EPD SIMULATION: STATUS UPDATE

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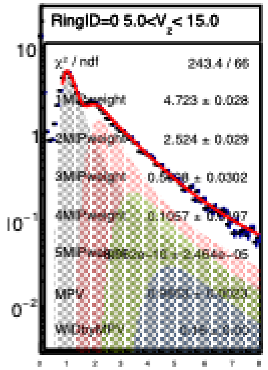
Measuring $dN/d\eta$ with the EPD

- EPD measures signal (ADC) → Convolution of several Landau distributions
- With "multiple Landau" fits, one can extract dN/dn_{MIP} for each ring
  - See details e.g.: https://drupal.star.bnl.gov/STAR/blog/lisa/extracting-dndeta-forward-region-unfolding



- Each event has a given hits in a given ring: $N(i_{\mathrm{Ring}})$
- Originates from an underlying $dN/d\eta$, $N(i_{\mathrm{Ring}})$ can be calculated as

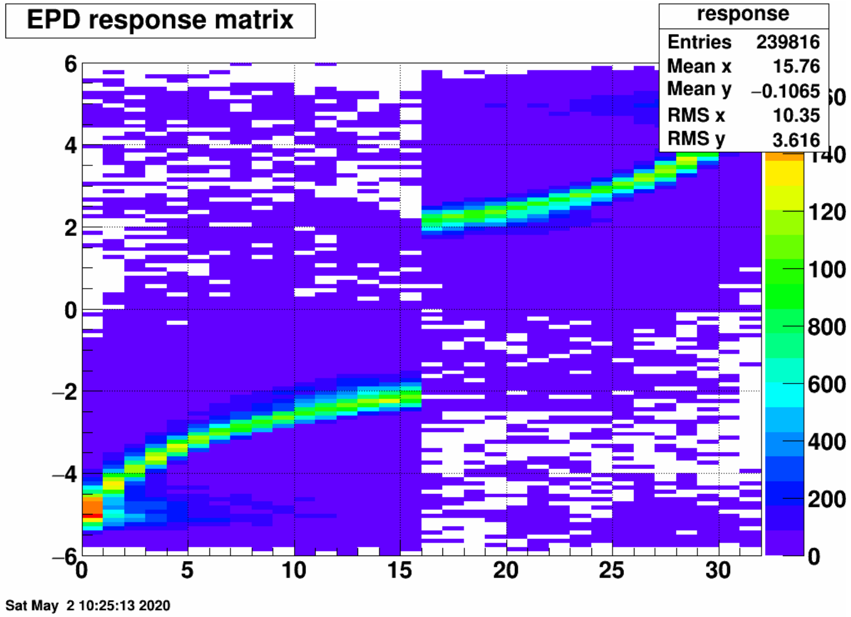
$$N(i_{\mathrm{Ring}}) = \int R(\eta, i_{\mathrm{Ring}}) \frac{dN}{d\eta} d\eta$$

- Here R is the response matrix: how many hits in given ring from particles with η
- How to invert this?
- Calculate R via simulations, determine $dN/d\eta$ via **unfolding**

Calculating the response matrix via simulation

- Use interative unfolding, based on G. D'Agostini, Nucl. Instr. Meth. A362 (1995) 487
- Implemented in RooUnfold, response matrix to be calculated as:

```
for(PrimaryTracks)
{
  if(no EPDhits from that Primary Track)
  {
    R->Miss(TrackEta); //This track "missed" the EPD
  }
  else
  {
    for(EPD hits of that Primary Track)
    {
      R->Fill(EPDeta,Tracketa);
    }
  }
}
```



- Simulation part: need
  - list of primary tracks
  - EPD hits and the primary track that caused them
- All possible in HIJING+GEANT simulator, using StarHijing (1.383) and StEpdFastSimMaker
  - Further utilities used: StarGeneratorUtil/Event/Base, St_geant_Maker, etc.

Technical details (how-to) of the simulation

1. Copy components from */star/u/mcsanad/newsim/hijingPlusGeantSim/submit/*
   starsim.C , *runEpdFastSim.C* , *runHijing.xml*, *makeMuDST.xml* (plus *StRoot* directory checked out)

2. Edit xml files to reflect on user directory and username,
   create *log*, *err*, *out* and *fzdroot* directories (given in xml files)

3. Edit settings in runHijing.xml:
   - SL version (SL19e seemed to work)
   - nProcesses (500 currently) and NEVENTS (10 currently)
   - geometry tag (y2018a seemed to work)
   - a random seed for the first job (currently 26544321)
   (*makeMuDST.xml* needs probably the same SL version)

4. Edit settings in starsim.C:
   ```
   hijing->SetFrame("CMS",200.0);  // CMS energy per nucleon pair
   hijing->SetBlue("Au");
   hijing->SetYell("Au");
   hijing->SetImpact(0.0, 1.0);  // b in [0 fm, 1 fm]
   ```

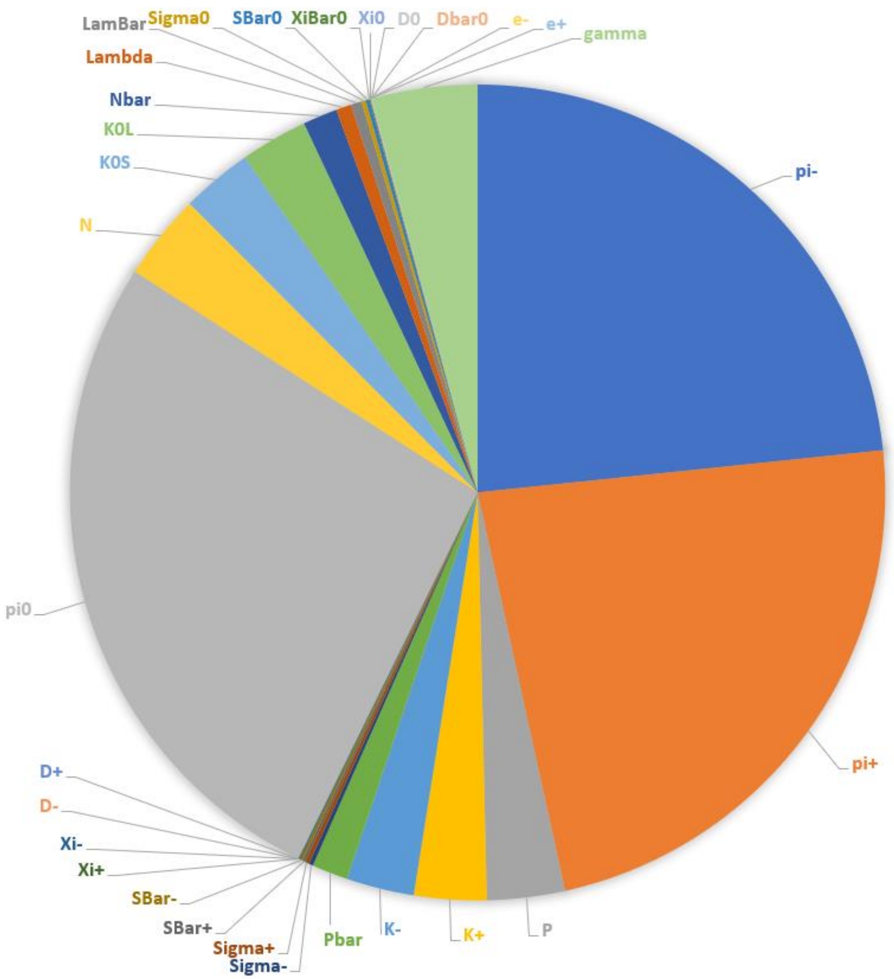
5. Submission: *star-submit runHijing.xml* (modify queue if needed)

6. List resulting fzd files in text file, edit *makeMuDST.xml* to use that list in *<input URL="filelist:…"/>*, then *star-submit makeMuDST.xml*

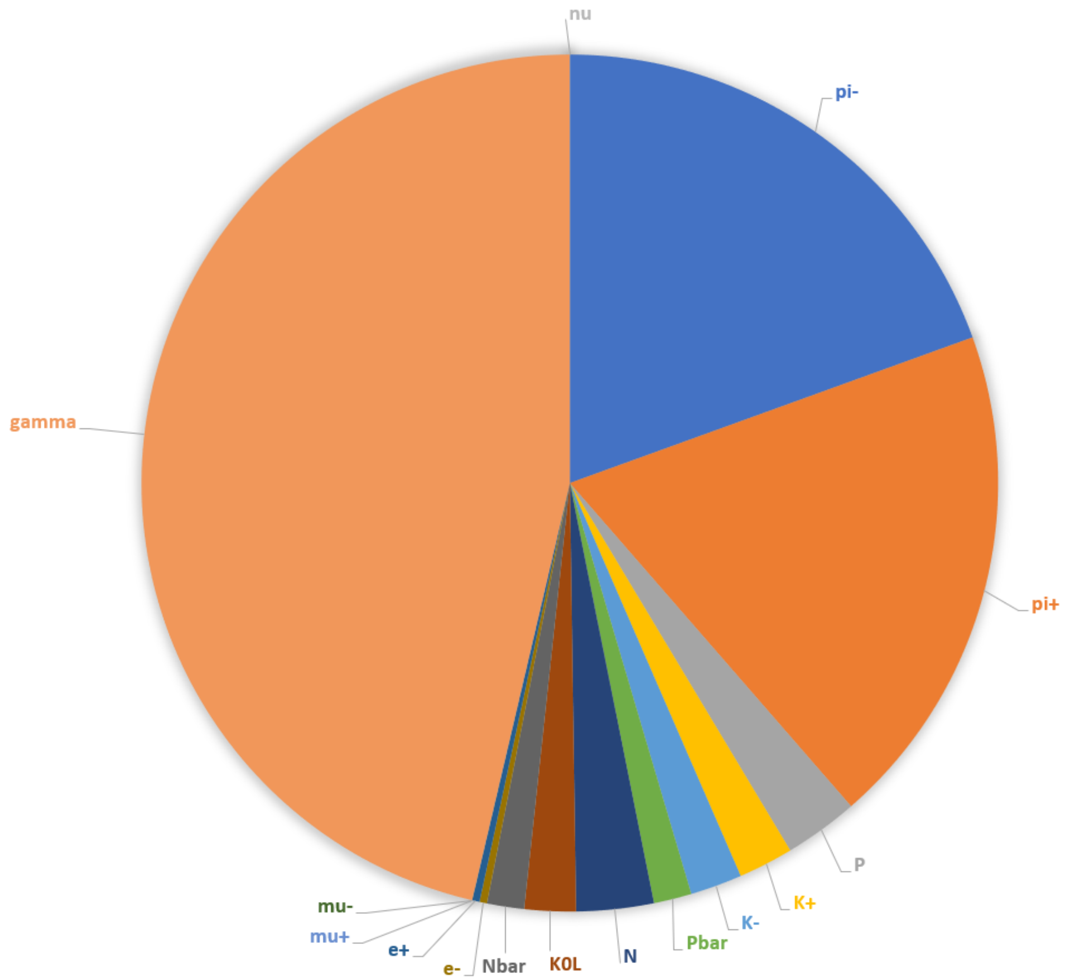
7. Example analysis codes are in
   /star/u/mcsanad/newsim/
   see for example: *root.exe -b -q lMuDST.C ZvtxBinnedResponse.C+*

What particles are there in the simulation?

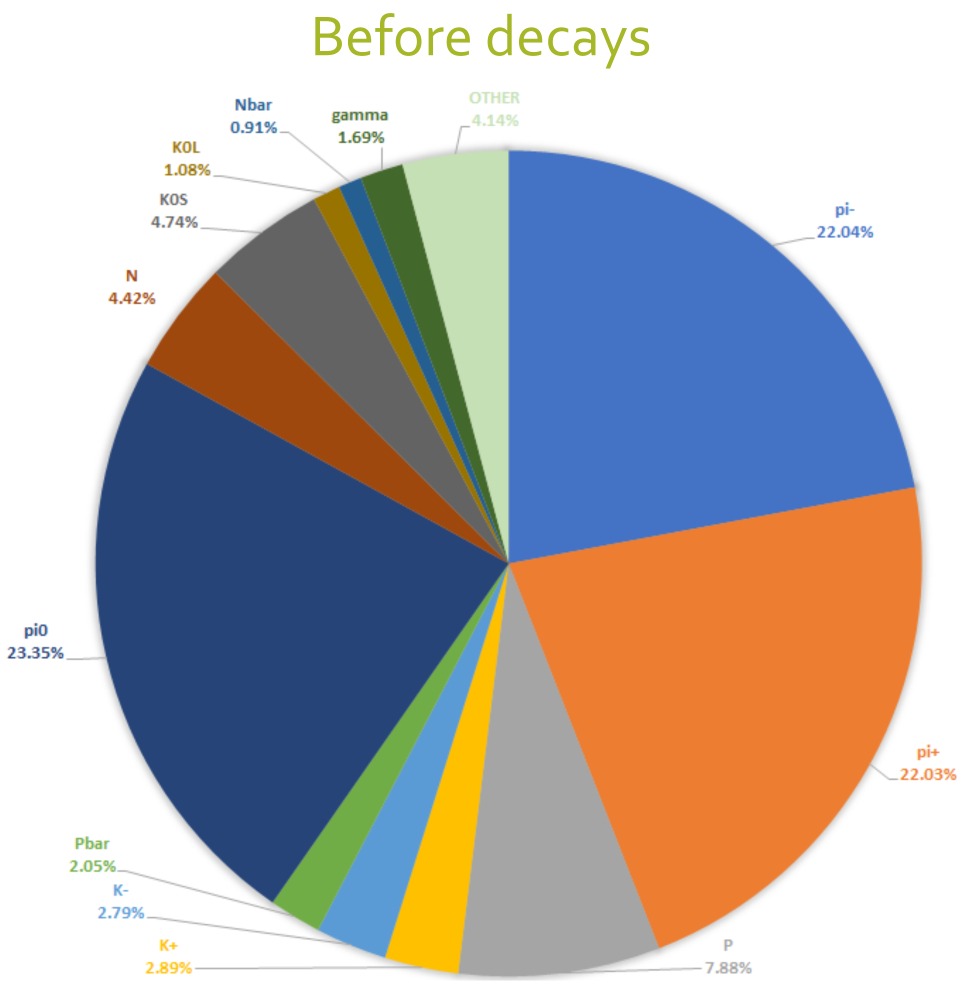
Before decays

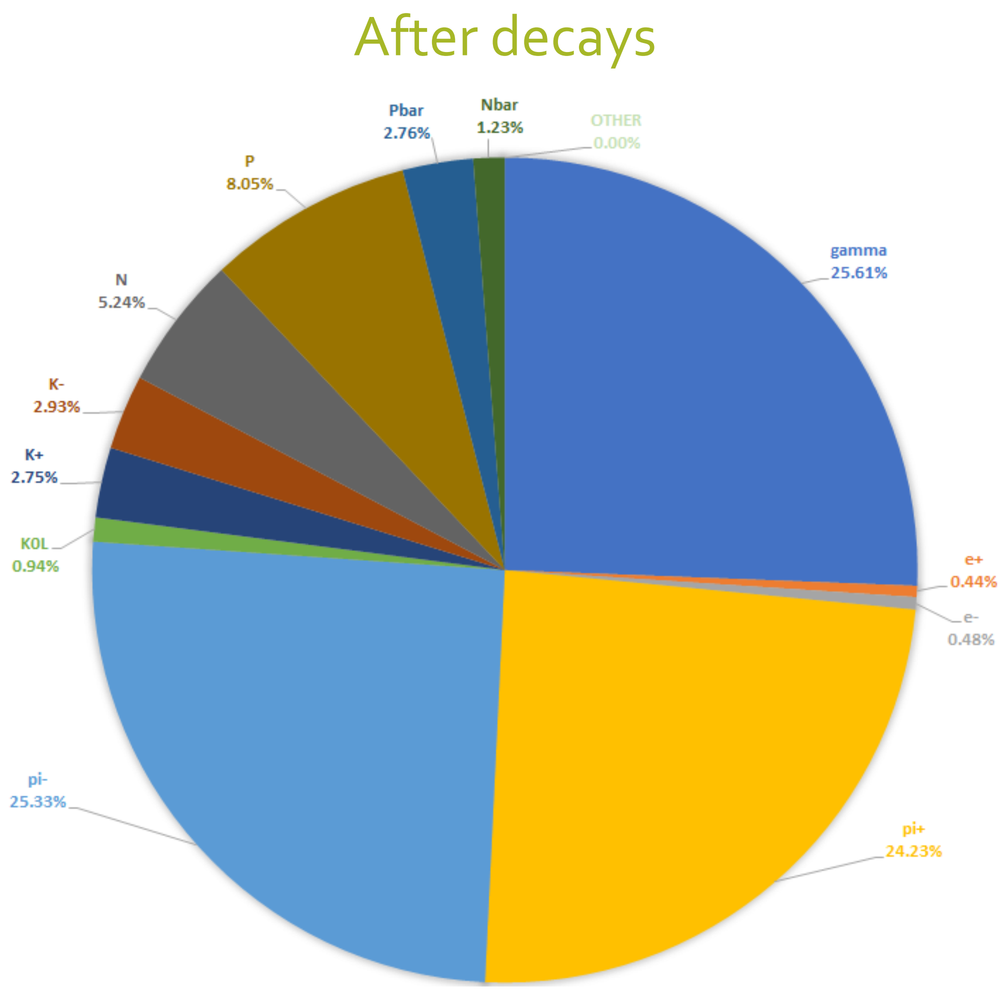


After decays



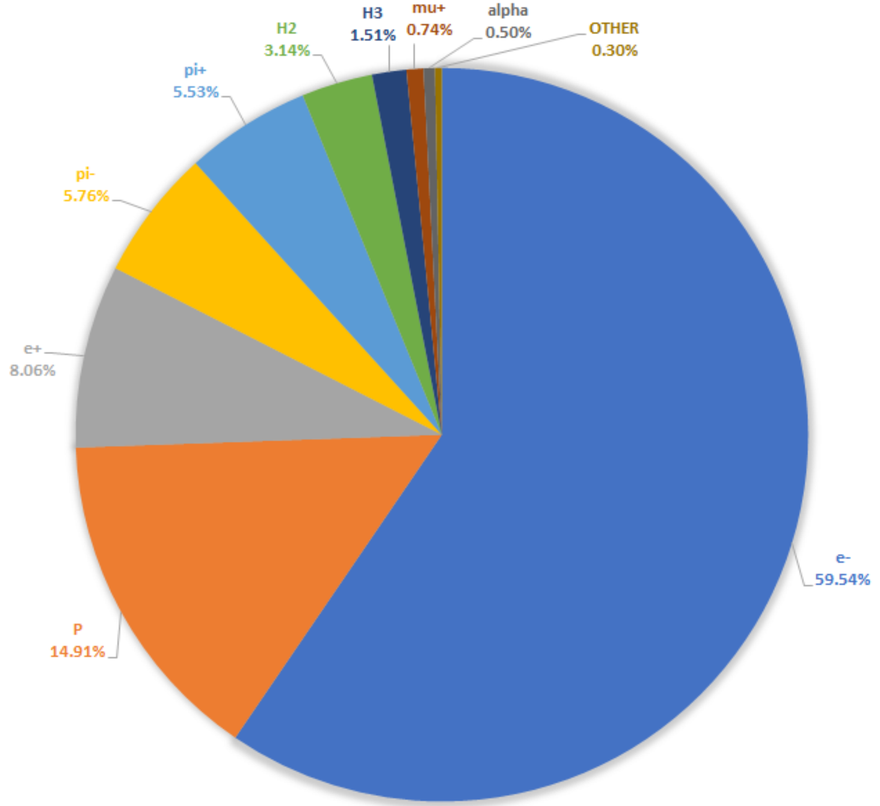
"Original" particles causing hits in the EPD

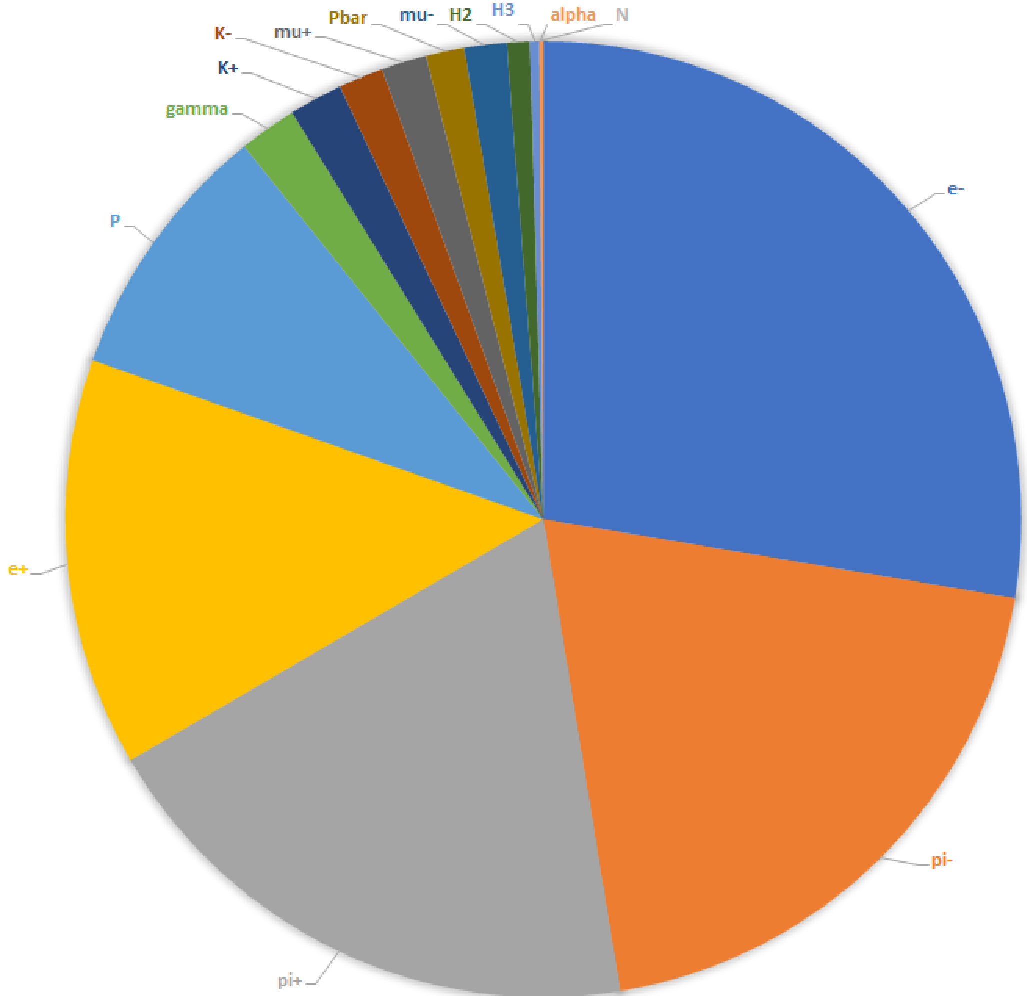




Particles directly hitting the EPD

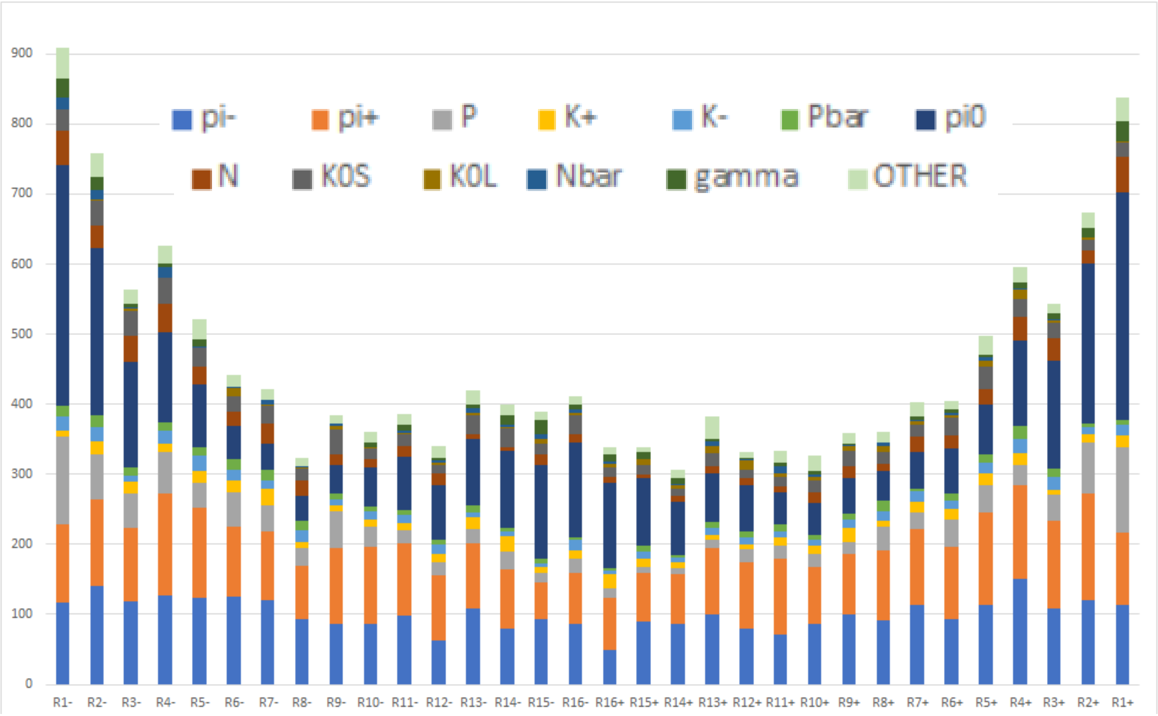
- Mostly secondary (i.e. GEANT)
- Some are born inside the EPD
  - Not entirely clear, but small effect

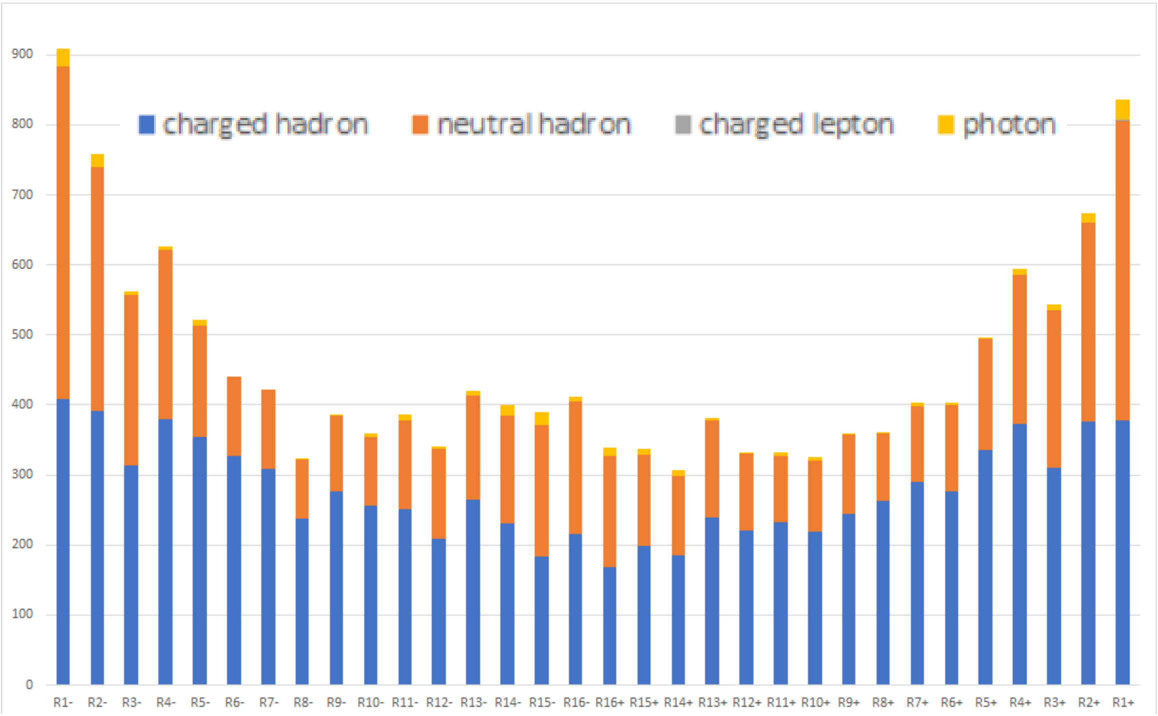




EPD hit causing primaries, ring-by-ring

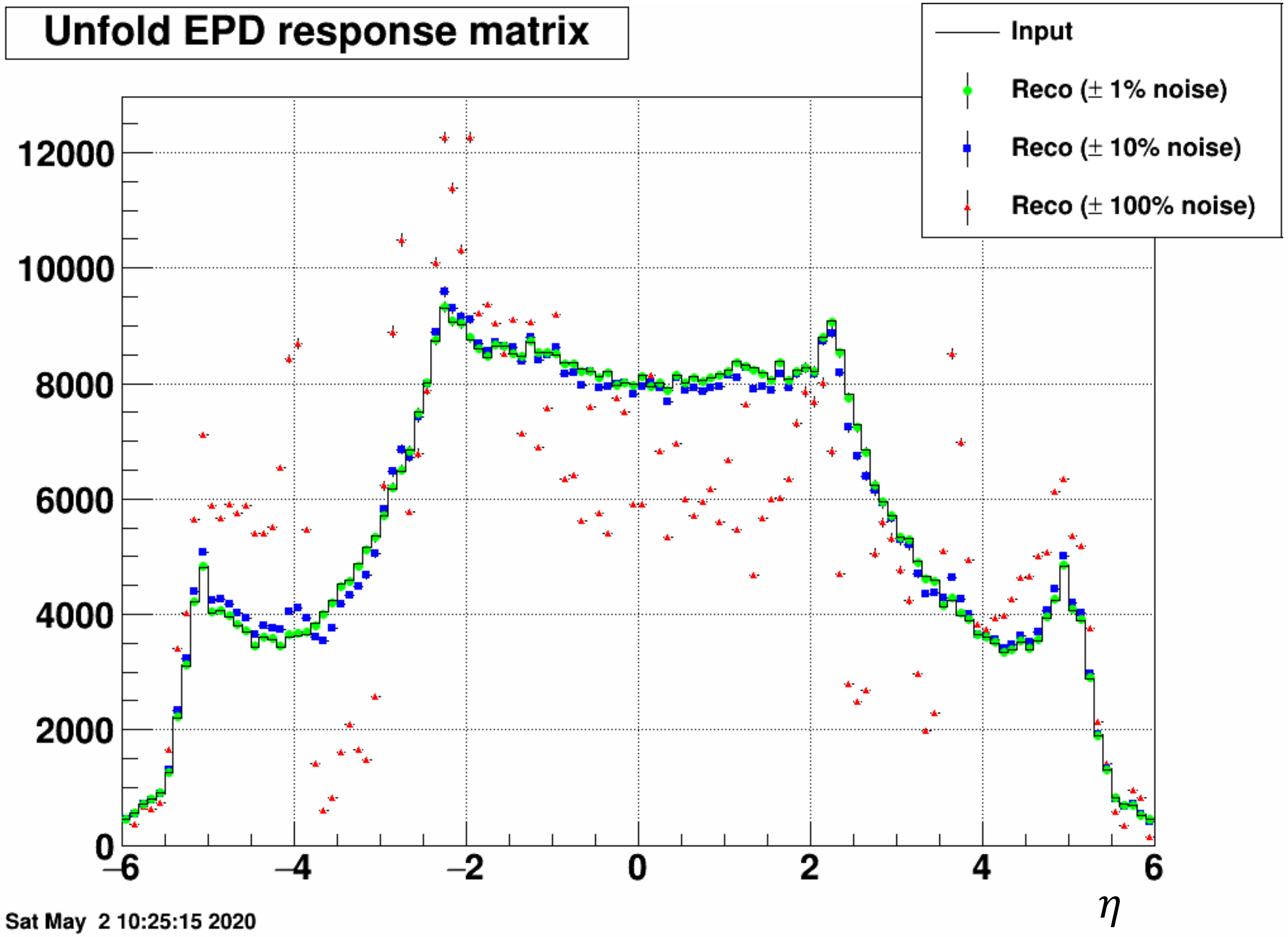
- Fraction of charged hadrons <50% for inner&outer rings, >70% for medium rings
- Rest: neutral hadrons (mostly π^0, neutron, K^0), few photons





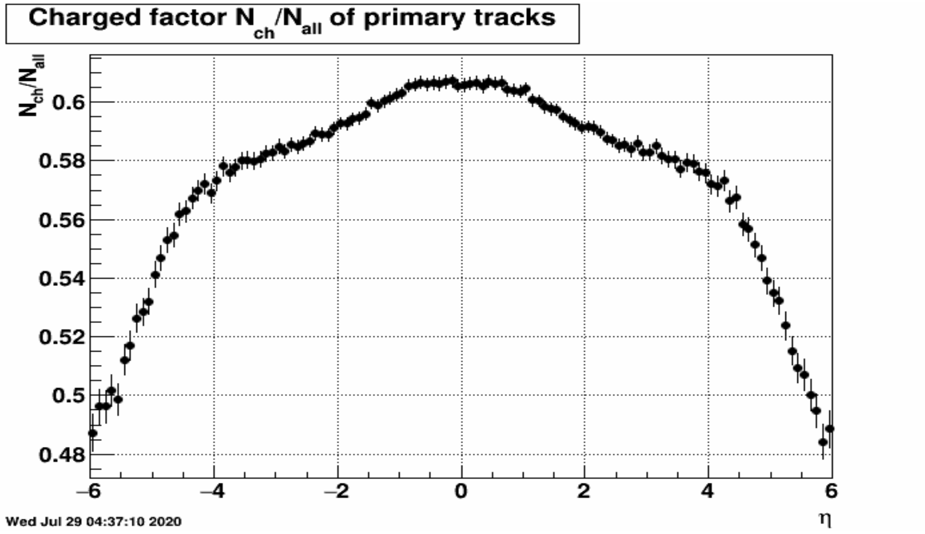
Does the unfolding work?

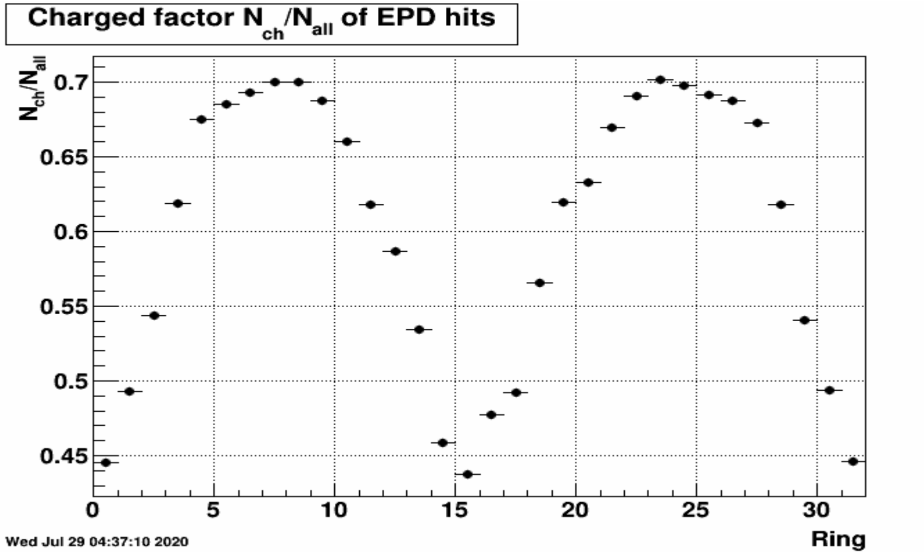
- If unfolding on training sample: returns input perfectly
- Adding some noise: imperfect but still good
- Why the peaks near $\eta = 5$?
  - One unfolded track for each individual EPD hit
  - Many tracks cause multiple hits → need to correct for this!
- How can it work near $\eta = 0$?
  - It reconstructs $dN/d\eta$ of input!
  - Need to investigate sytematic uncertainty from input sample



Measure charged tracks only?

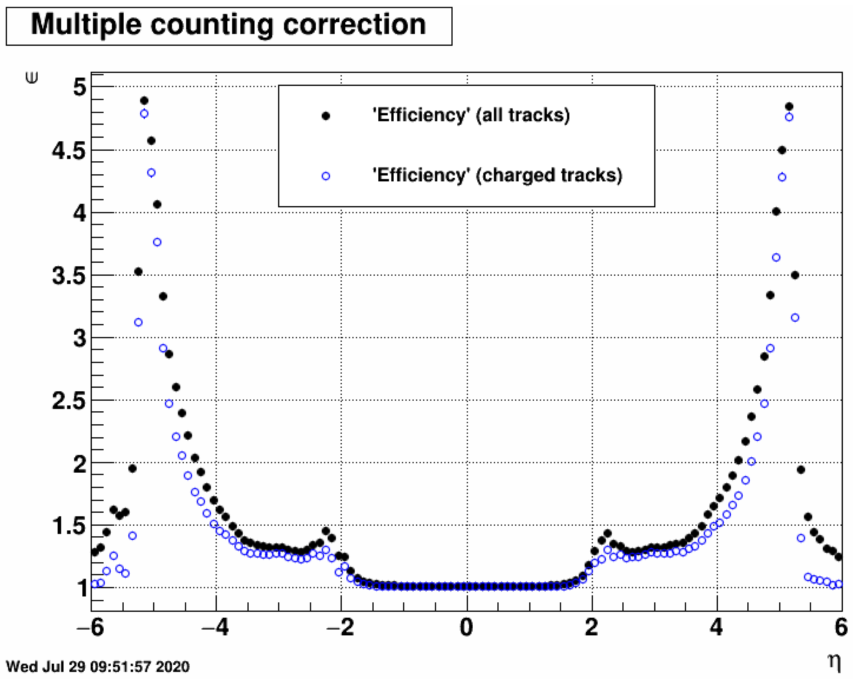
- Known in simulations: charged factor
  - For primary tracks
  - For EPD hits (based on primary cause)
- Tried 3 possible methods:
  1. Unfolding $dN/d\eta$; correcting via $N_{\mathrm{ch}}(\eta)/N_{\mathrm{tot}}(\eta)$
  2. Correcting via $N_{\mathrm{ch}}(i_{\mathrm{ring}})/N_{\mathrm{tot}}(i_{\mathrm{ring}})$; unfolding "corrected" EPD distribution
  3. Use RooUnfold's "Fakes" (neutrals ⇔ "fake" hits)
- First two work well
- Method 3: more dependence on input $dN/d\eta$
- Difference of methods: incorporate in systematics

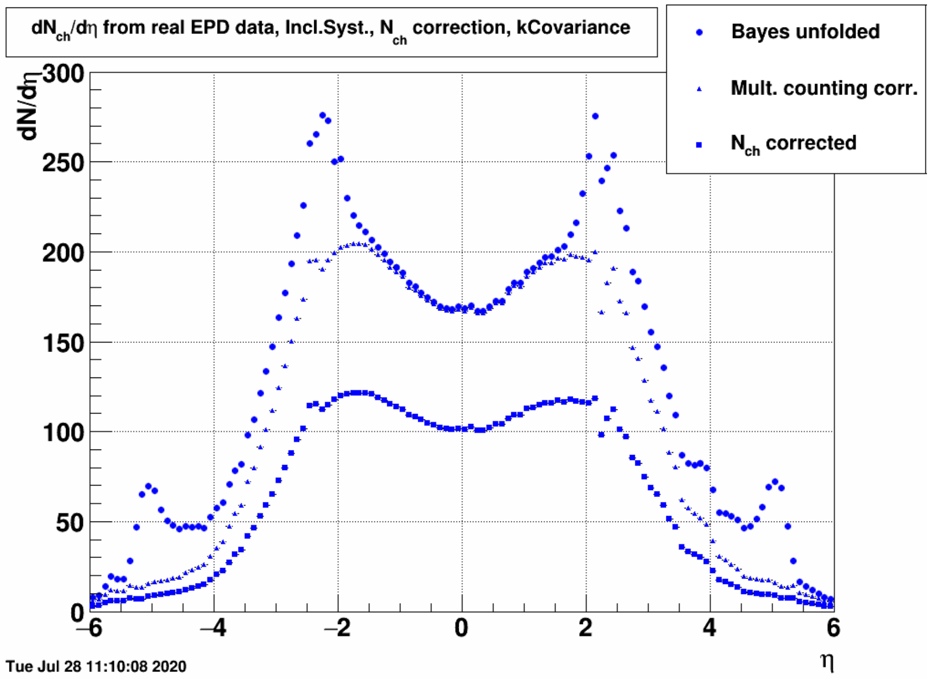




Multiple hits inverse efficiency correction

- Need to correct for multiple counting (many hits from one primary track)
  - Check "inverse efficiency": how many hits on average at given η
- Need to unfold charged tracks only



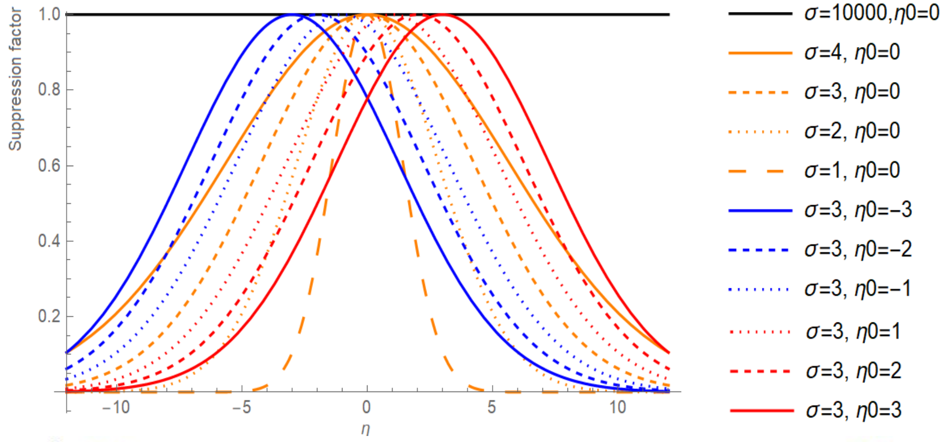


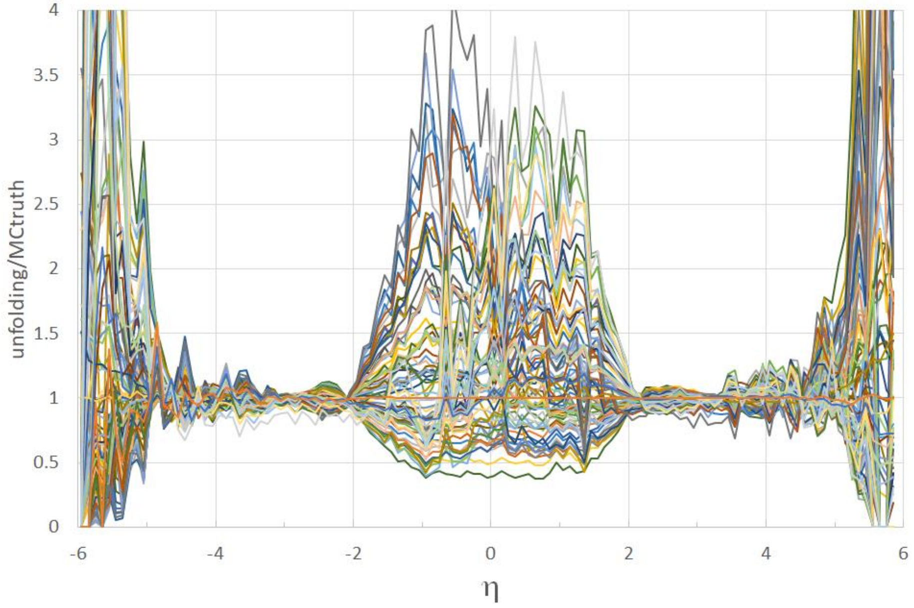
Dependence on input distribution

- Distort simulated sample with suppression factor:

```
for(primary MC tracks with nonzero EPD hits)
{
  if(random_selection_based_on_Gaussian_distortion) continue;
  float eta = mctrack->Eta();
  MCtruth->Fill(eta);
  if(no_EPD_hits_for_this_primary) response->Miss(eta);
  for(EPD hits of this primary track)
  {
    int ring_bin = number between 0...31 (15&16 are the outermost rings of the two sides)
    response->Fill(ring_bin,eta);
  }
}
```

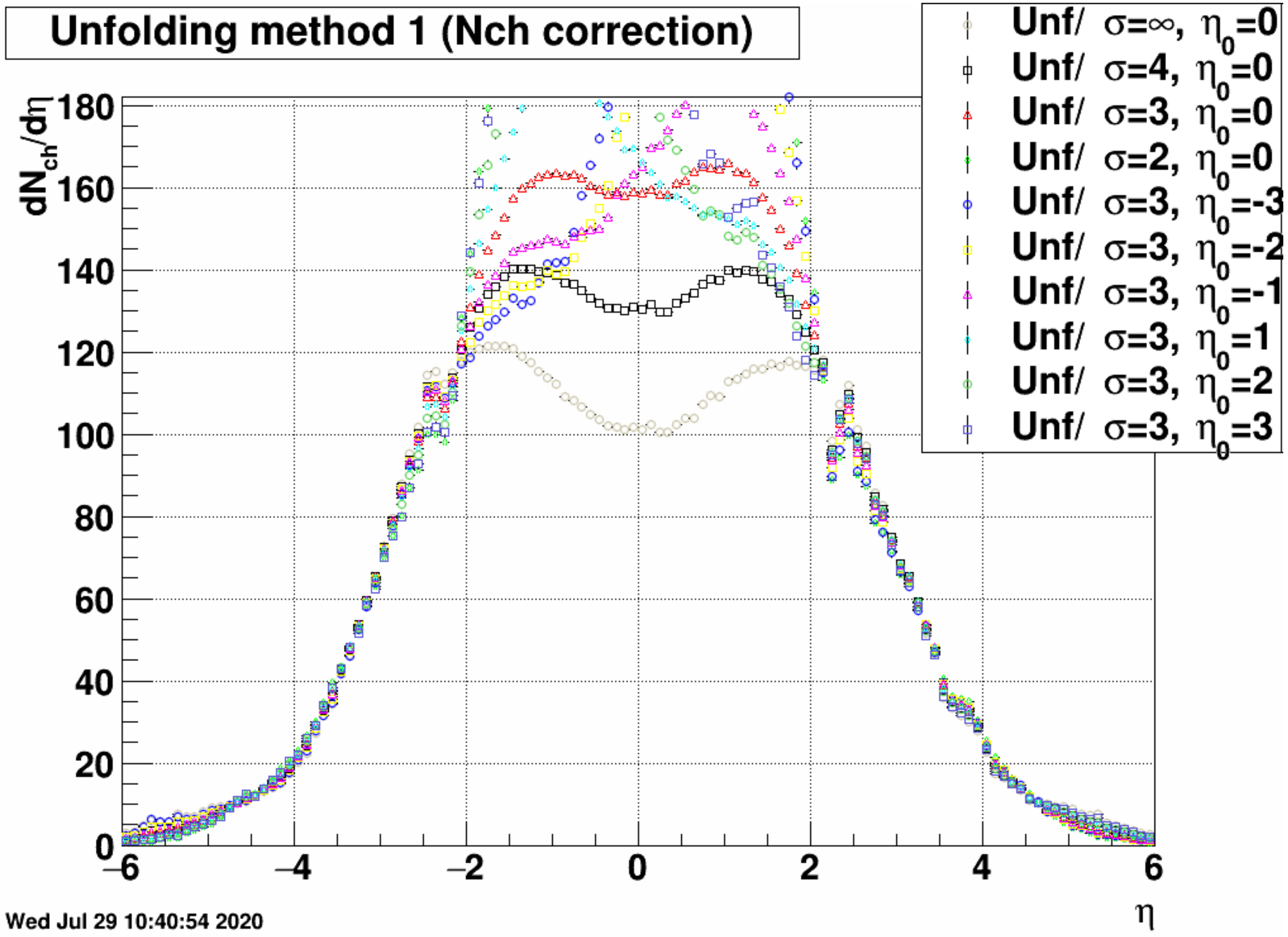
- Measure response with distorted sample
- Analyzed all combinations:
  - Unfold i-th sample with j-th distortion
  - If i=j: perfect unfolding
  - If distorting $\sigma \approx 1$ or smaller: bad unfolding
  - Otherwise: ~10% dependence in the EPD η region





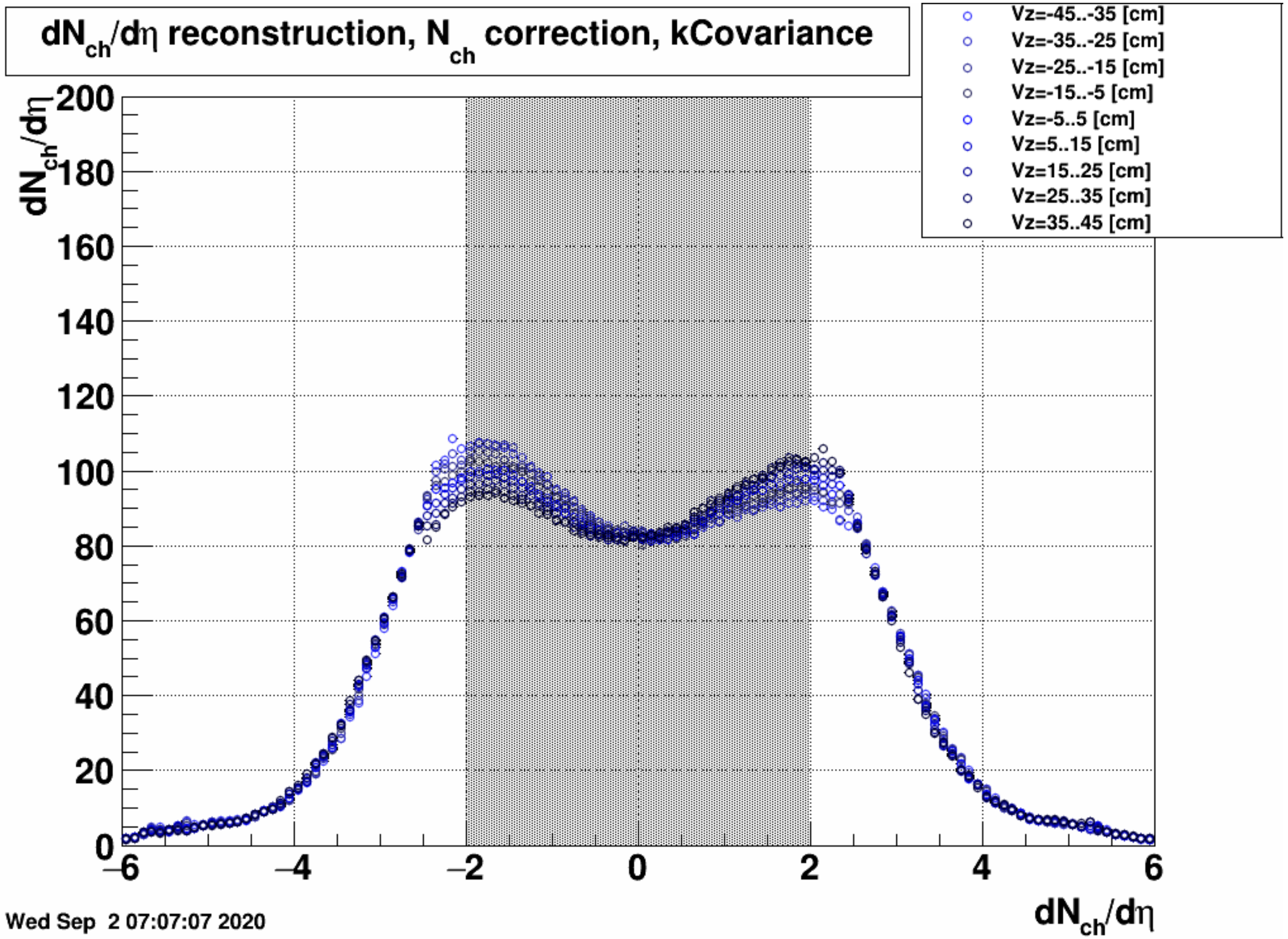
Systematics: input $dN/d\eta$

- Most important systematic uncertainty: choice of input $dN/d\eta$
- Huge uncertainty in the midrapidity region
- Mostly positive uncertainty: all distorted samples made distribution less wide
- Distortion that makes sample wider (i.e. rejecting midrapidity tracks) would yield negative uncertainty (i.e. lowering $dN/d\eta$)



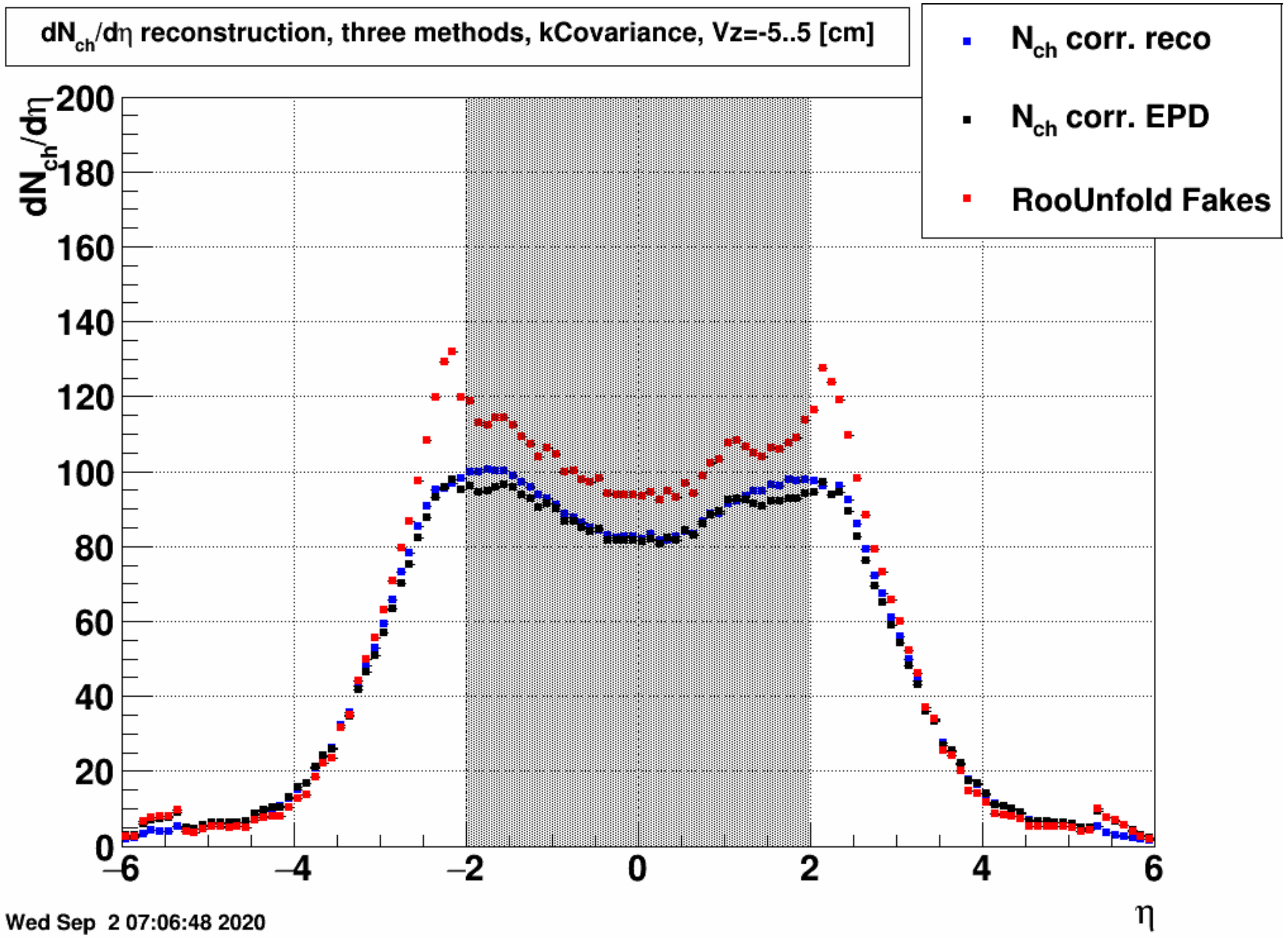
Systematics: Vz binning

- Unfolded result depends on Vz bin
- Even if simulation also Vz-binned
- End result ($dN/d\eta$) clearly needs to be Vz-independent
- Largest effect around $|\eta| \approx 2$
- Differences to be included in systematics



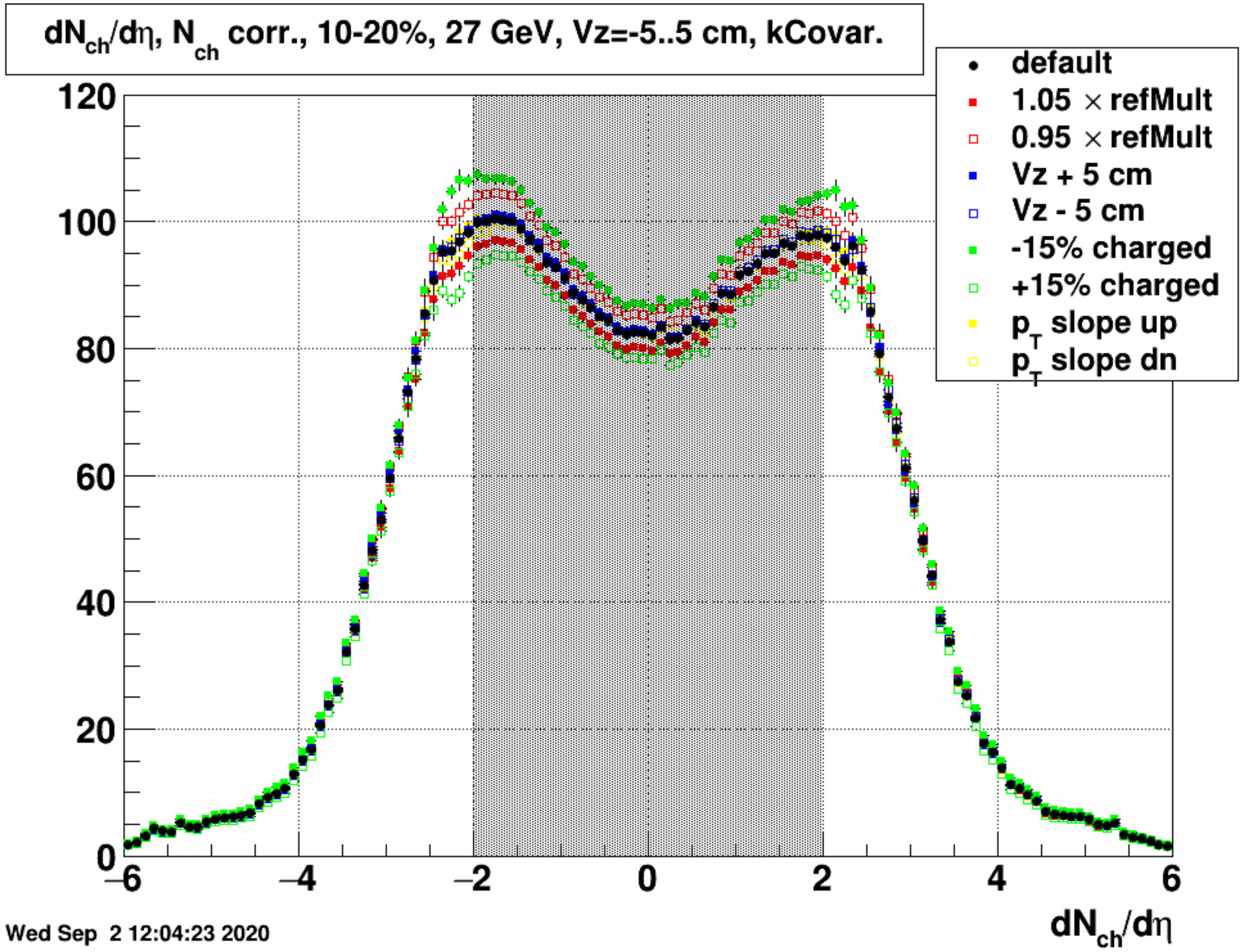
Systematics: unfolding method

- Applied 3 different methods
  1. Unfolding $dN/d\eta$; correcting via $N_{\rm ch}(\eta)/N_{\rm tot}(\eta)$
  2. Correcting via $N_{\rm ch}(i_{\rm ring})/N_{\rm tot}(i_{\rm ring})$; unfolding "corrected" EPD distribution
  3. Use RooUnfold's "Fakes" (neutrals ⇔ "fake" hits)
- "Fakes" different from the others
  - Also least reliable in terms of dependence on input $dN/d\eta$
  - Reason of this unclear yet
- Other two methods match nicely



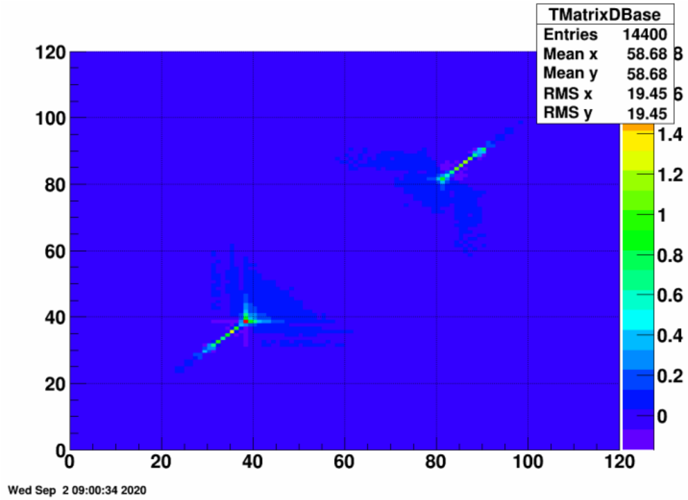
Systematics: centrality, pT, charged ratio

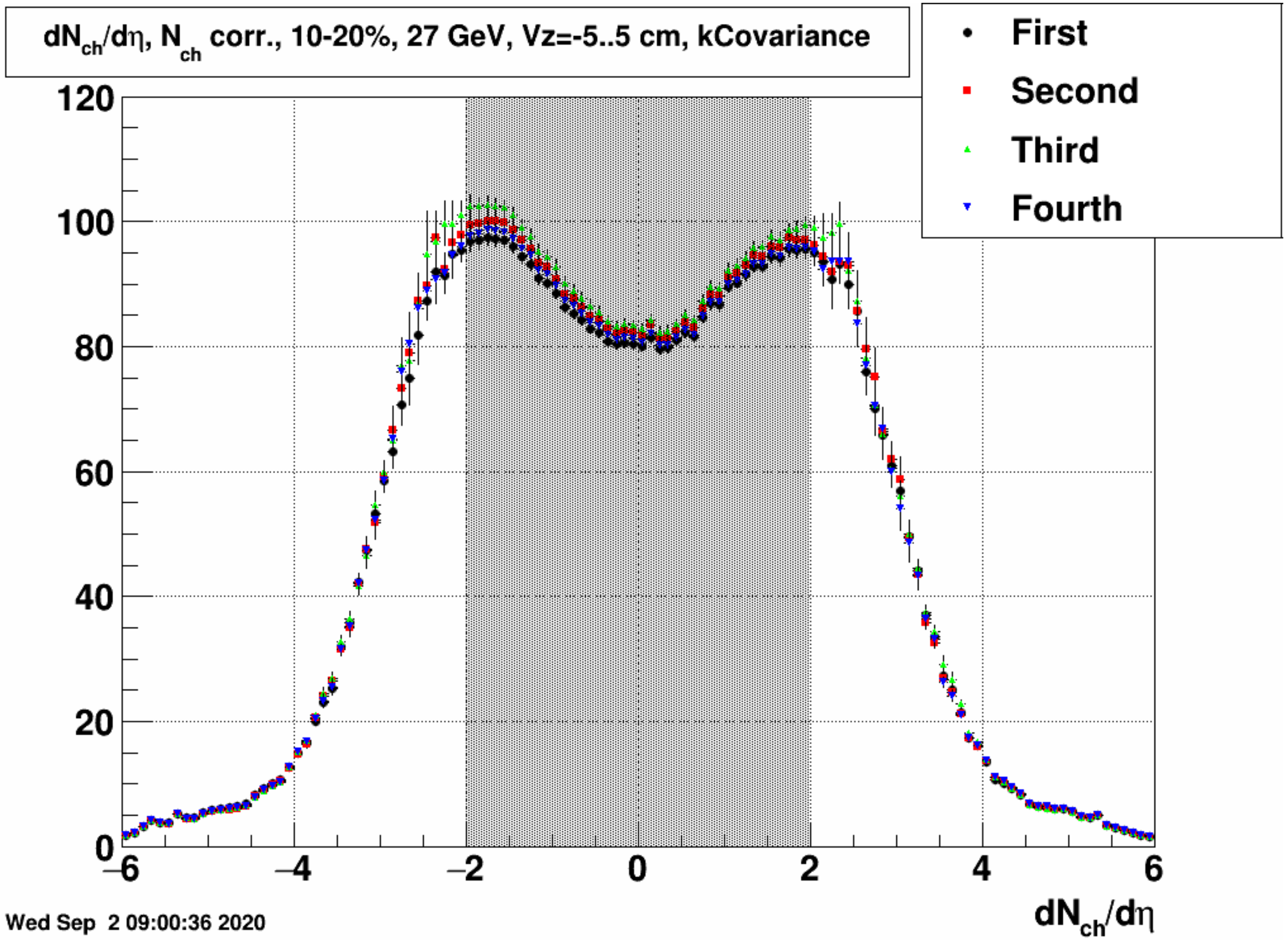
- Other sources of systematic uncertainty:
  - Centrality definition
  - Vz determination (this differs from Vz choice!)
  - Fraction of charged particles
  - pT slope of input sample
- These have a smaller effect than sources shown on previous slides
- Combined, still non-negligible



Statistical uncertainties

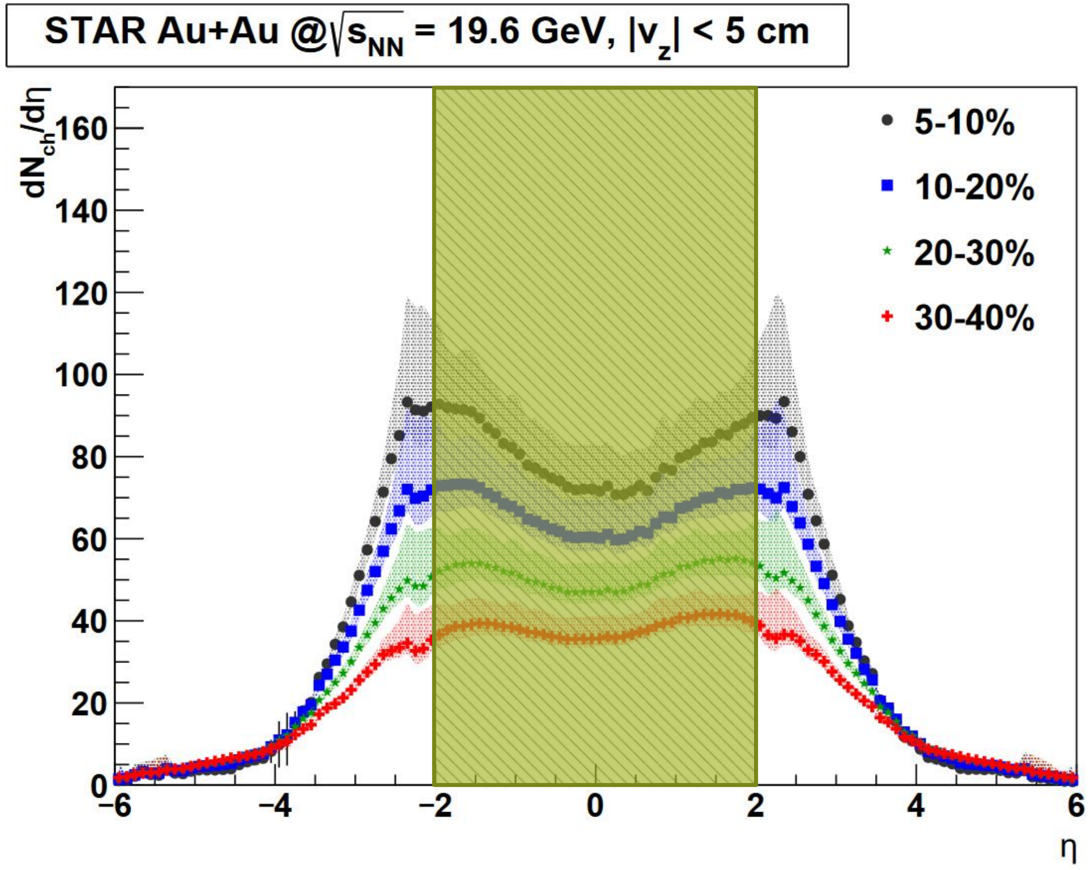
- Are statistical uncertainties of $dN/d\eta$ datapoints reliable?
- Divided data sample into four sub-samples; these have a reasonable matching confidence level
- Covariance also available in ROOT:

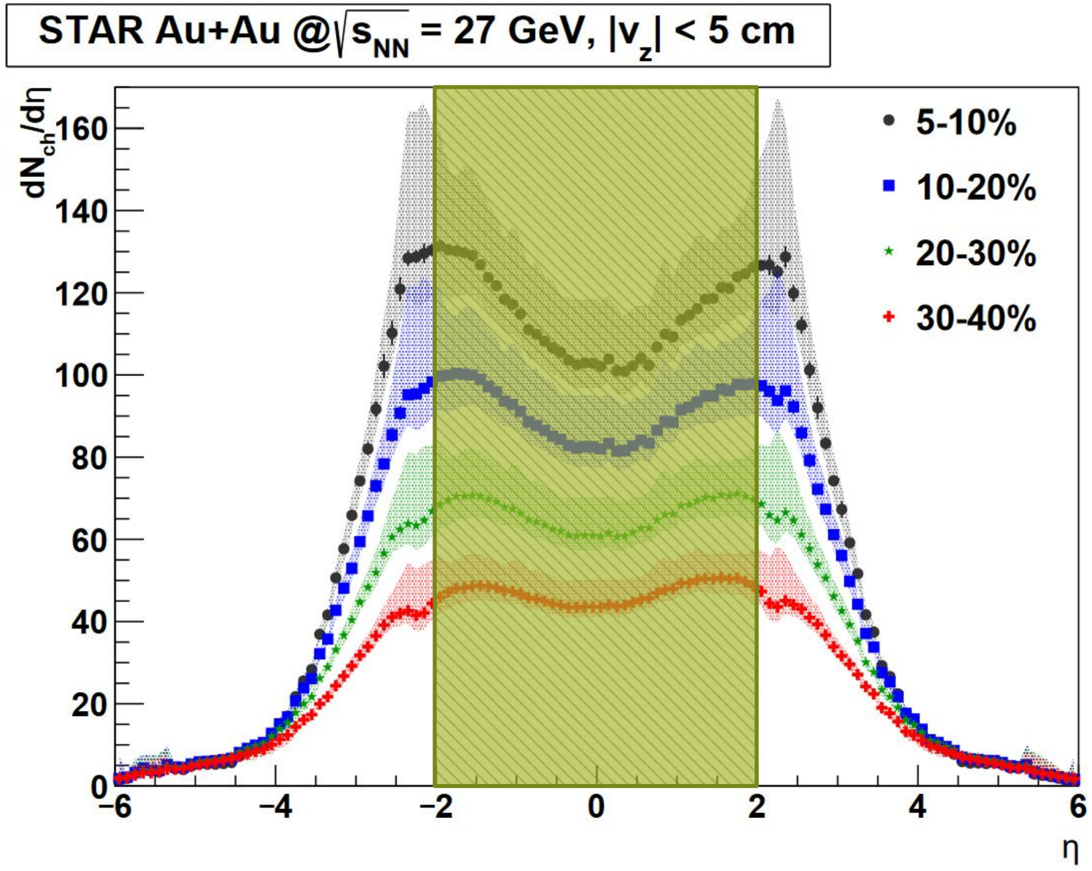




Results at 19.6 & 27 GeV

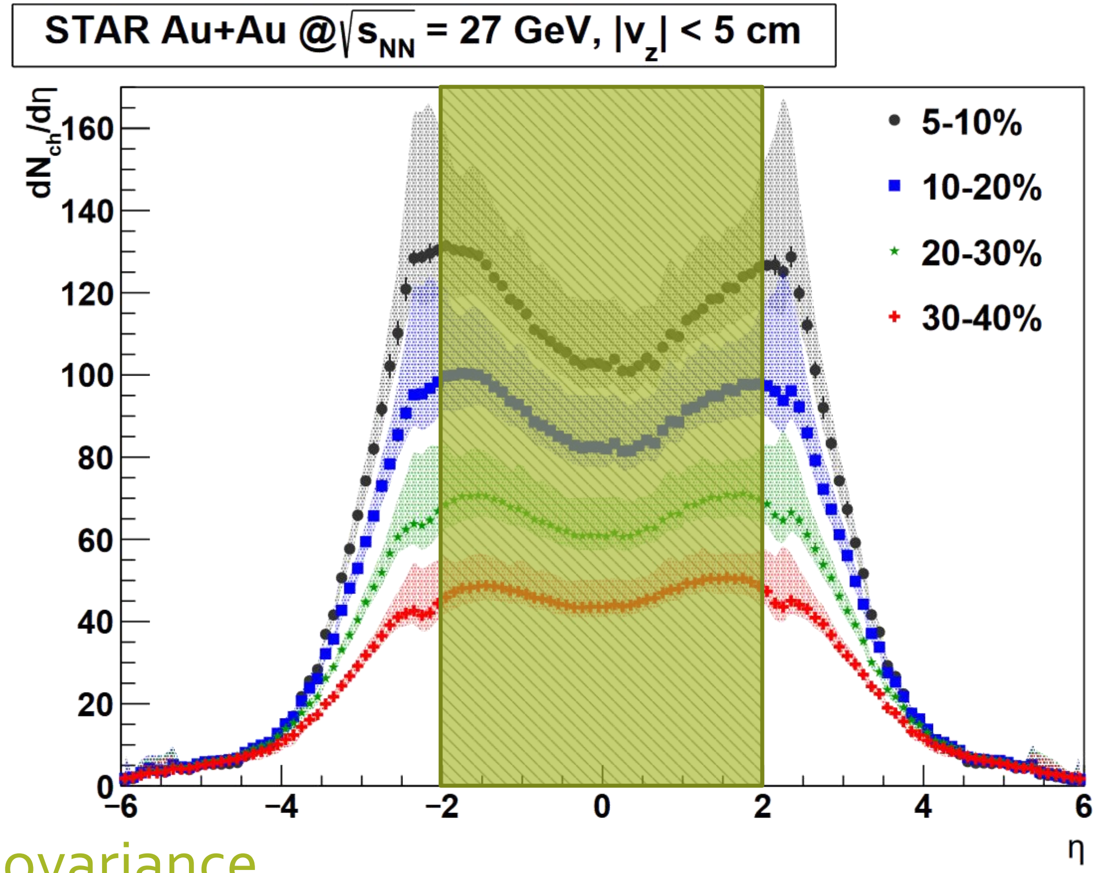
- Unfolded results plotted with major systematic uncertainty sources
- Uncertainty from input $dN/d\eta$: huge for $|\eta| < 2$, region shaded out





Summary

- Analysis mature, based on "provisional" data
- Systematic uncertainties considered:
  - Vz determination
  - Centrality determination
  - Vz choice (+40 & -40 cm compared)
  - Unfolding method
  - Charged/neutral ratio of training sample
  - pT slope of training sample
- Systematic uncertainty from input $dN/d\eta$
  - In the $|\eta| < 2$ region: huge uncertainty, region "shaded out" on plots



- Statistical uncertainties: very small, known covariance