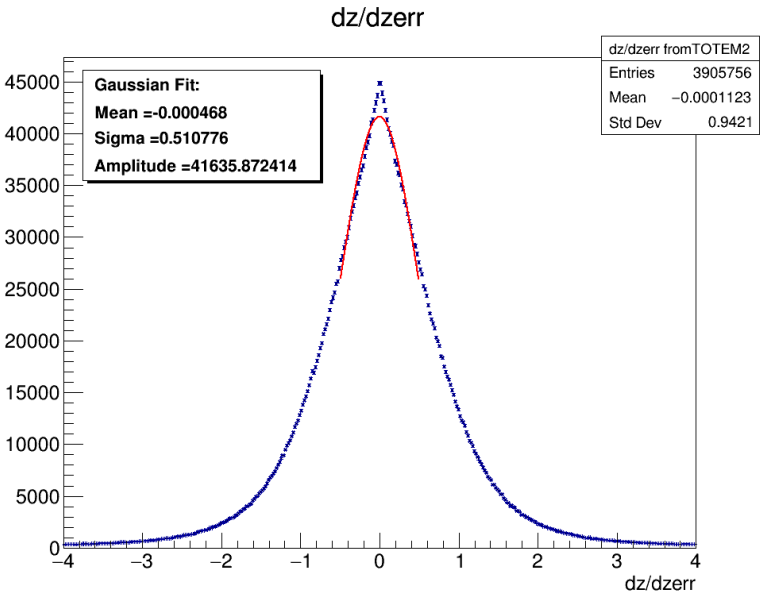
$$\chi^2_x := \sum_{i=1}^{ntrk=4} \frac{(\mu_x - x_i)^2}{\sigma_x^2}, \text{ for } x \in \{\text{zPV}, \text{dxy/dxyerr}, \text{dz/dzerr}\}$$

- $\mu_x, \sigma_{\text{zPV}}$ are constants coming from gaussian fit of x over entire data set
- $\sigma_{\text{dxy/dxyerr}} = \sigma_{\text{dz/dzerr}} = 1$ (dxy/dxyerr and dz/dzerr already dimensionless)
- 4-track system originating from $X \to \overline{K_s} K_s \to \pi^+\pi^-\pi^+\pi^-$ should have higher χ^2_x values

Gaussian fits for χ^2-like variable definition from TOTEM2

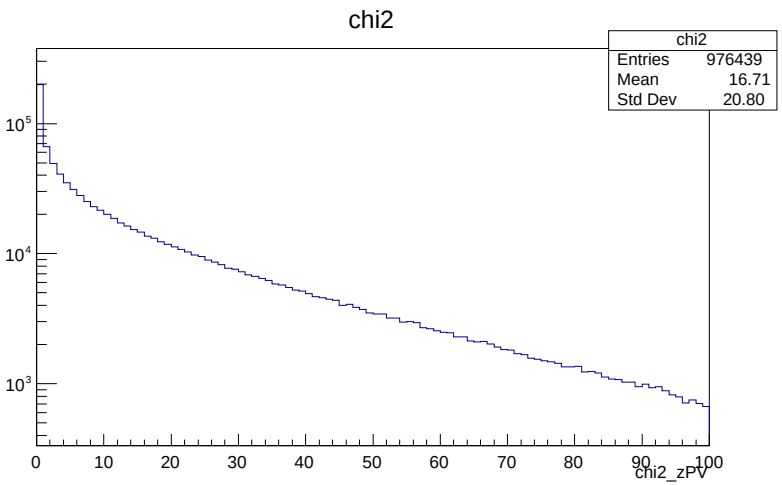




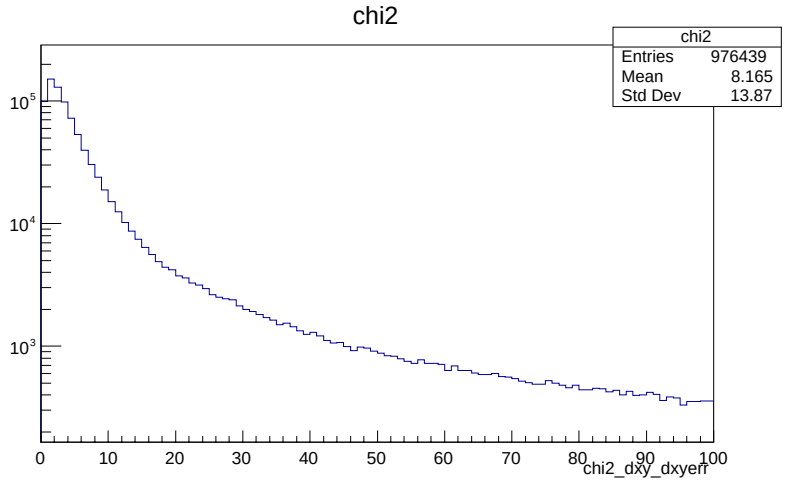


$\Rightarrow$ define χ^2_{zPV}, $\chi^2_{\text{dxy/dxyerr}}$, $\chi^2_{\text{dz/dzerr}}$ branches and add them to tree

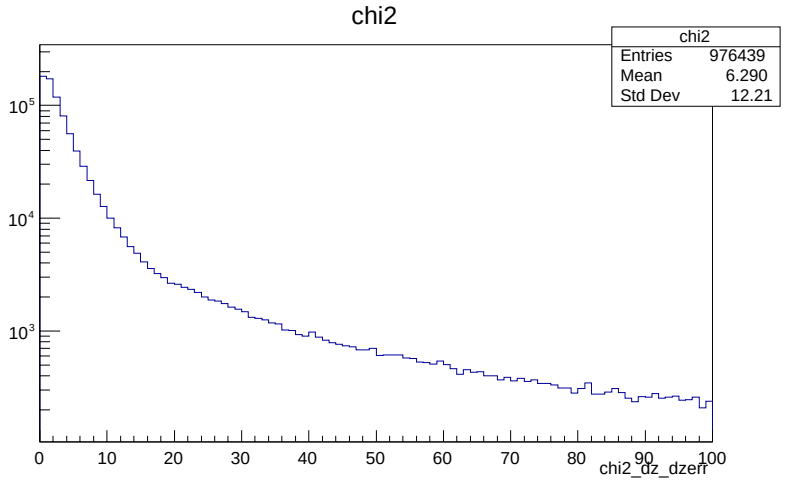
χ^2-like variables from TOTEM2



zPV



dxy/dxyerr



dz/dzerr

Effect of χ^2 cuts

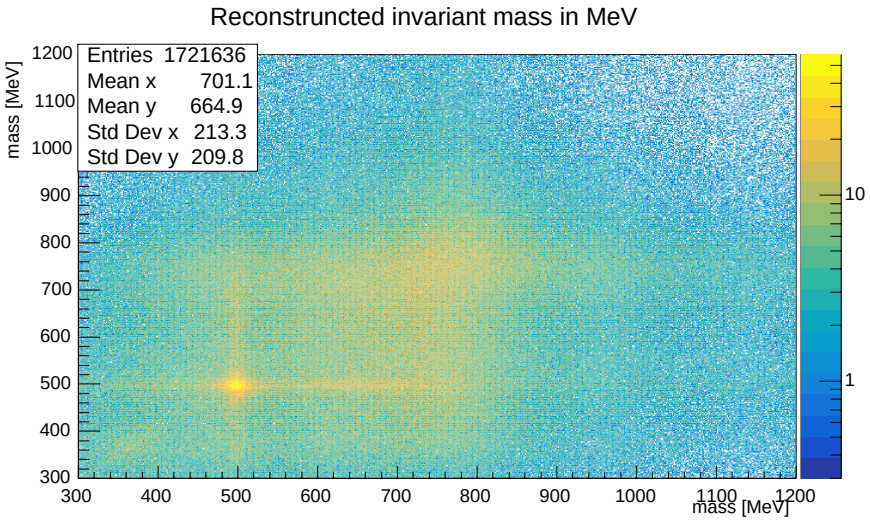


Figure: TOTEM2 before χ^2 cut

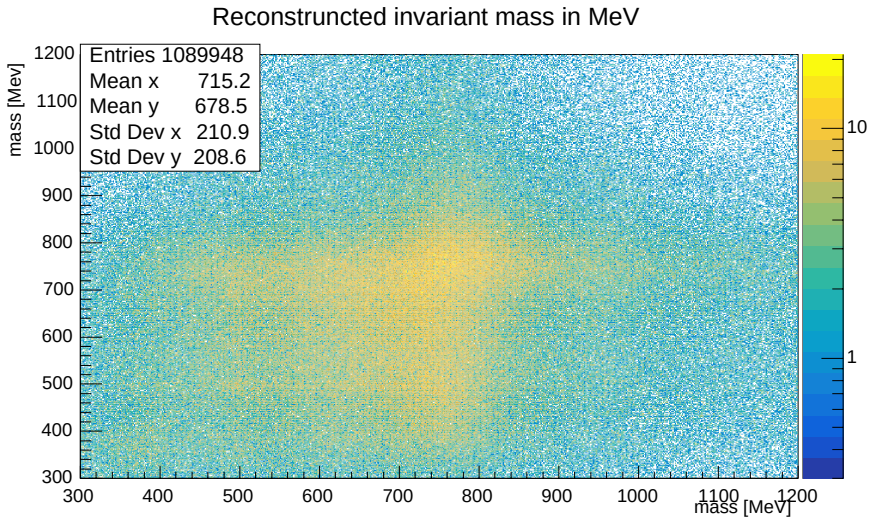


Figure: TOTEM2 after χ^2 cut

- Cuts at $\chi^2_{\text{zPV}} < 30$ and $\chi^2_{\text{dxy/dxyerr}} < 30$ and $\chi^2_{\text{dz/dzerr}} < 30$

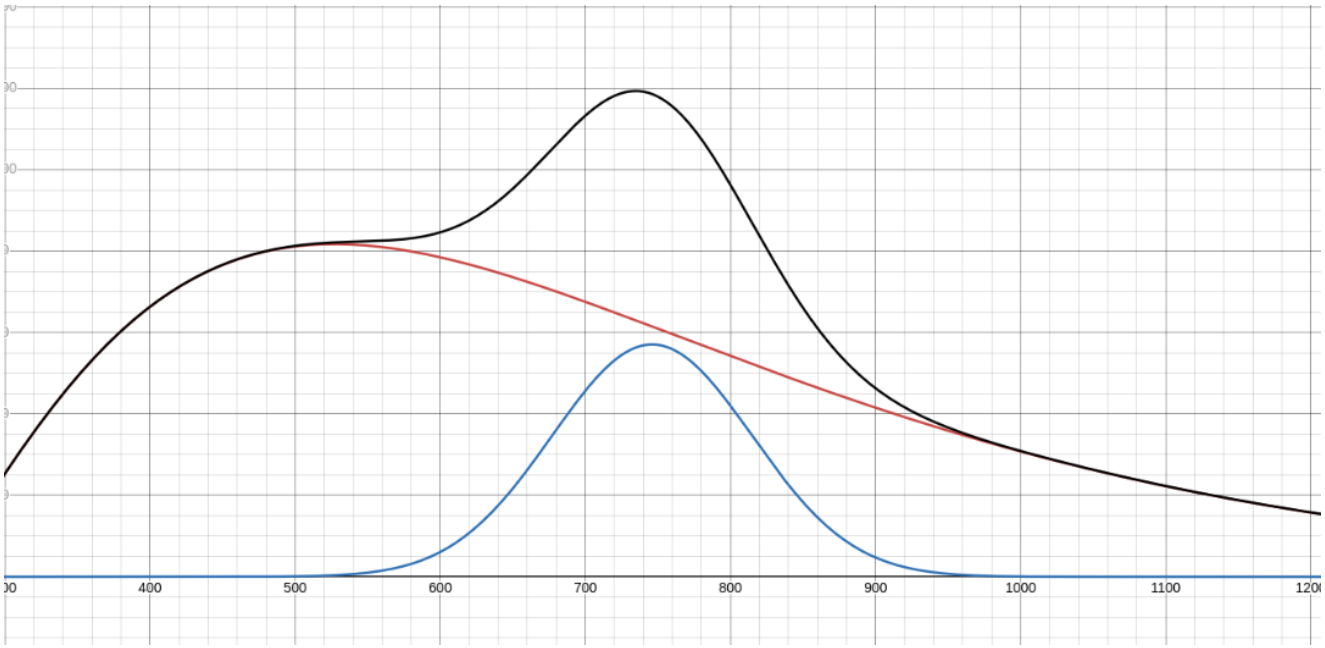
Conclusion

Cuts are effectively removing Kaon events as desired

ρ mass fits on χ^2-cutted data

- We project onto x and y axis in the range 600 MeV to 900 MeV
- Formula for fit

$$f(x) = f_{\text{bg}}(x) + f_{\text{sg}}(x) = A(x - B)^C e^{Dx} + N \exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)$$



ρ invariant mass analysis TOTEM2

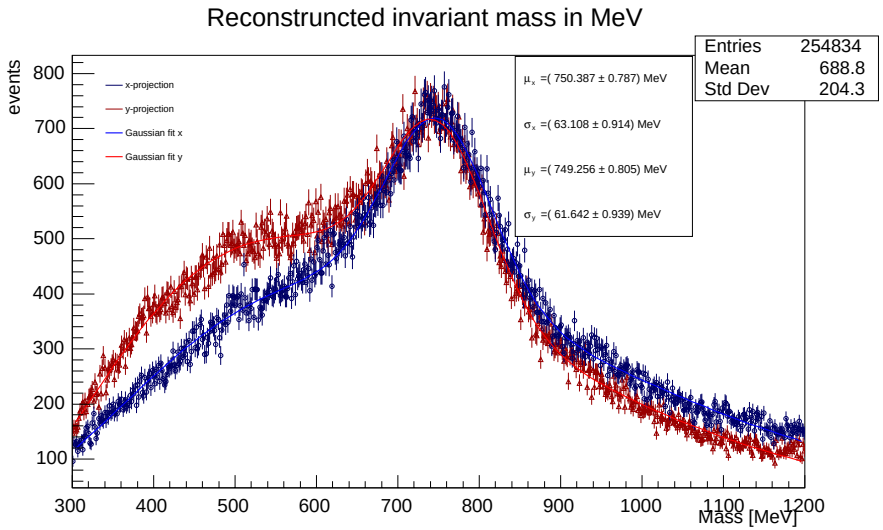


Figure: Cuts $\chi^2 < 10$ for all three

- $\langle \mu_2 \rangle_{\chi^2<10} = 749.823(796)\,\text{MeV}$
- $\langle \sigma_2 \rangle_{\chi^2<10} = 62.375(927)\,\text{MeV}$

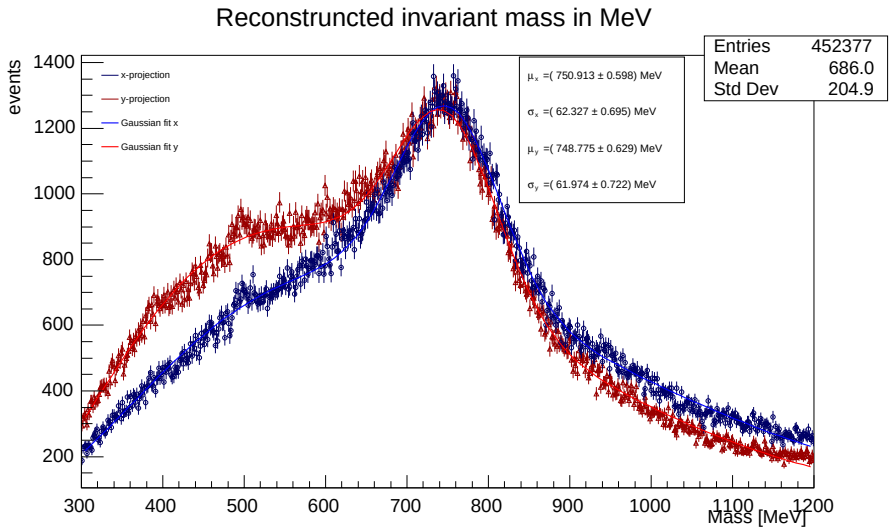


Figure: Cuts $\chi^2 < 30$ for all three

- $\langle \mu_2 \rangle_{\chi^2<30} = 749.844(614)\,\text{MeV}$
- $\langle \sigma_2 \rangle_{\chi^2<30} = 62.151(709)\,\text{MeV}$

Conclusion

No big differences, but smaller fit uncertainty for less restrictive cuts.

Comparison to PDG

Source	K_S^0 **mass [MeV]**	ρ **mass [MeV]**	ρ **width [MeV]**
TOTEM2	497.903(173)	749.844(614)	146.366(1670)
TOTEM4	497.865(164)	748.330(548)	150.008(1505)
PDG	497.611(13)	766.5(11)	150.2(24)

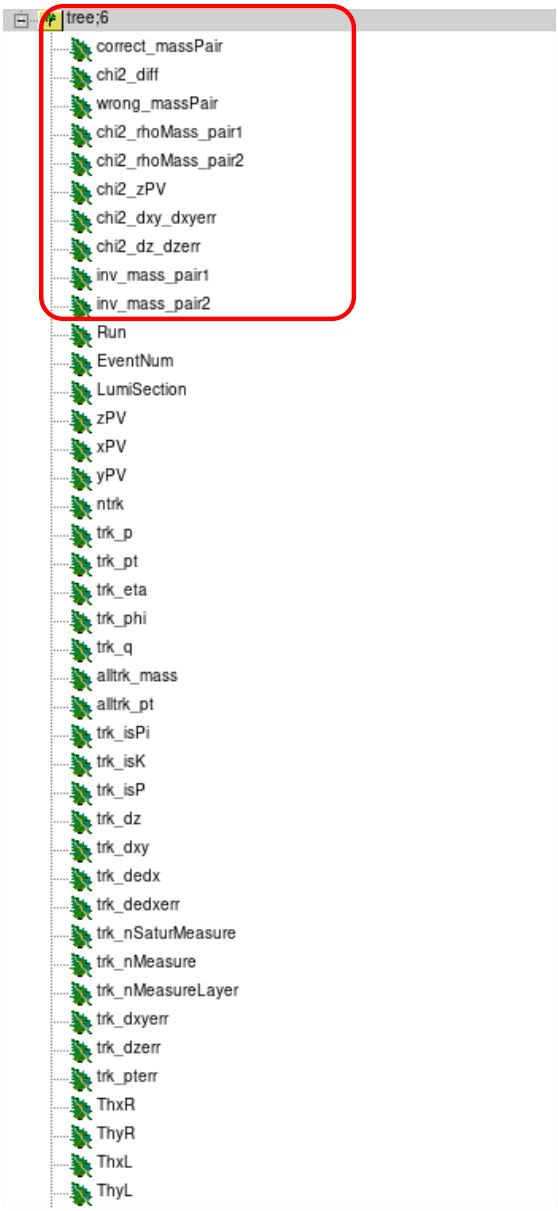
Conclusion

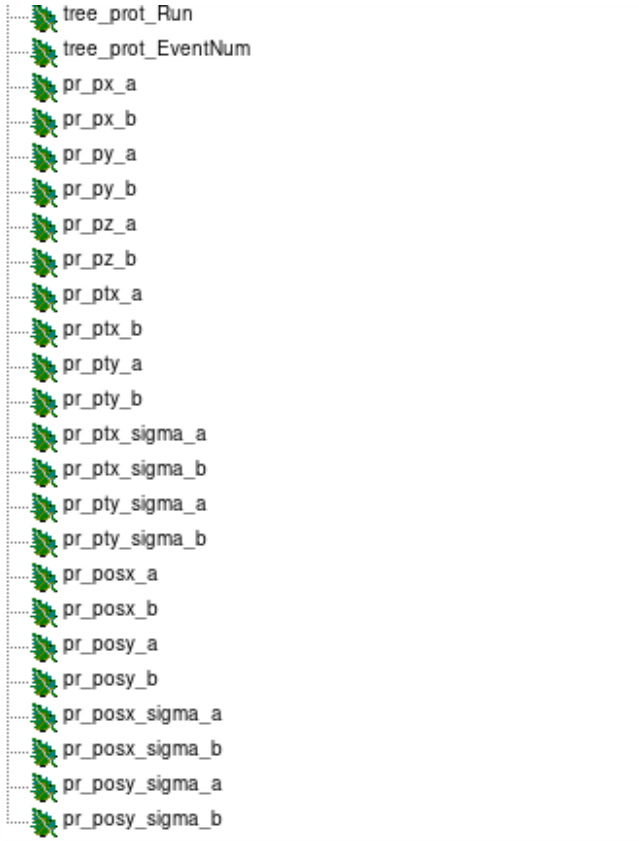
Kaon fits agree very well with PDG. Rho fits underestimate mass but give correct width.

Define χ^2-like variable for invariant mass

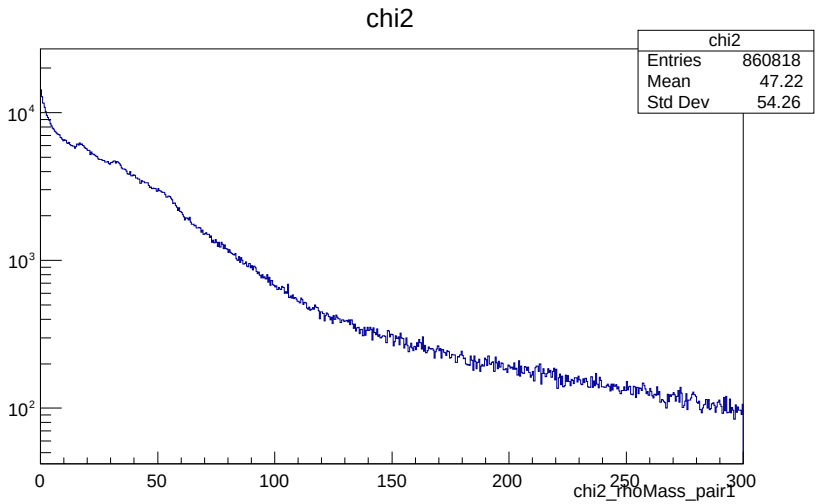
- Define
$$\chi^2_{m_\rho} := \frac{(m_\rho - m_1)^2}{\sigma_\rho^2} + \frac{(m_\rho - m_2)^2}{\sigma_\rho^2}$$
- Take m_ρ and σ_ρ from previous fit
- We get two $\chi^2_{m_\rho}$, one for each pair
- Add two χ^2 branches to tree
- Mass pairing with lower χ^2 is the "correct" one.
- Add branches for correct and wrong mass pairs and for difference of χ^2s of different pairings

New Tree structure

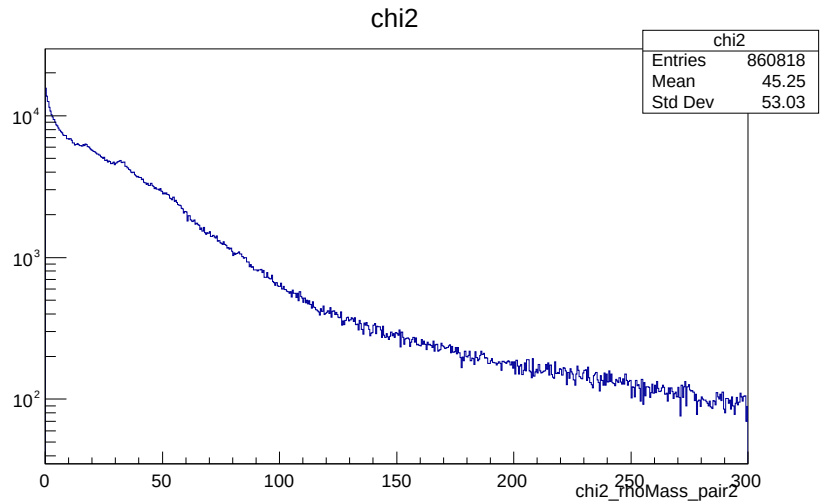




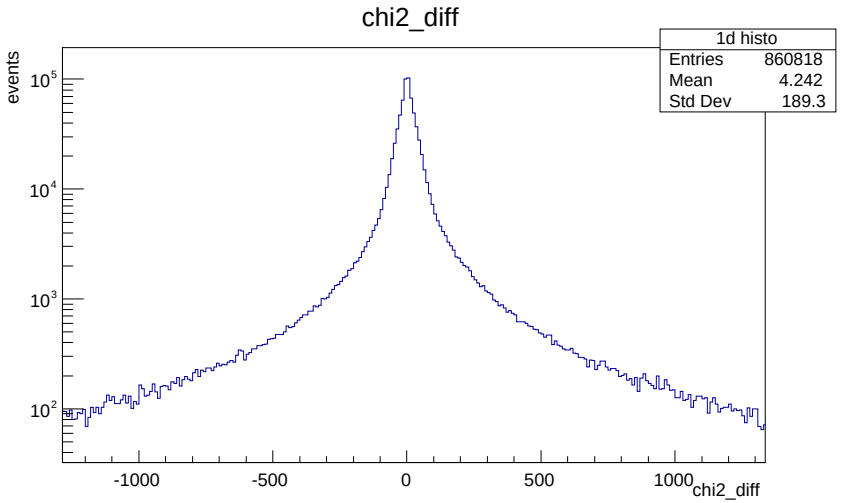
$\chi^2_{m_\rho}$ from TOTEM2



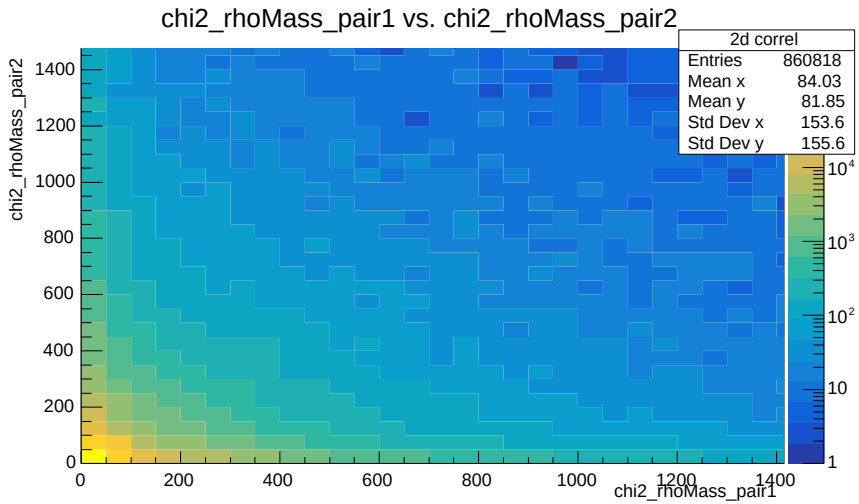
mass pair 1



mass pair 2

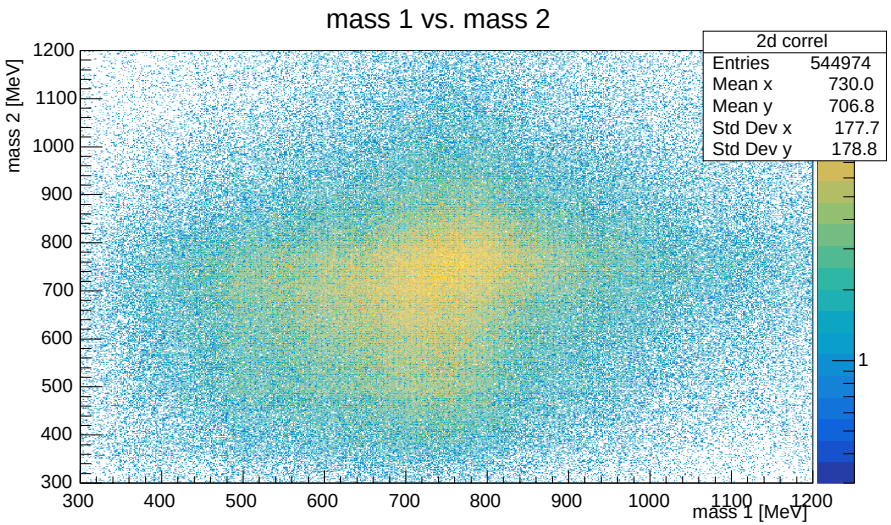


$\chi^2_{m1} - \chi^2_{m2}$

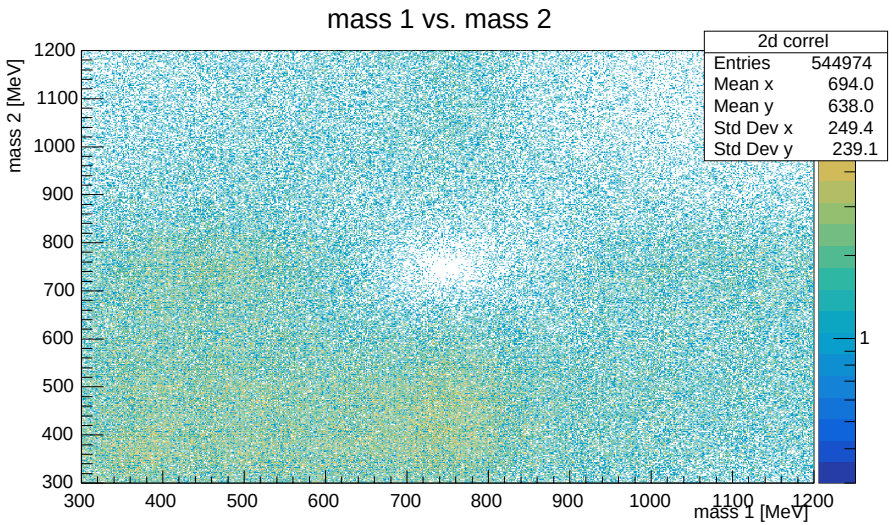


χ^2_m correlation

Identifying correct pairs $\chi^2_{\text{zPV,dxy,dz}} < 30$ cut TOTEM2



correct pairs

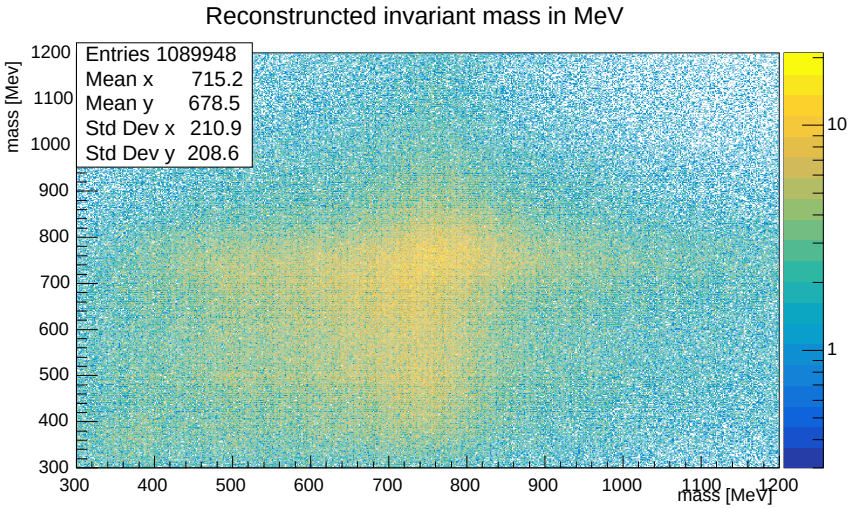


wrong pairs

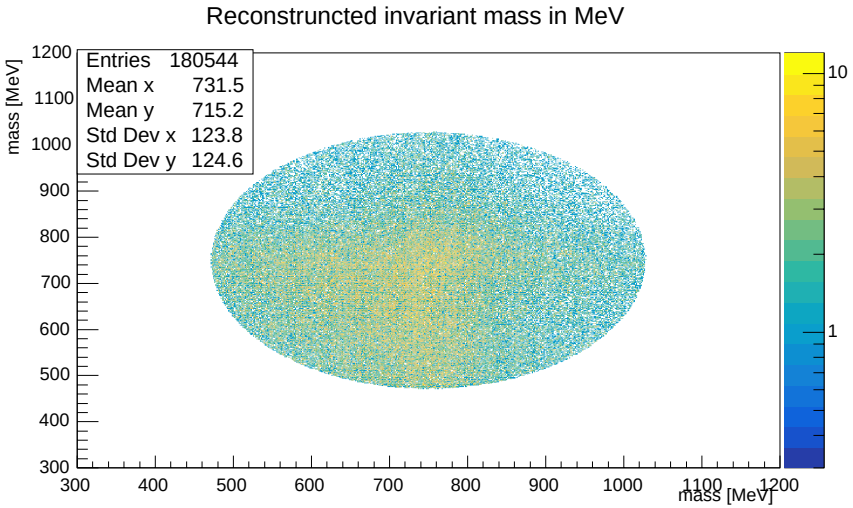
Conclusion

Identification of mass pairs seems to work, but the difference of χ^2 is centrally distributed and the two χ^2 are uncorrelated

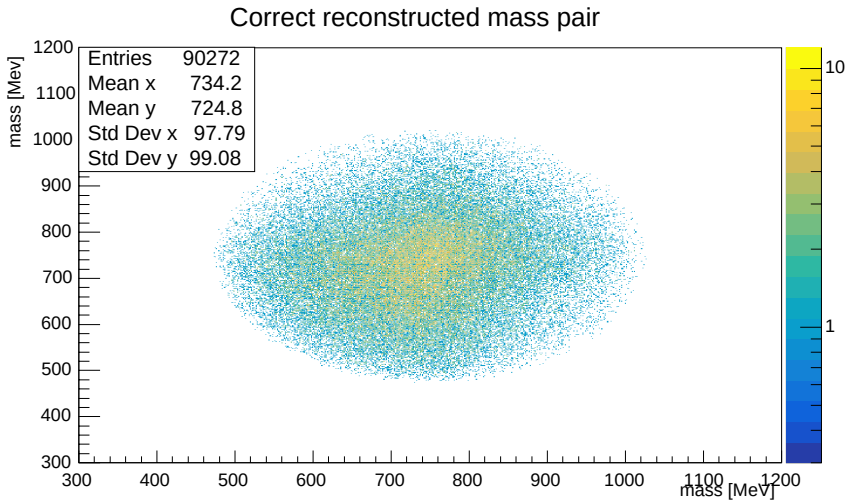
Effect of $\chi^2_{m_\rho}$ cuts on TOTEM2



$\chi^2_{\text{zPV,dxy,dz}} < 30$



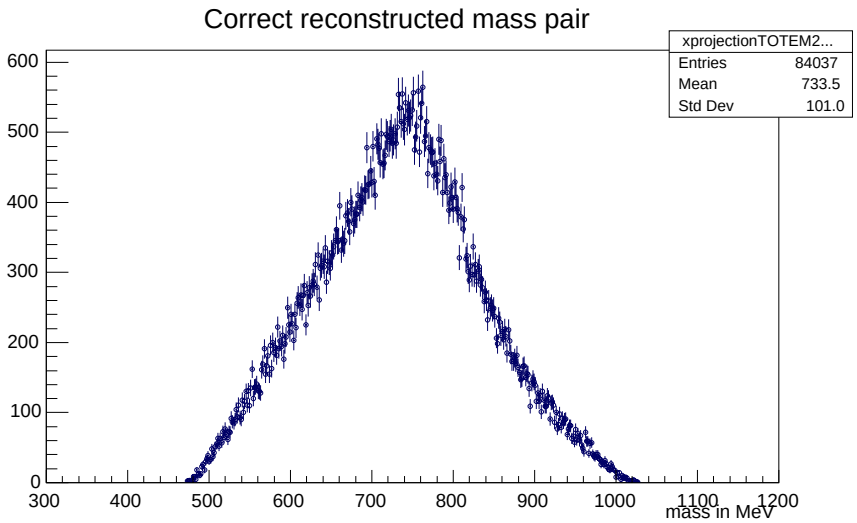
$\chi^2_{\text{zPV,dxy,dz}} < 30$ and $\chi^2_{m_\rho} < 20$



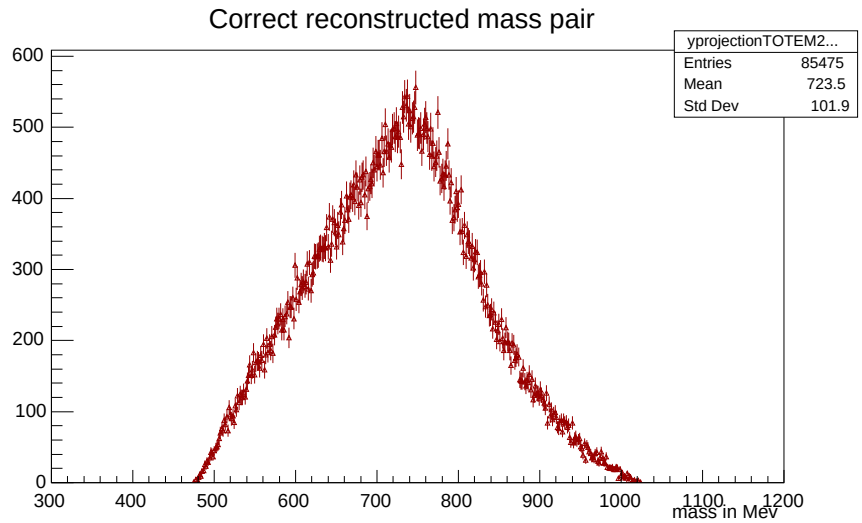
same cuts only correct pairs

Cuts $\chi^2_{\text{zPV,dxy,dz}} < 40$ and $\chi^2_{m_\rho} < 30$ on TOTEM2

- We make projections and use the sum range 600 to 900 MeV

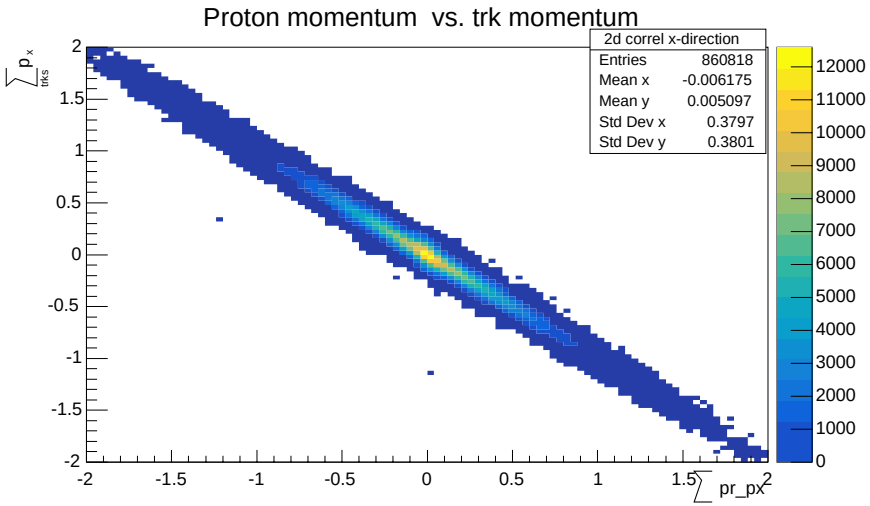


x-projection

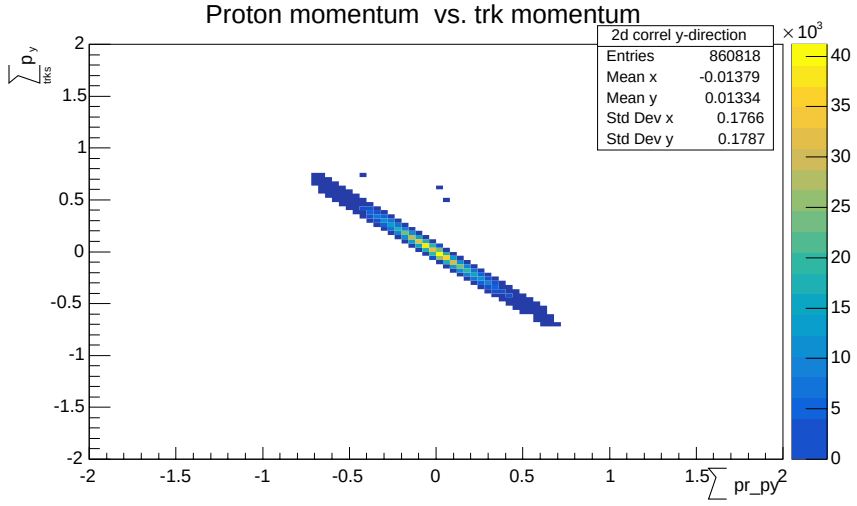


y-projection

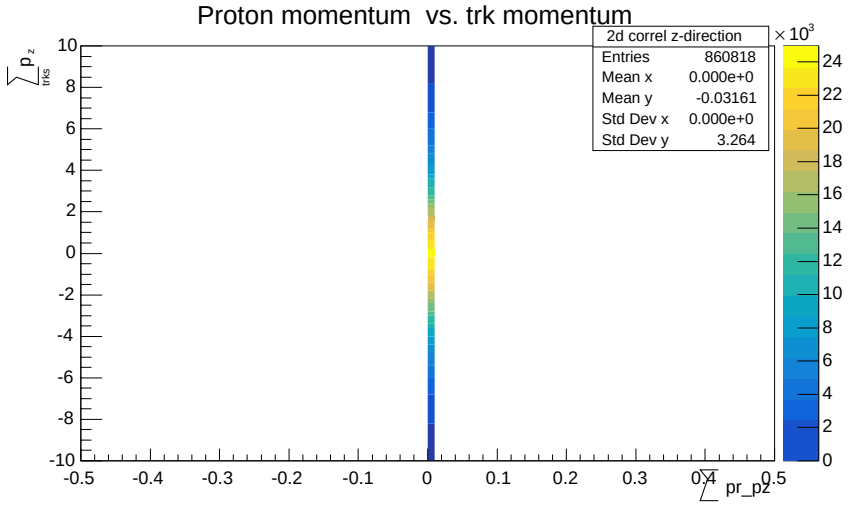
Momentum correlation uncut TOTEM2



p_x

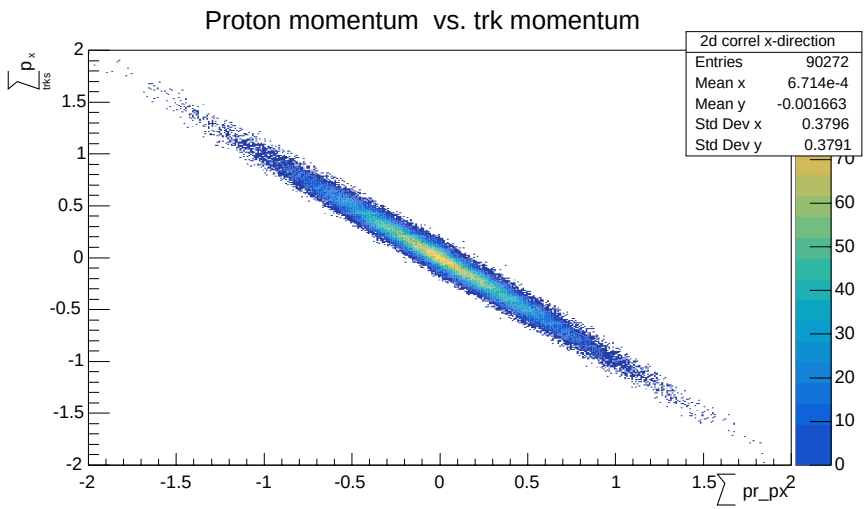


p_y

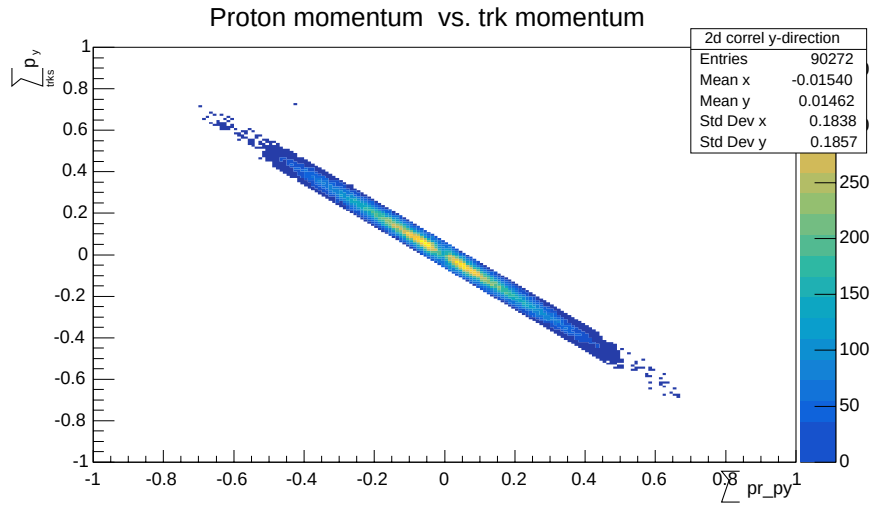


p_z

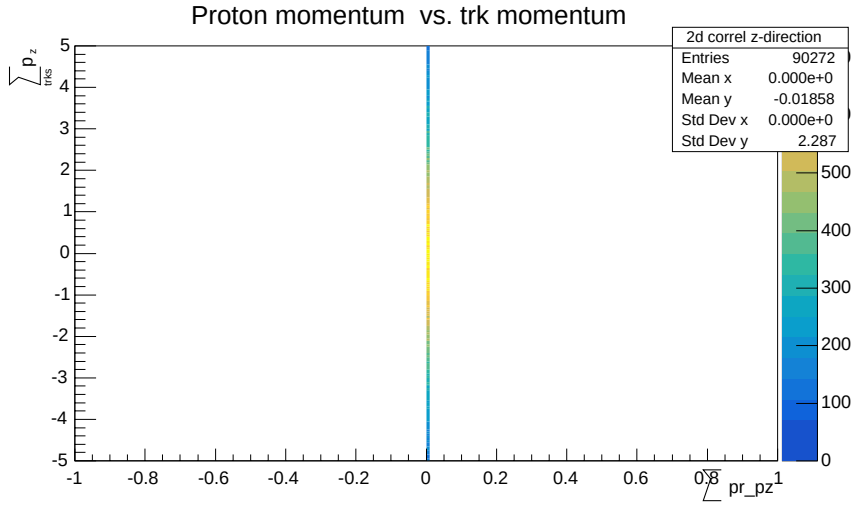
Momentum correlation χ^2-cutted TOTEM2



p_x

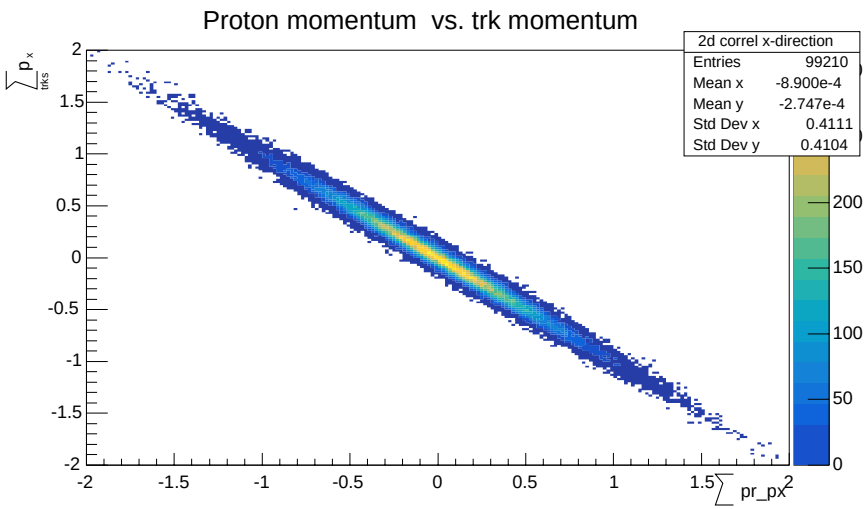


p_y

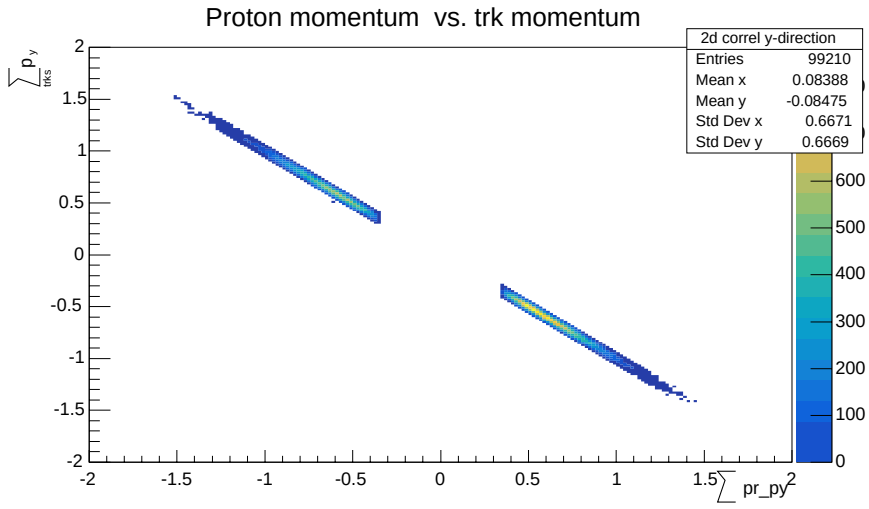


p_z

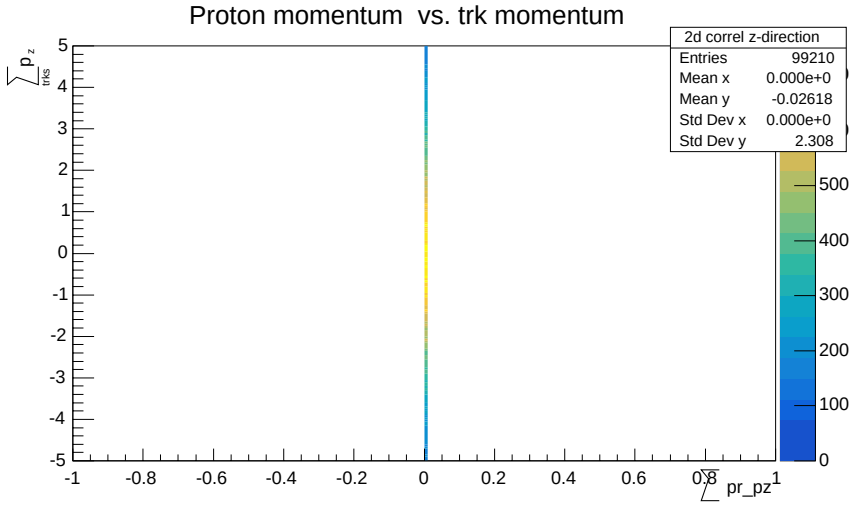
Momentum correlation χ^2-cutted TOTEM4



p_x



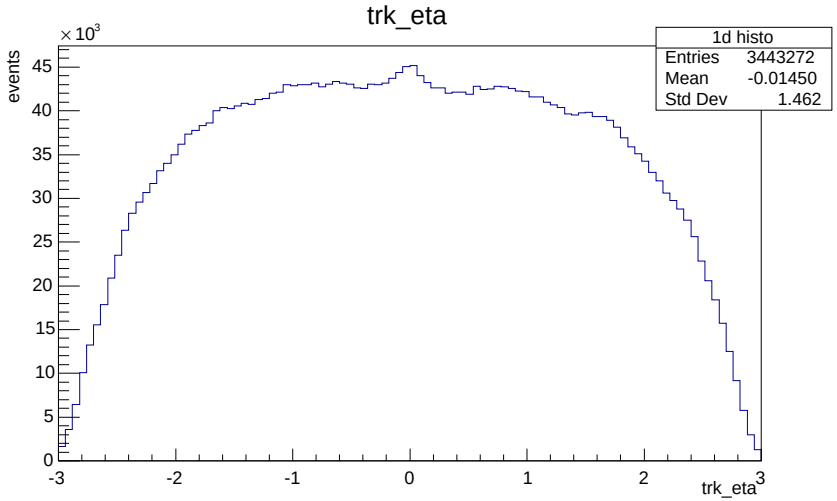
p_y

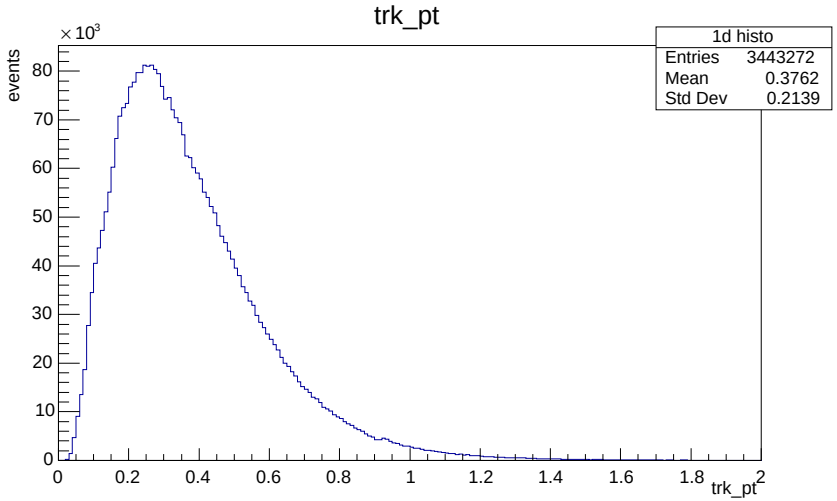


p_z

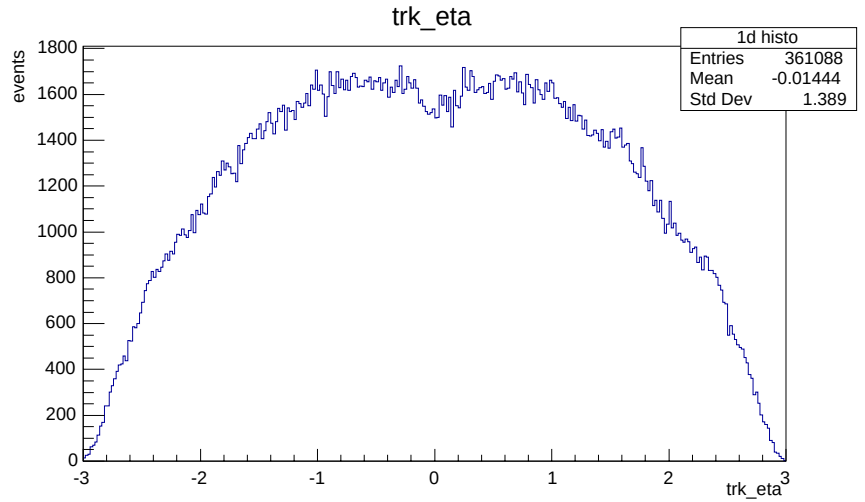
Pseudorapidity and transverse momentum of cutted data

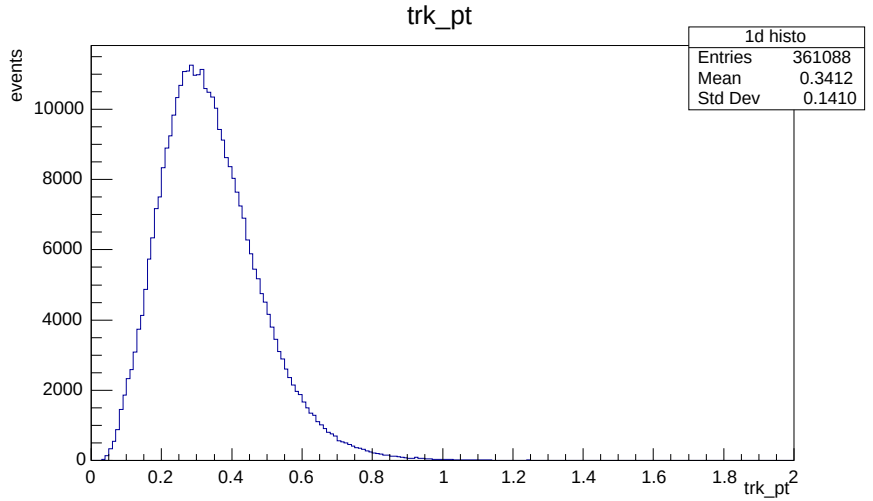
Uncut TOTEM2





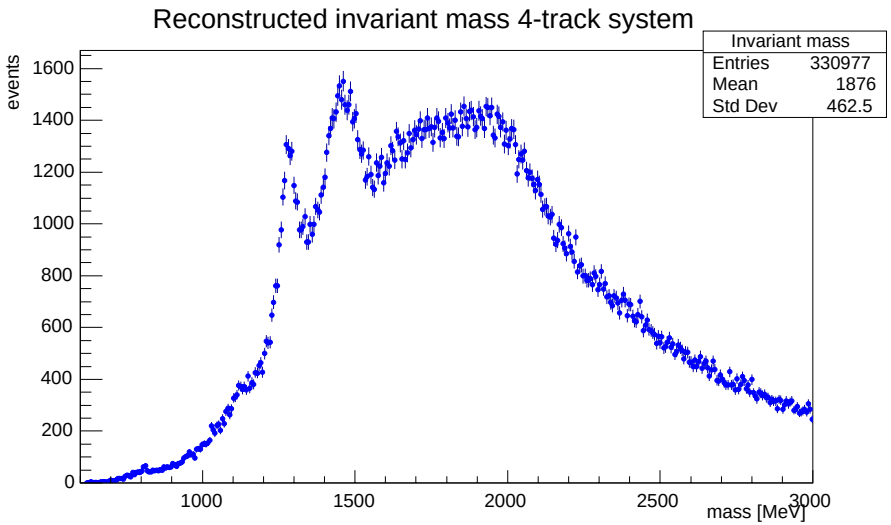
χ^2-cut TOTEM2



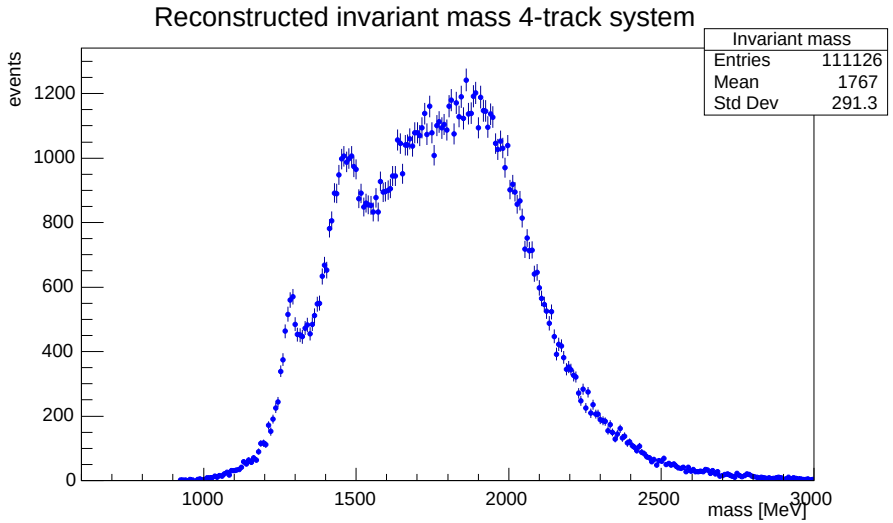


4-track invariant mass reconstruction TOTEM2

For all ntrk=4 and net charge zero



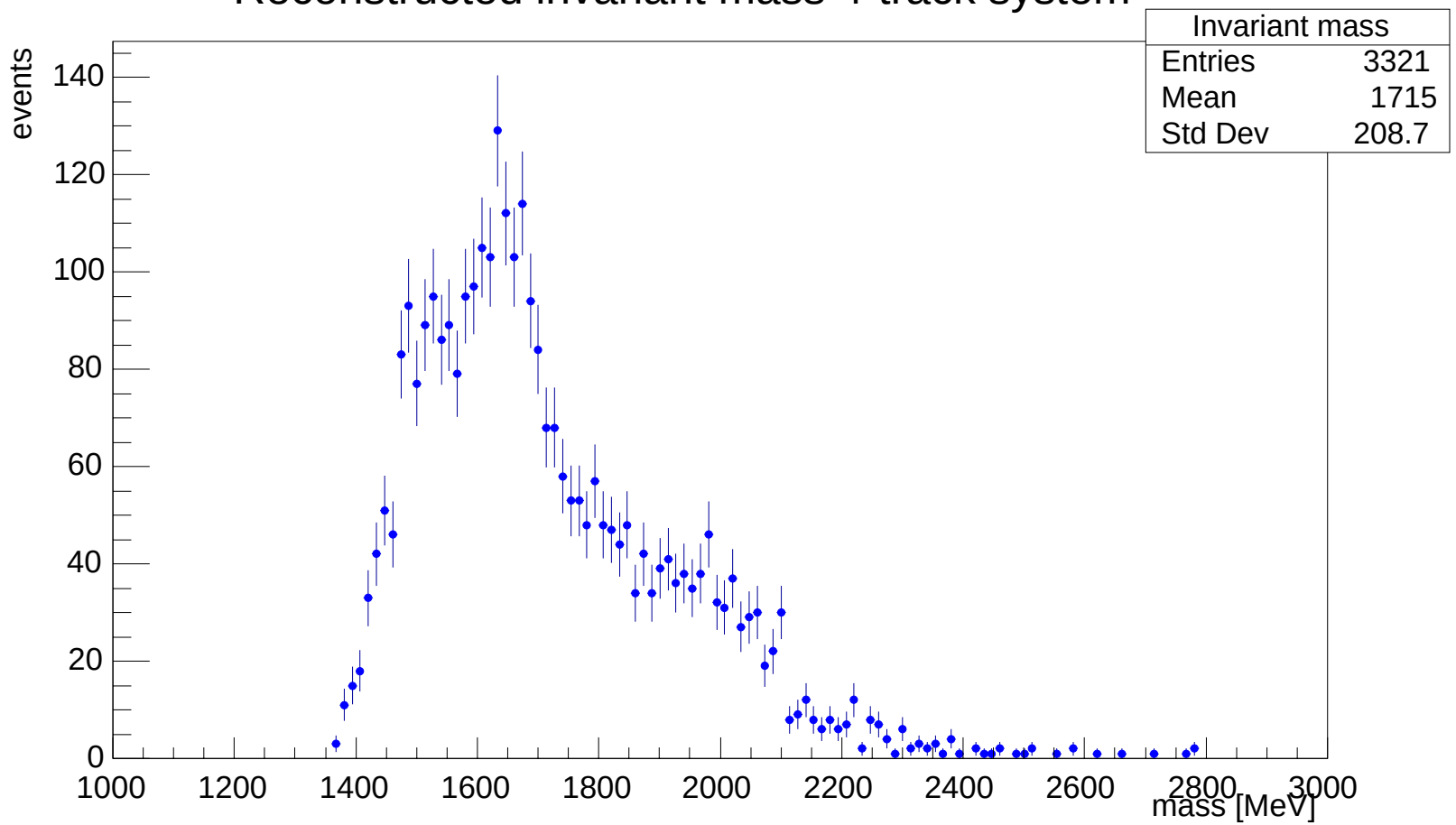
only $\chi^2_{\text{zPV,dxy,dz}} < 10$



$p_t < 800\,\text{MeV}$, $|\eta| < 3.0$,
$\chi^2_{\text{zPV,dxy,dz}} < 50$ and $\chi^2_{m_\rho} < 50$

4-track invariant mass reconstruction TOTEM2

For all ntrk=4 and net charge zero

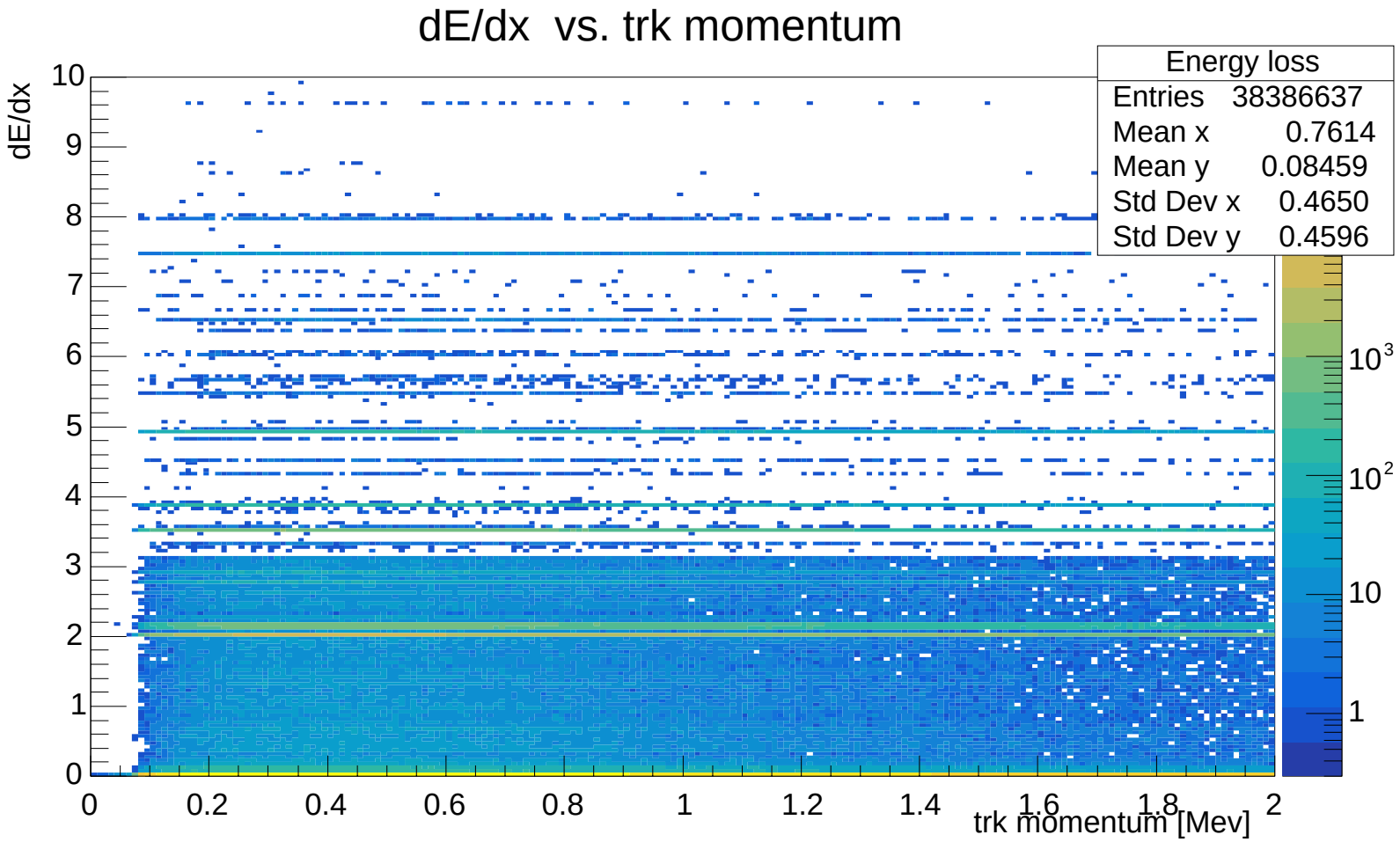


$\sum p_t < 800\,\text{MeV}$, $|\eta| < 3.0$, $|\text{dxy}| < 0.0435$, $|\text{zPV}| < 5$, $\chi^2_{\text{zPV,dxy,dz}} < 16$ and $\chi^2_{m_\rho} < 4$

Thanks for your attention!

Questions are welcome.

Backup


dE/dx vs. trk momentum
Energy loss
Entries 38386637
Mean x 0.7614
Mean y 0.08459
Std Dev x 0.4650
Std Dev y 0.4596
dE/dx
trk momentum [Mev]
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
1
2
3
4
5
6
7
8
9
10
10^3
10^2
10
1