Update of flow studies with multiparticle correlations

Ante Bilandzic
Technical University of Munich
"46th CBM Collaboration Meeting", Lanzhou, China, 22/10/2025

Outline

- Introduction – see some of my talks at previous CBM meetings

  e.g. **42nd CBM Collaboration Meeting** in Bucharest https://indico.gsi.de/event/17147/contributions/74248/
- General-purpose MC production with 2 (“dielectron”) geometries:
  - “Day-1 (Geant 3)” => **3.99 M** events after all cuts
  - “Day-1 (Geant 4)” => **0.80 M** events after all cuts
  - “cfv” (“currently funded version”, Geant 3) => **3.91 M** events after all cuts
- Control event and particle histograms
- Results
  - 2-particle azimuthal correlations vs. Multiplicity and vs. Centrality
- Summary & wishlist

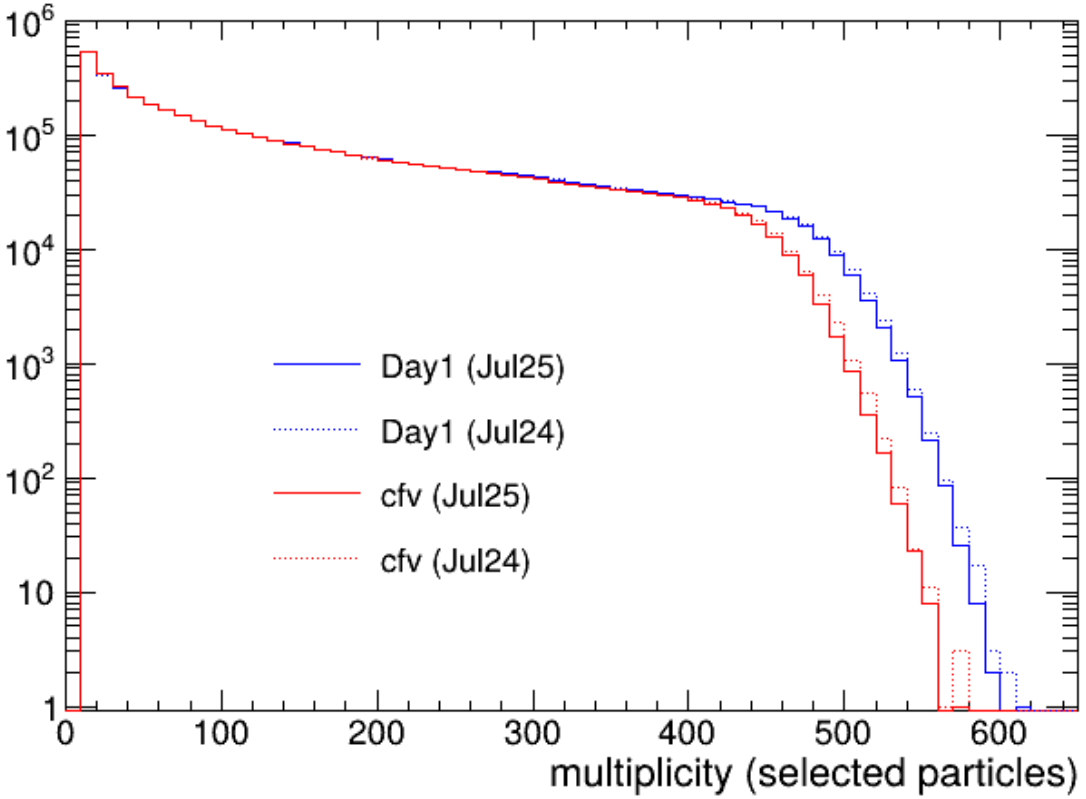
Datasets

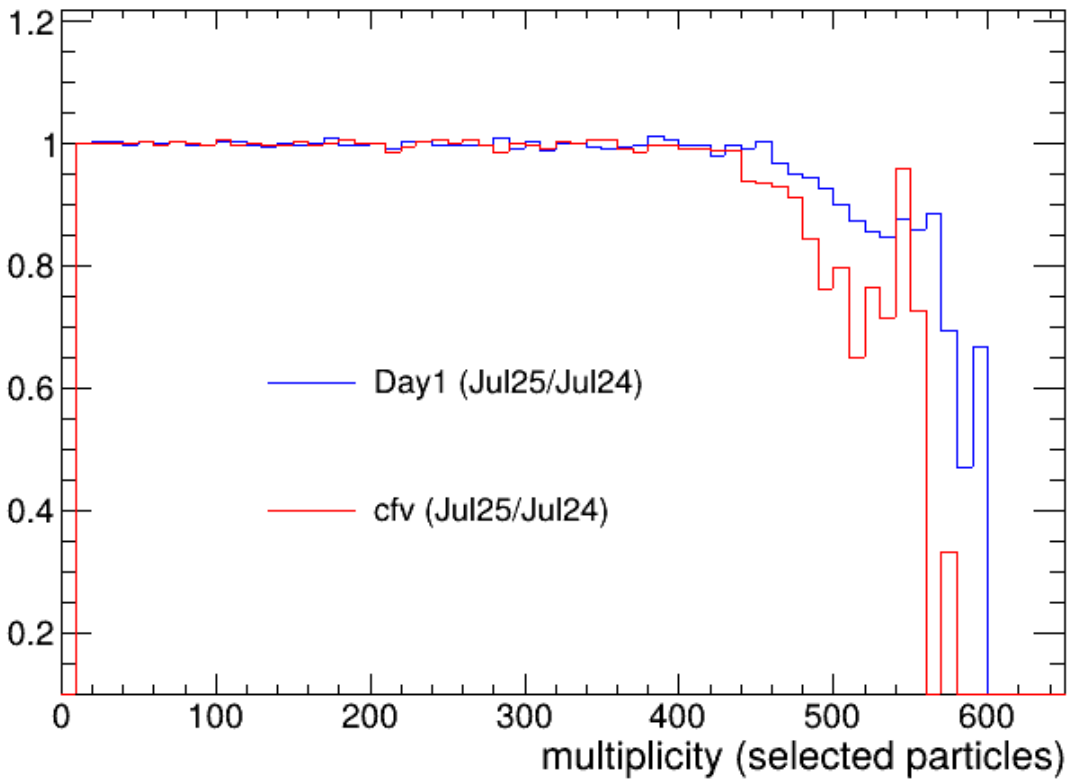
- Starting poínt: **AnalysisTree**
- Analyzed the post-processed production with centrality information added:
  - “Day-1 (Geant 3)”: /lustre/cbm/users/fkornas/mc/data/release/jul25_patches/phqmd52_winn/geant3/auau/pbeam12agev/mbias/small_clusters/day-1/AT
  - “Day-1 (Geant 4)”: /lustre/cbm/users/fkornas/mc/data/release/jul25_patches/phqmd52_winn/geant4/auau/pbeam12agev/mbias/small_clusters/day-1/AT
  - “cfv (Geant 3)”: /lustre/cbm/users/fkornas/mc/data/release/jul25_patches/phqmd52_winn/geant3/auau/pbeam12agev/mbias/small_clusters/cfv/AT
- Documentation:
  - Wiki: https://cbm-wiki.gsi.de/PWG/JUL25CommonProductionSep2025?validation_key=2e9a095fdf64b64c4df9e0c94fc9eec1
  - Redmine: https://redmine.cbm.gsi.de/issues/3706
  - Federic’s slides from Physics Forum in October, 2025: https://indico.gsi.de/event/23247/

Control event and particle histograms

Multiplicity distributions

- Multiplicity (“selected particles”) is defined as the total number of particles that pass all selection criteria:
  - $0 < p_T < 5.0$ GeV/c and $1 < eta < 5$





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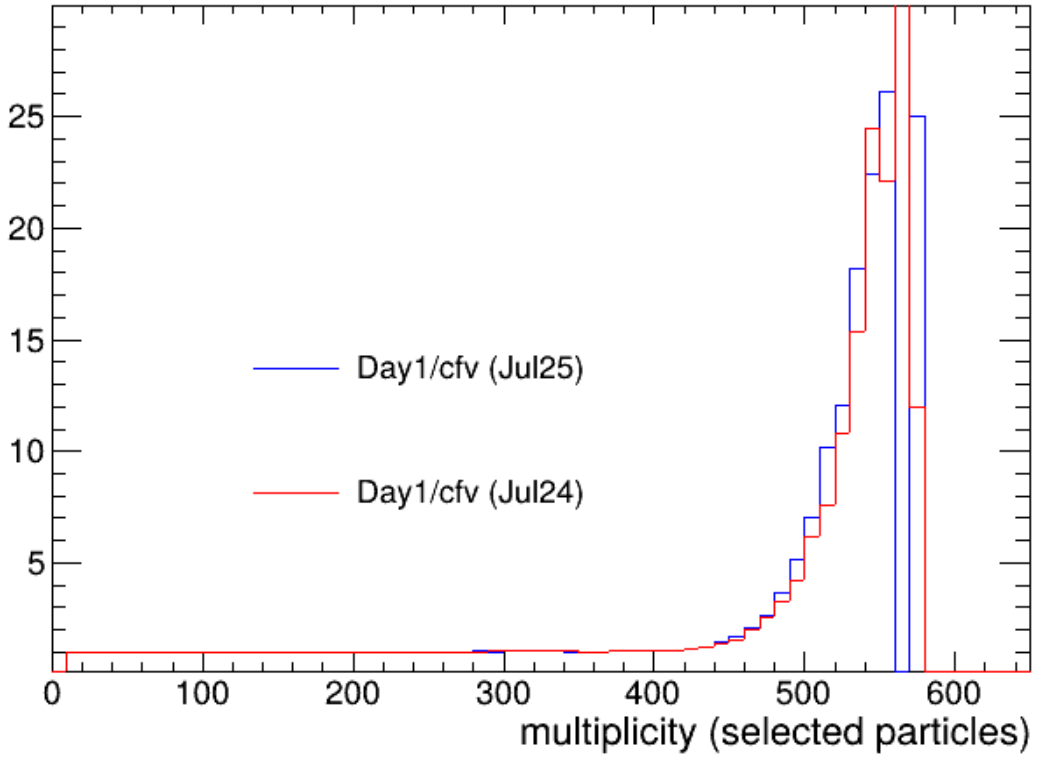

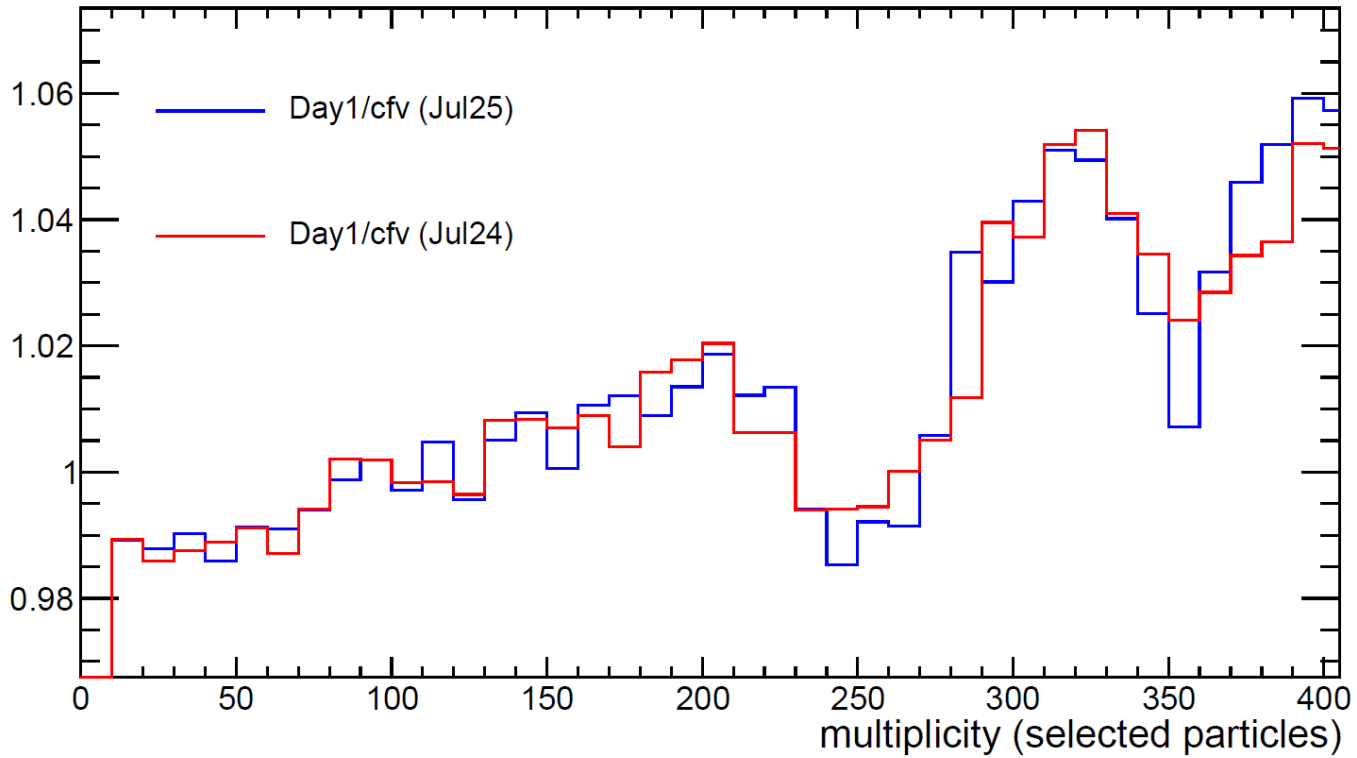

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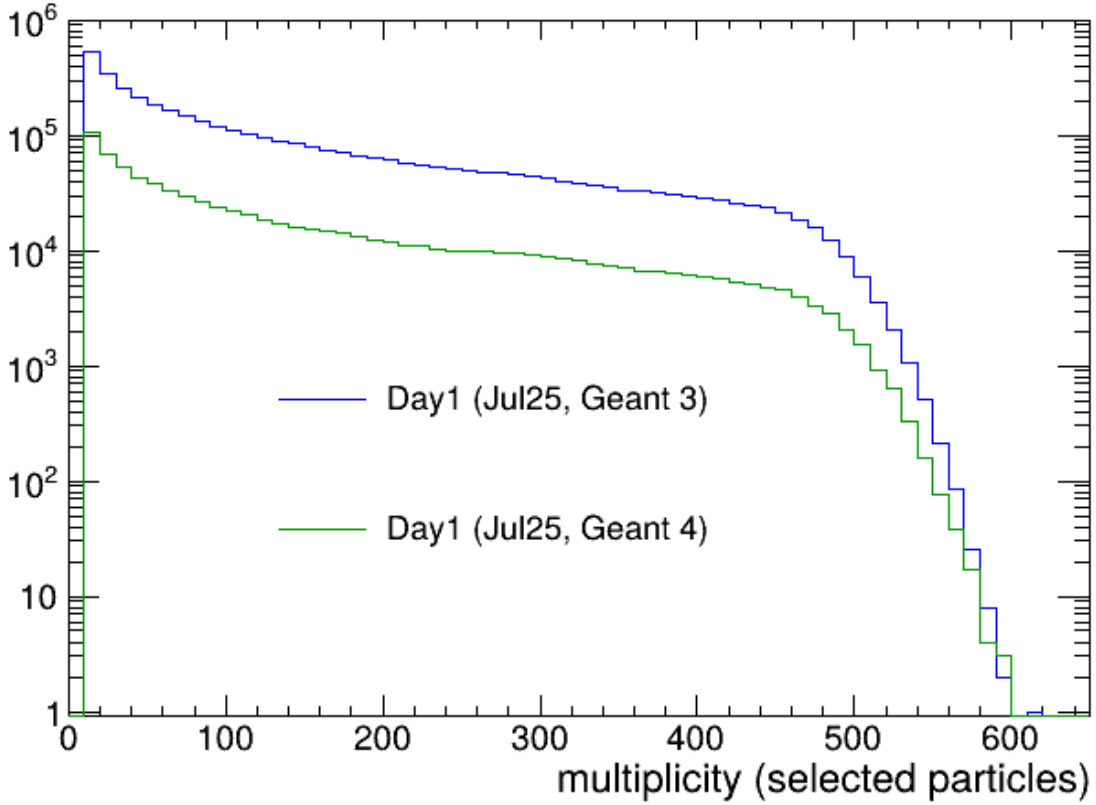

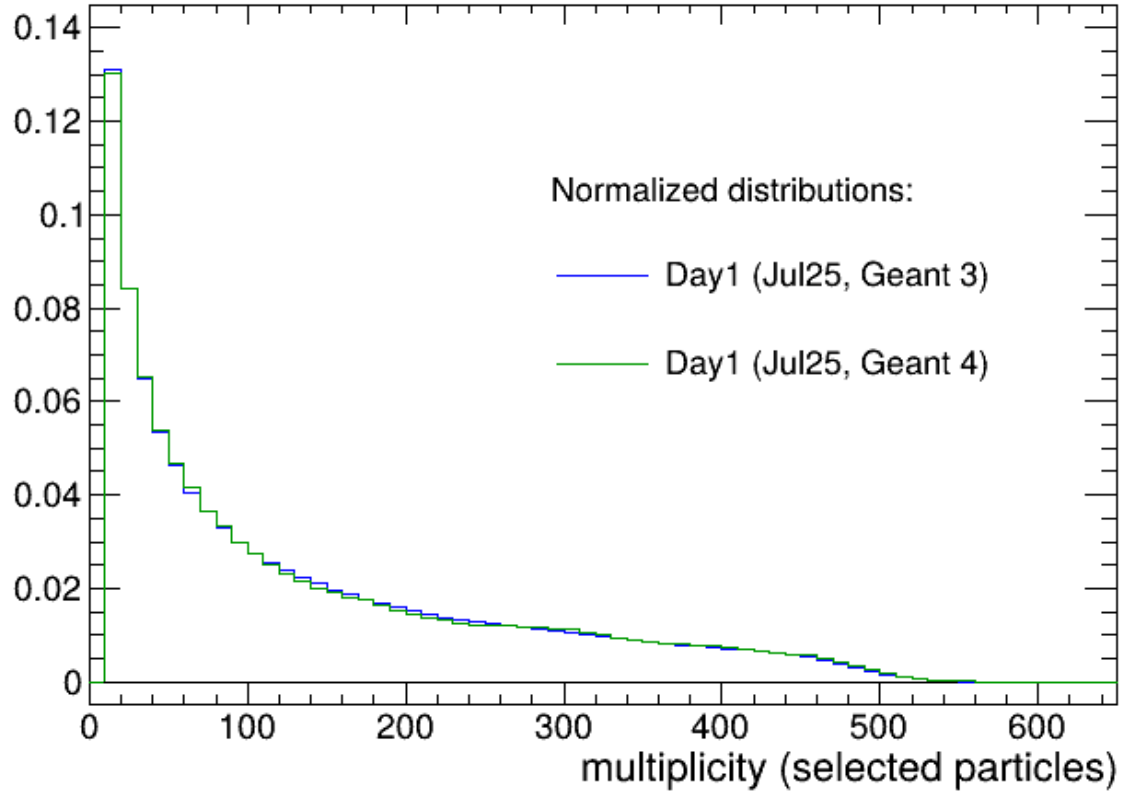

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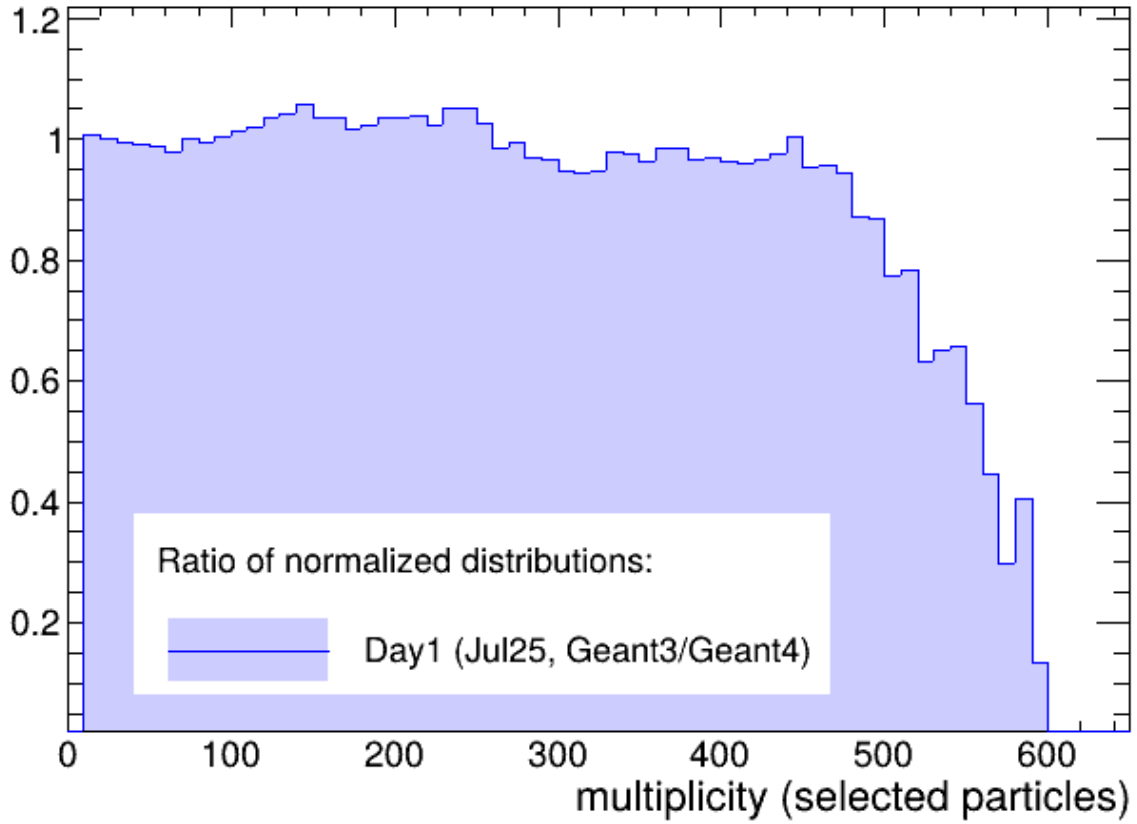
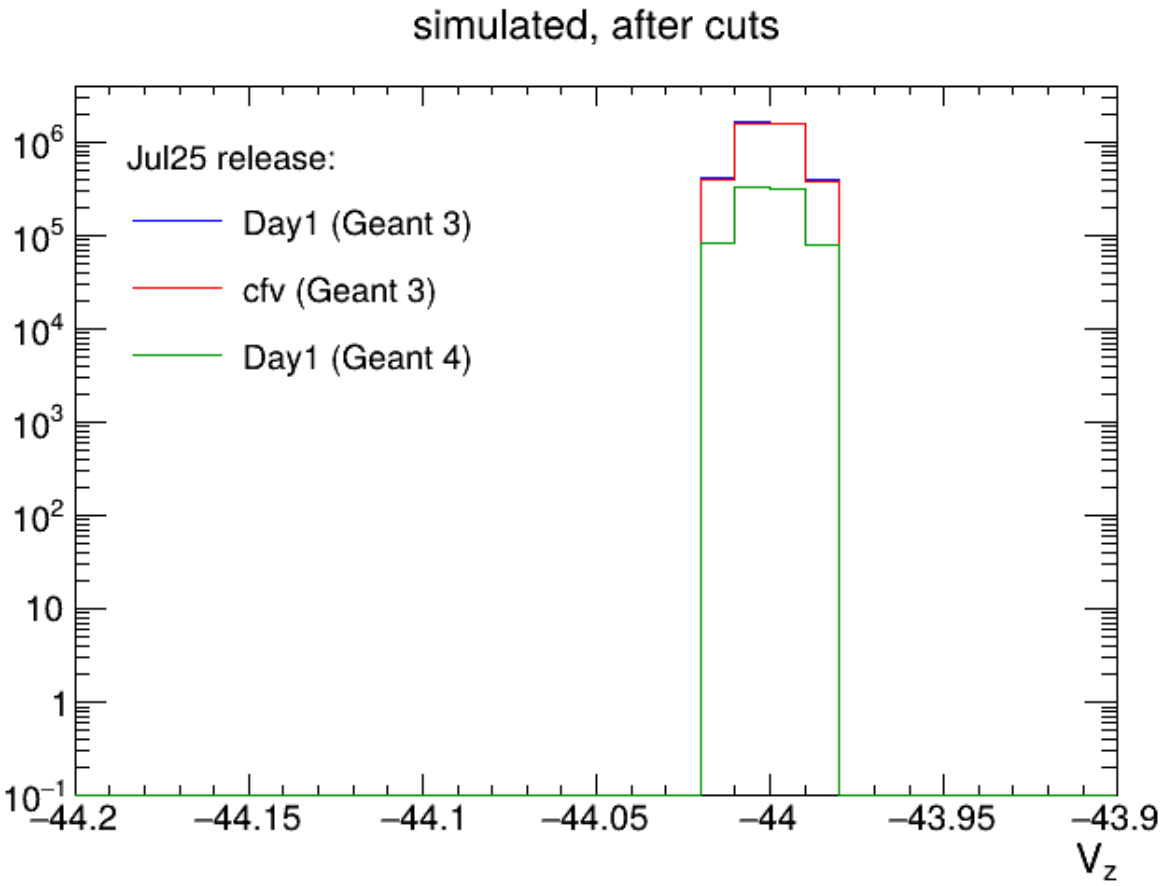
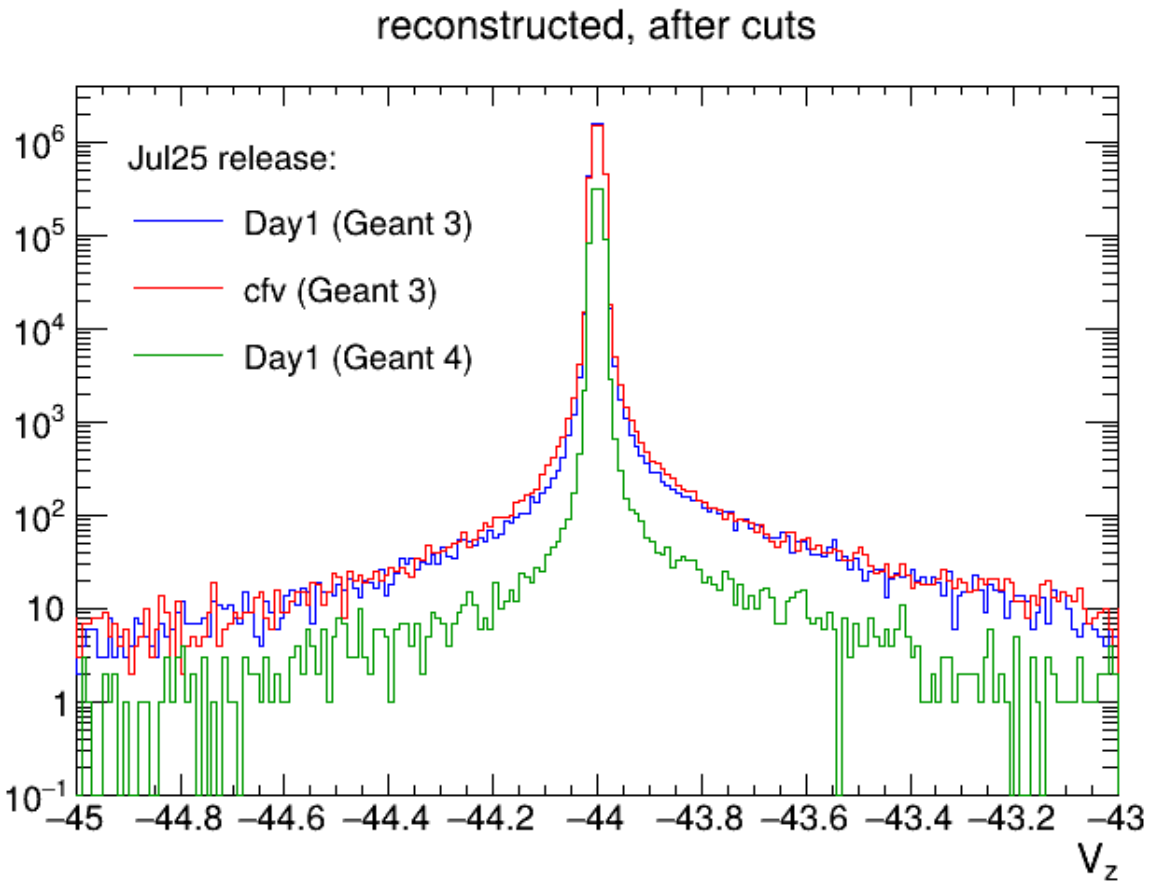


Vertex-z distributions

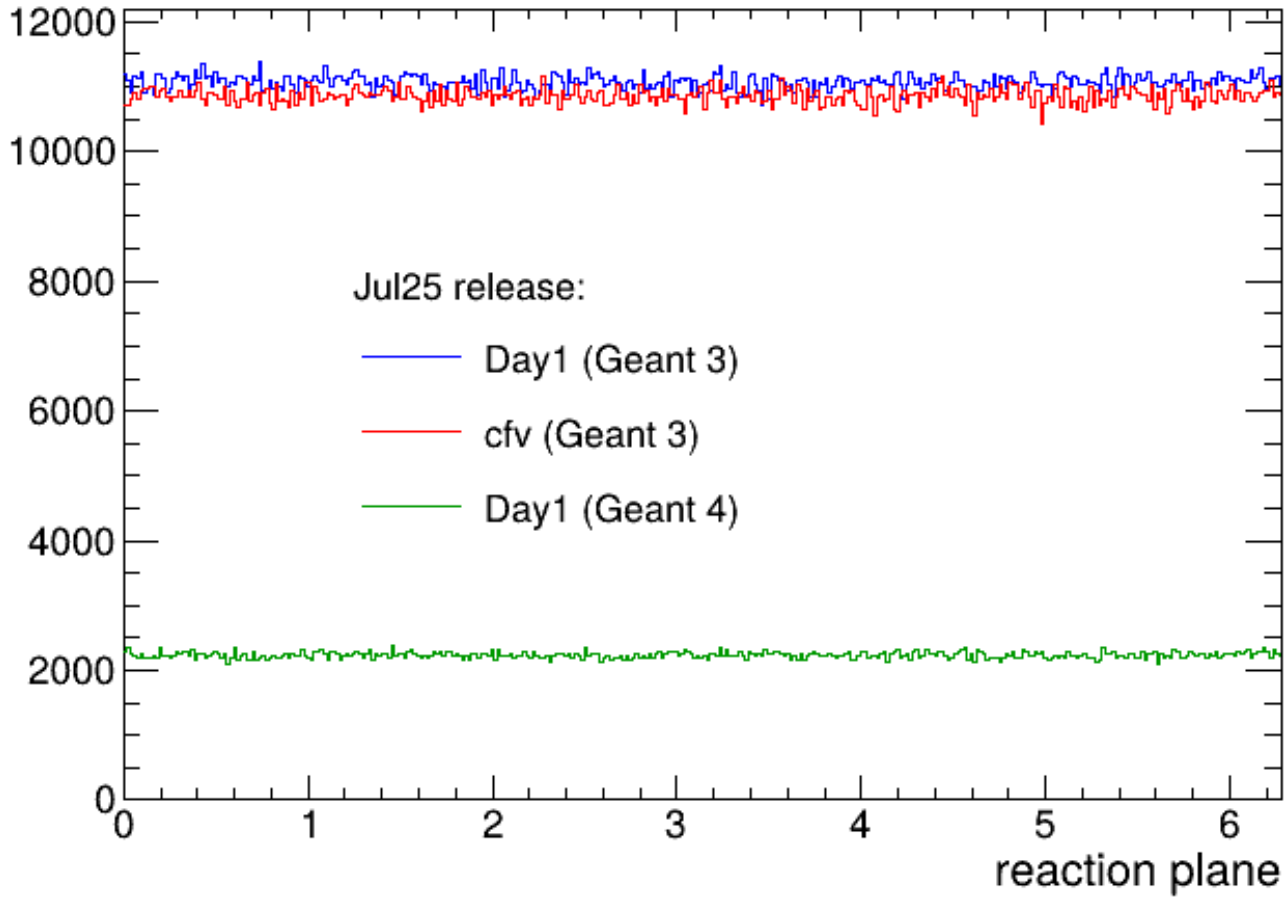
- In all productions vertex z is displaced at -44cm





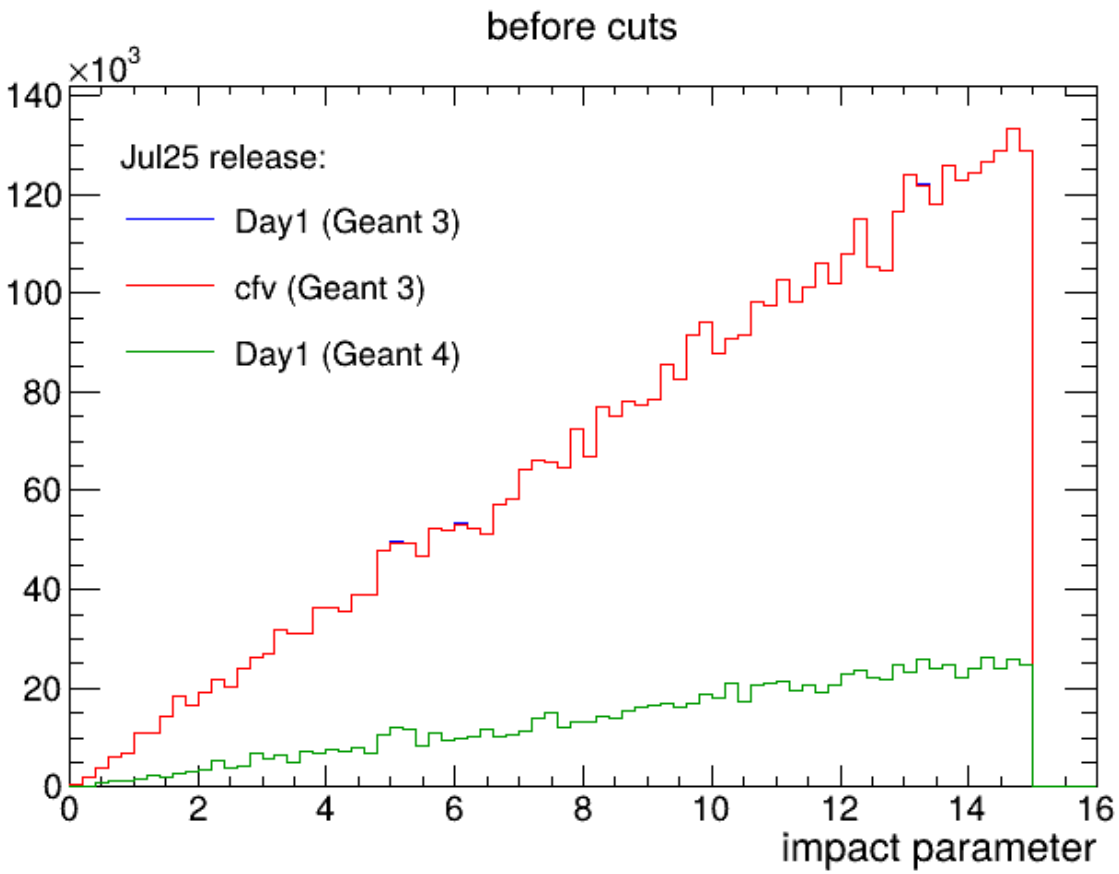
Reaction plane (RP) distributions

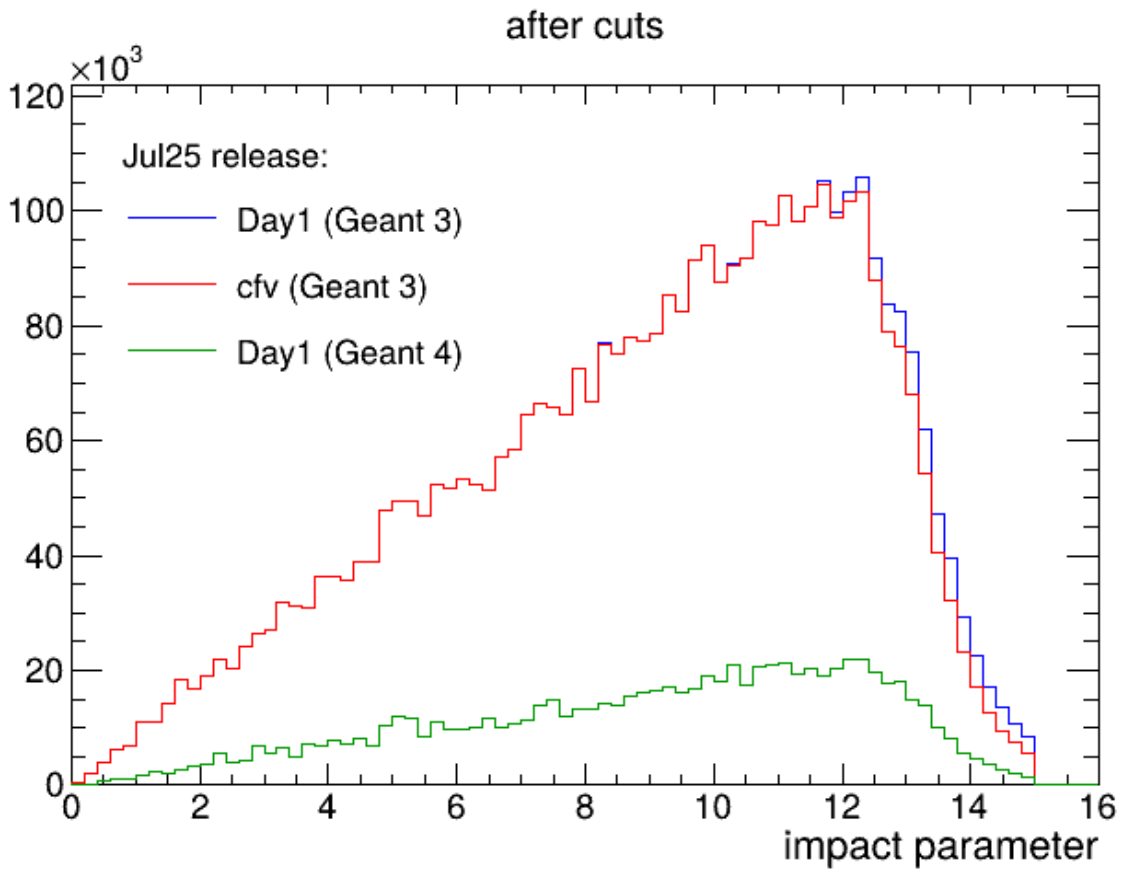
- Uniformly randomized in all three productions



Impact parameter (b) distributions

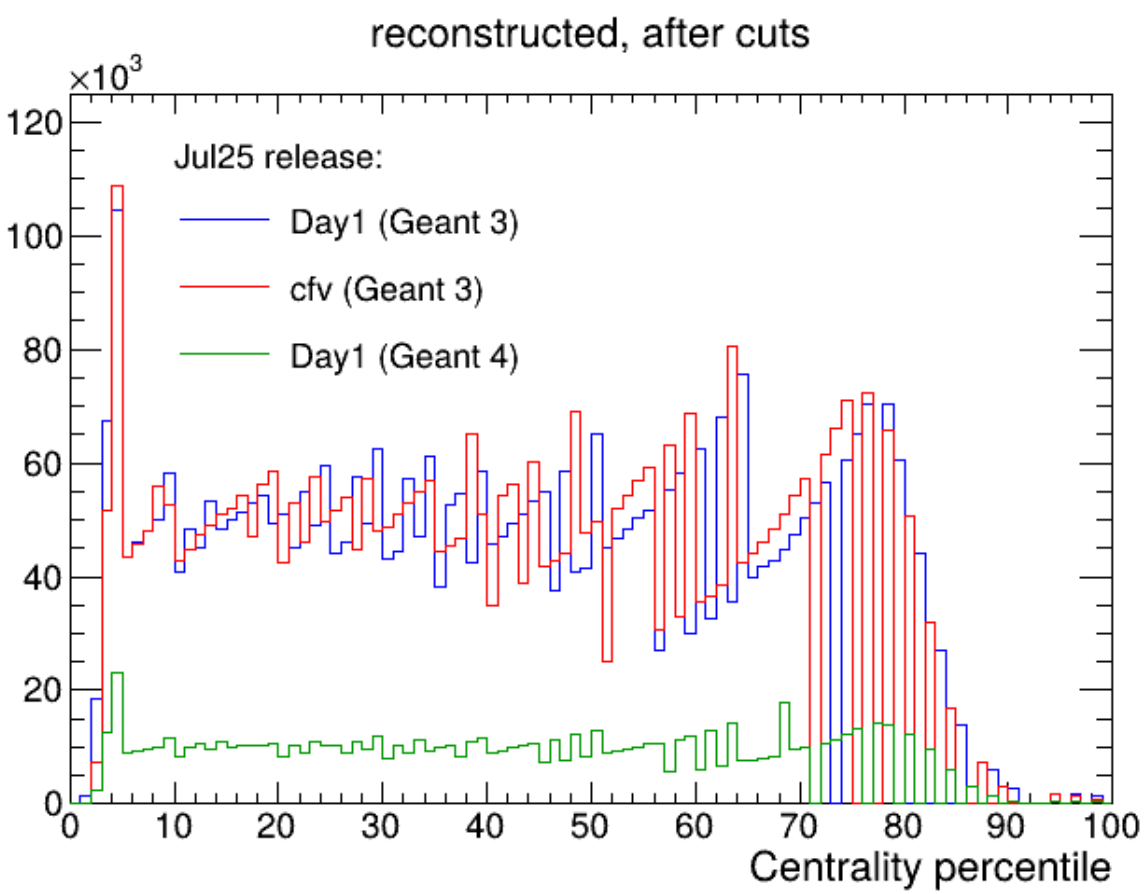
- With large statistics it looks OK, however...

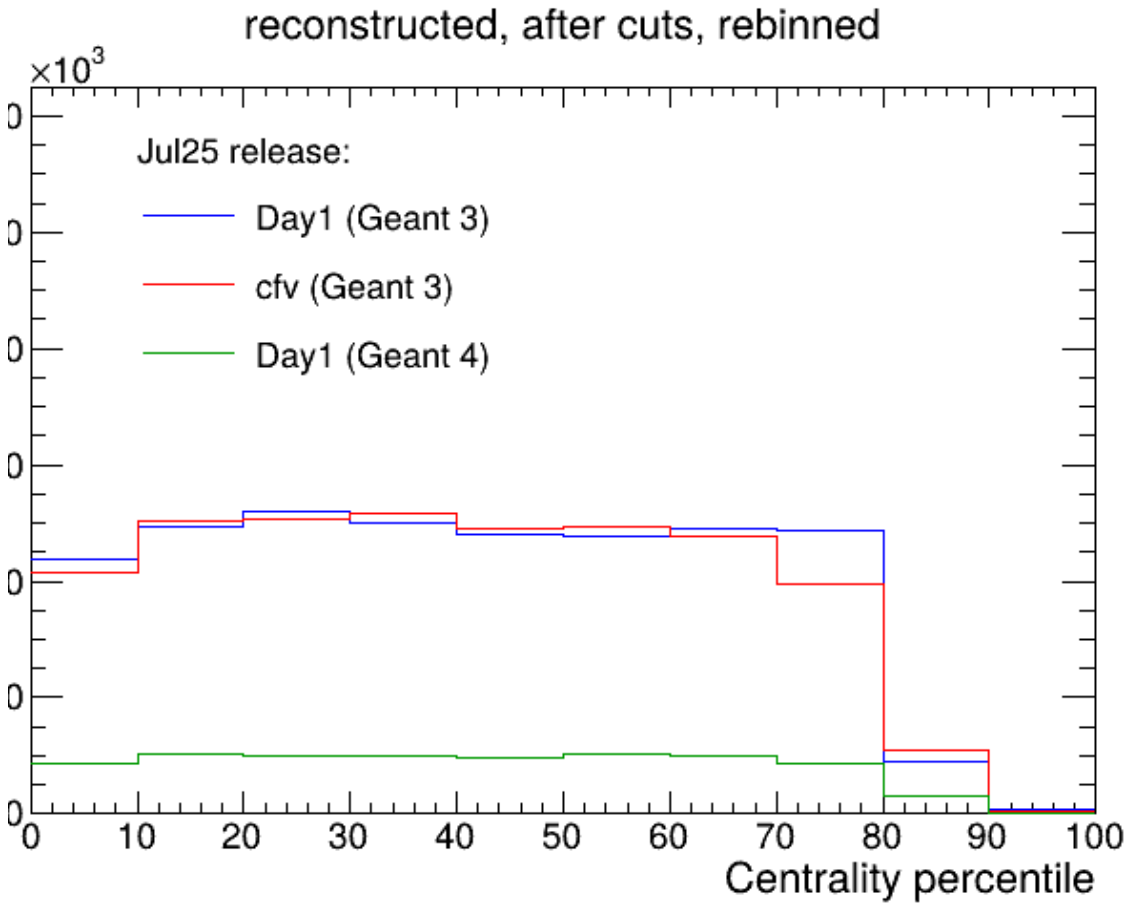




Centrality distributions

- Weird trends + not perfectly flat (it should be flat for minbias sample)

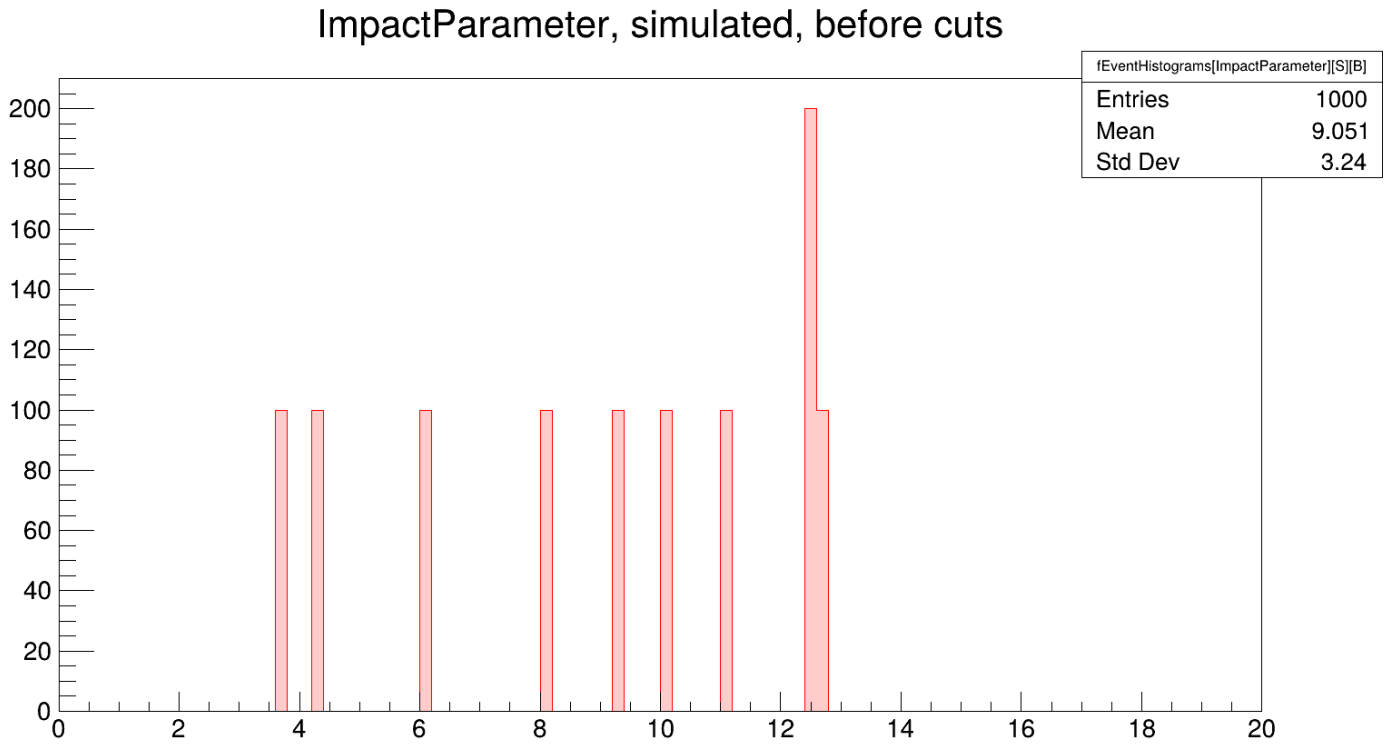




Is the seed for the random generator correctly set?

- The seed shall be unique in time and space
- Example file (“Day1, Geant 3”):

  /lustre/cbm/users/fkornas/mc/data/release/jul25_patches/phqmd52_winn/geant3/auau/pbeam12agev/mbias/small_clusters/day-1/AT/00010/00010.analysistree.root

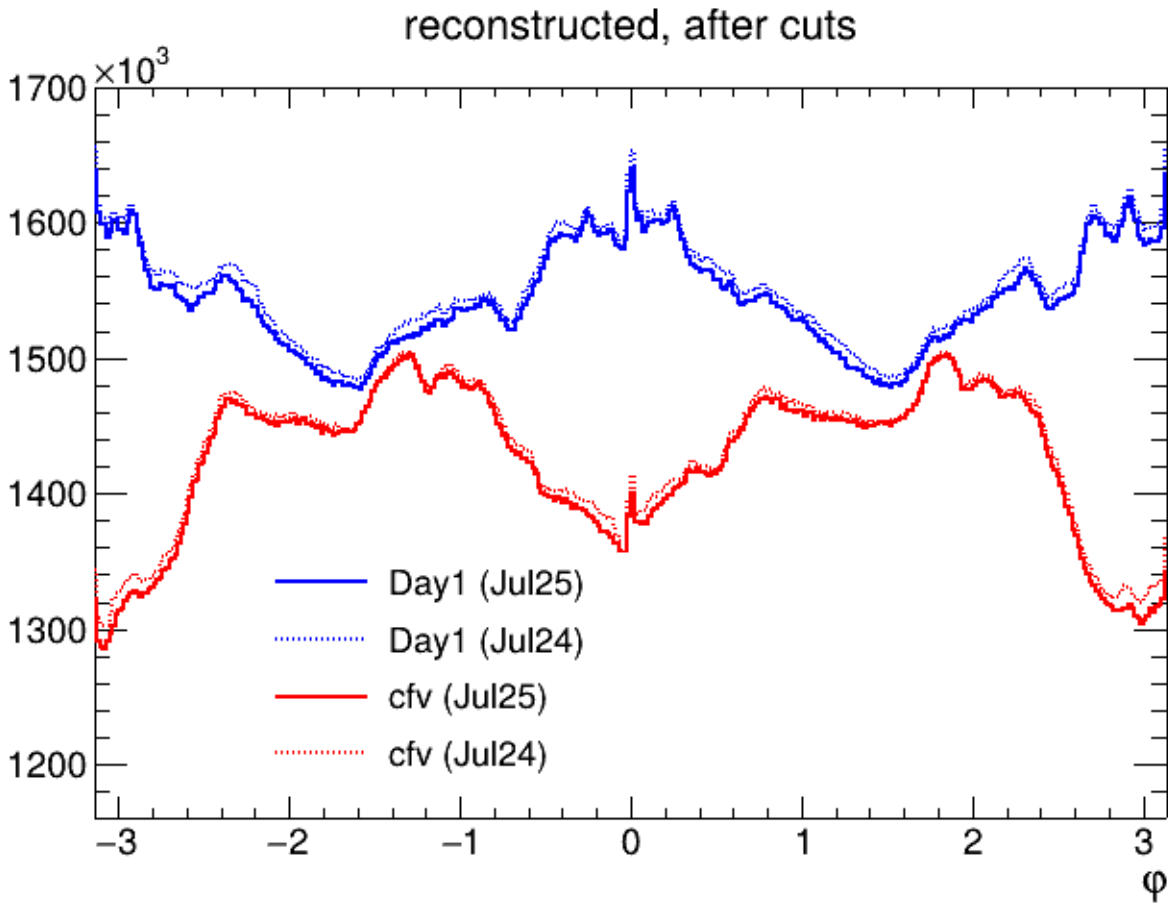


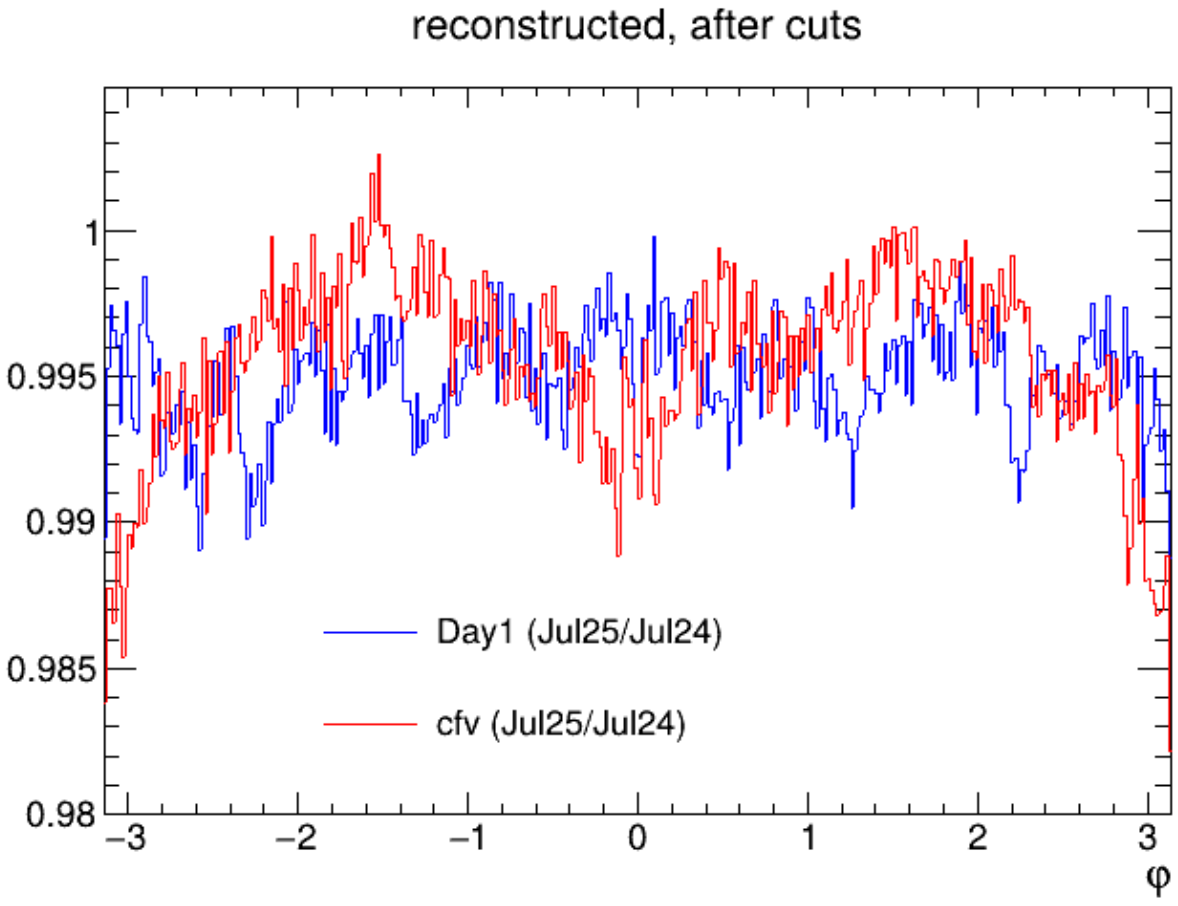
- 10x100 identical values for the impact parameter
- Unique seed in ROOT:

```
delete gRandom;
gRandom = new TRandom3(0);
```

Distribution of azimuthal angles

- Sizable non-uniform azimuthal acceptance





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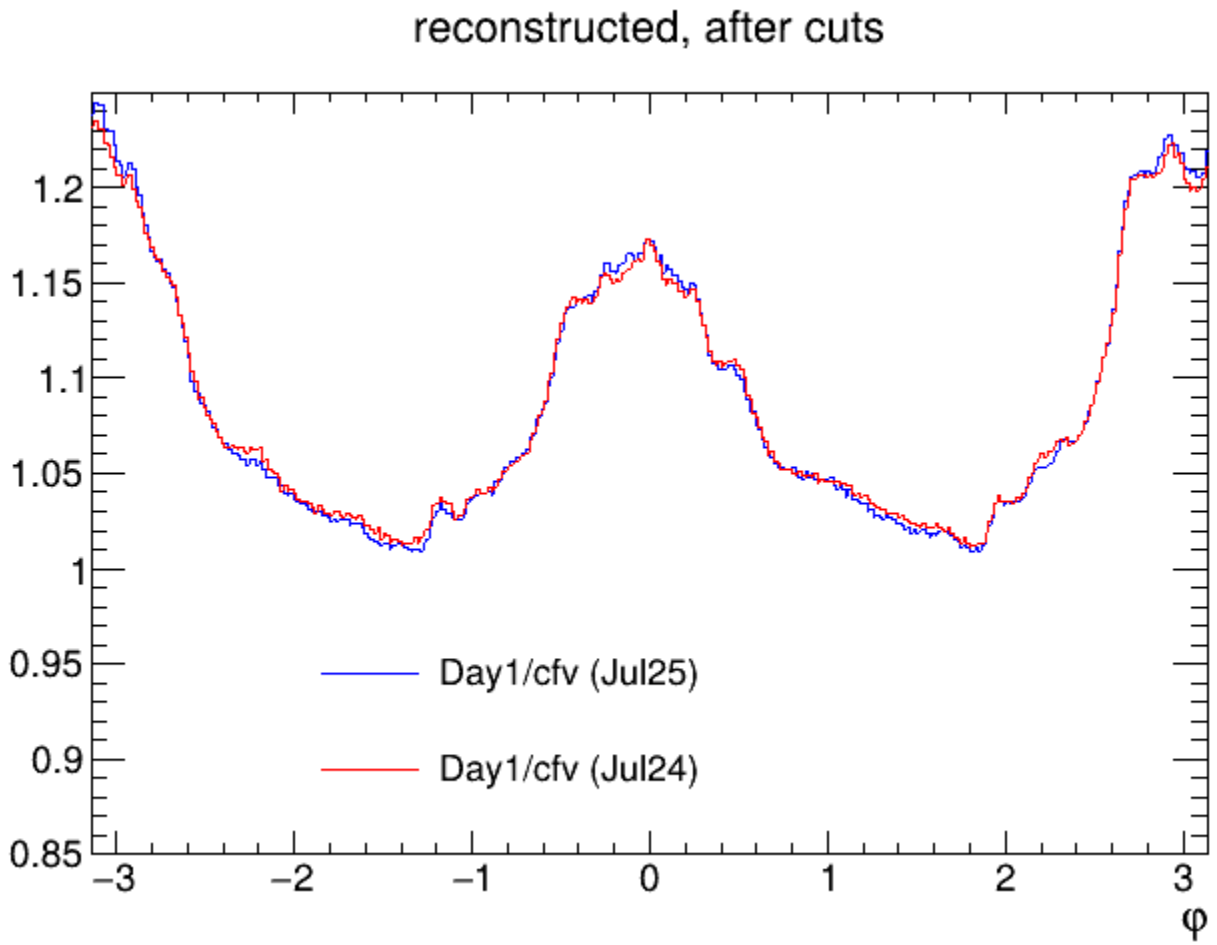

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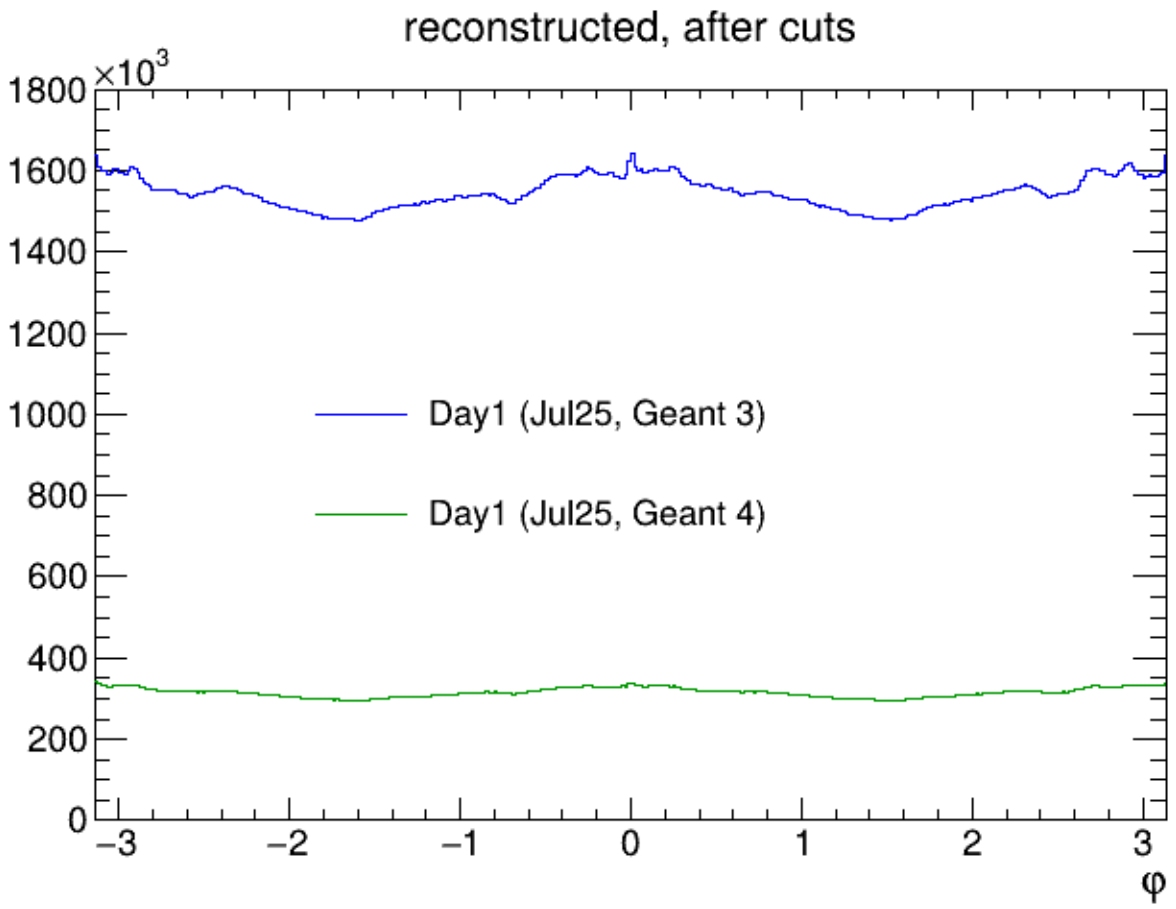
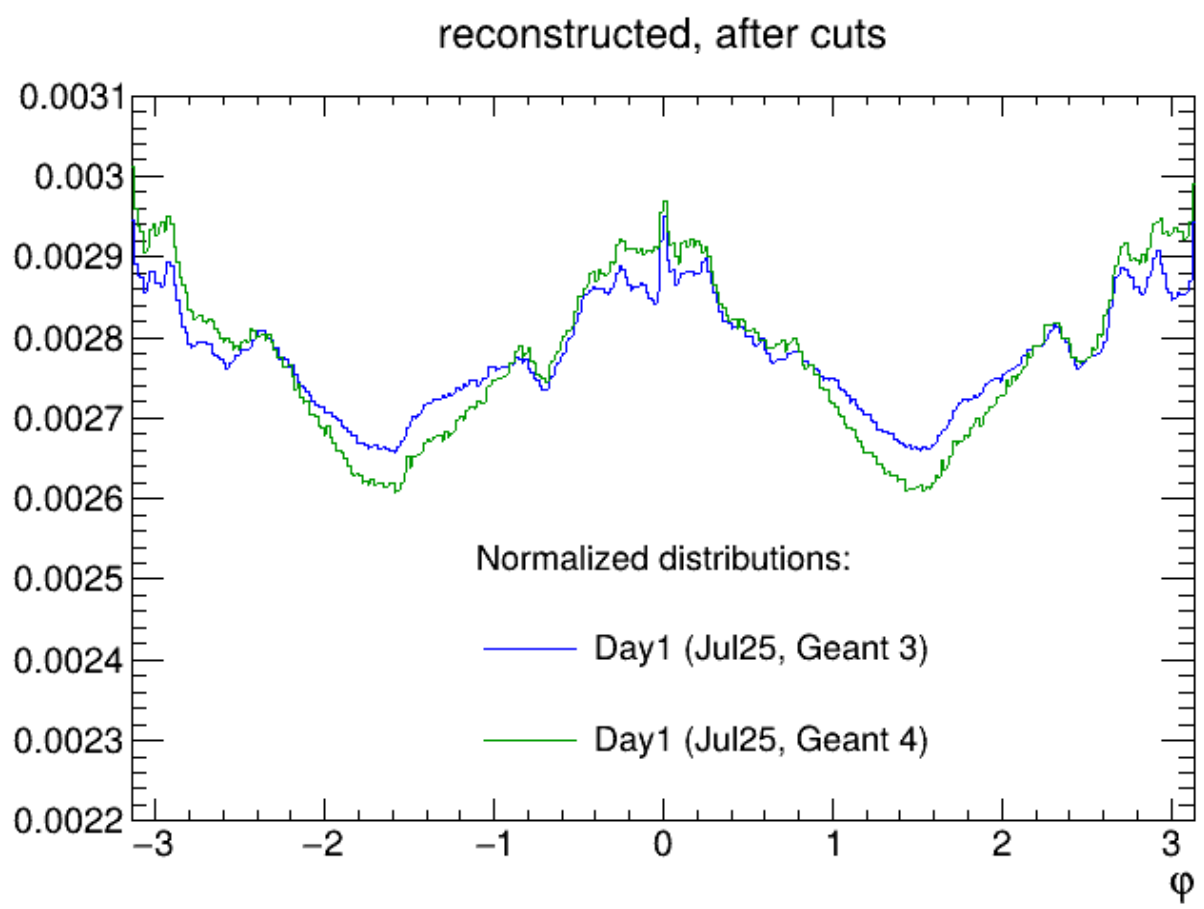
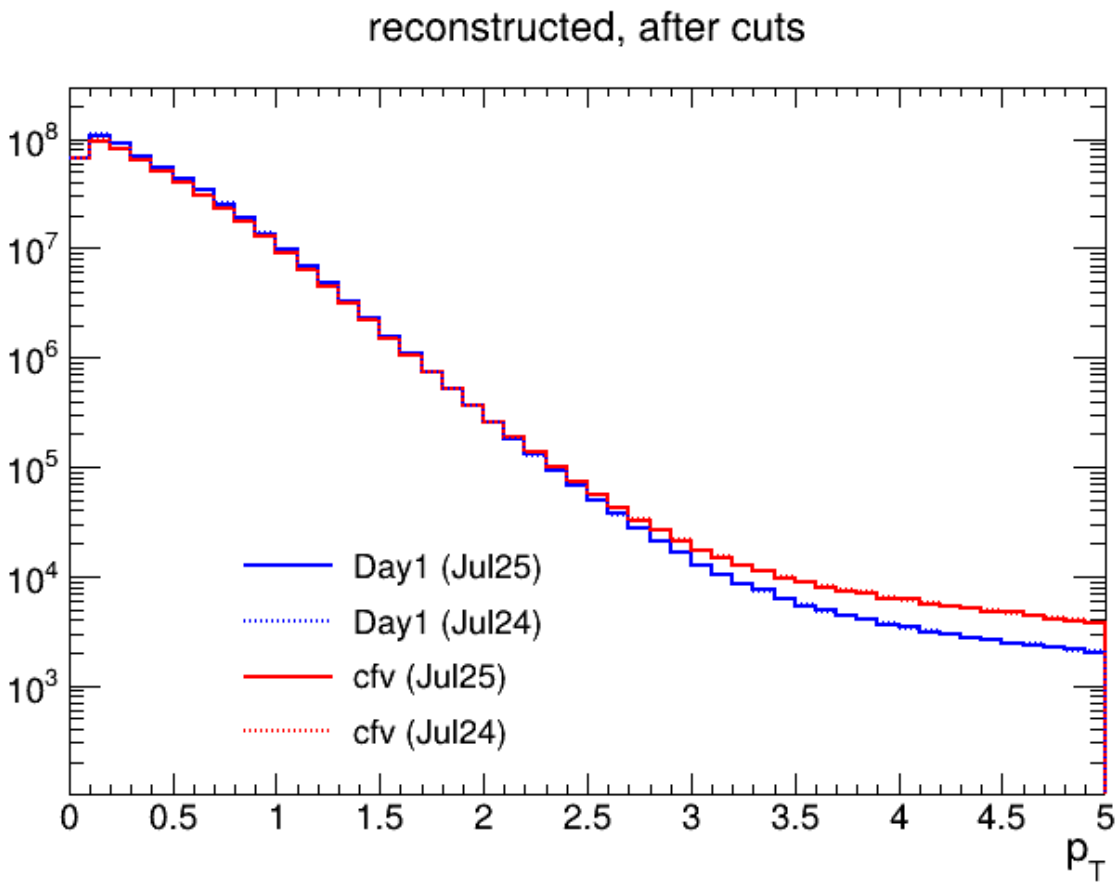
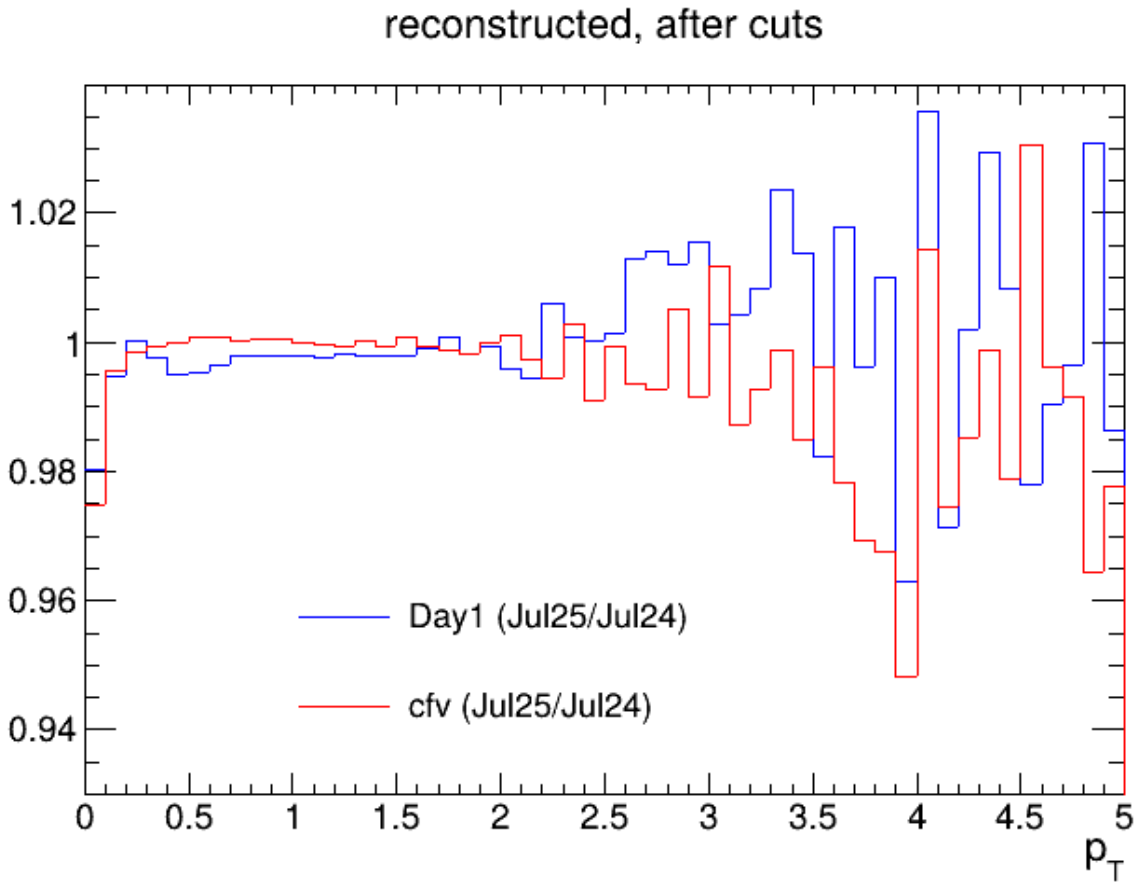




Distribution of transverse momentum

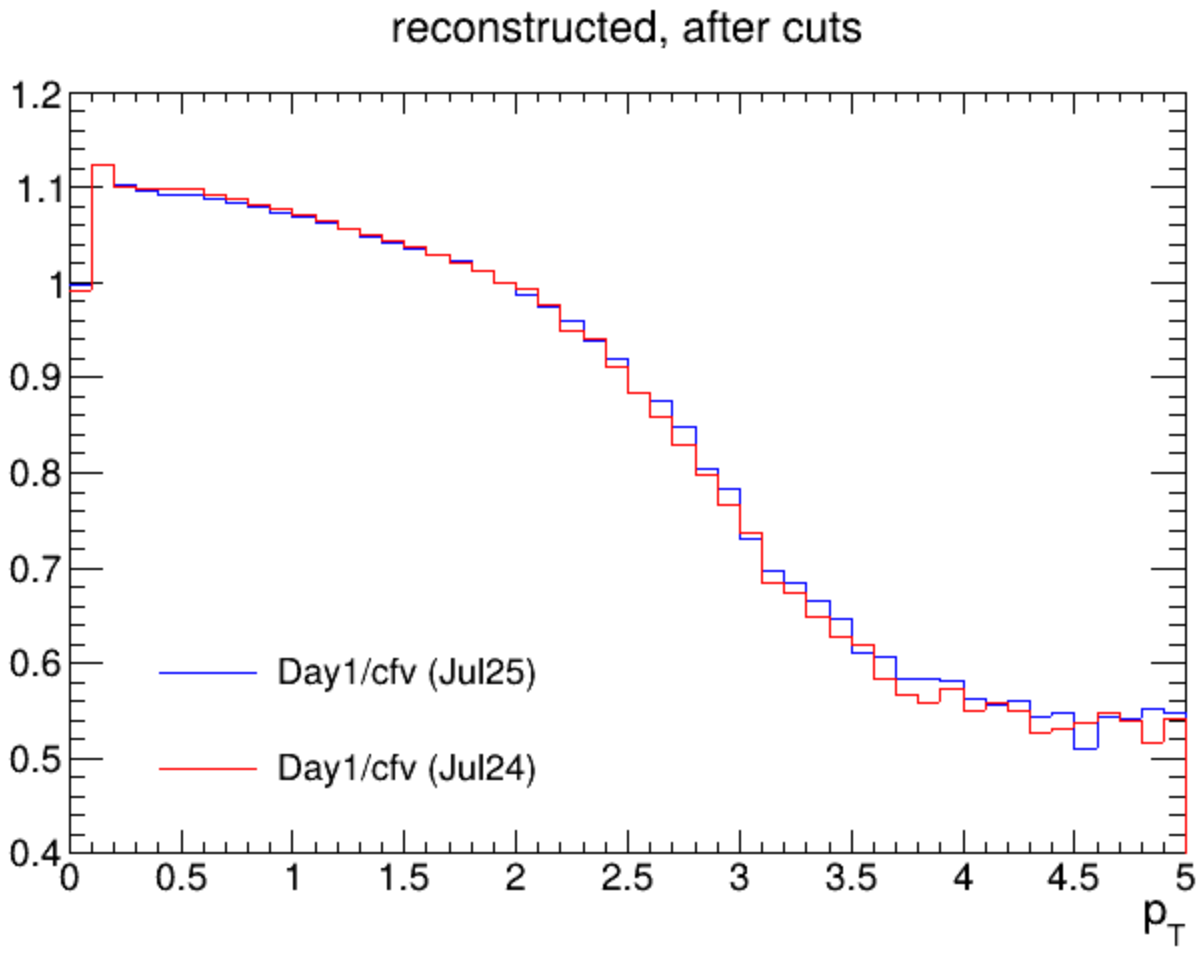
- Sizable discrepancy only at large p_T





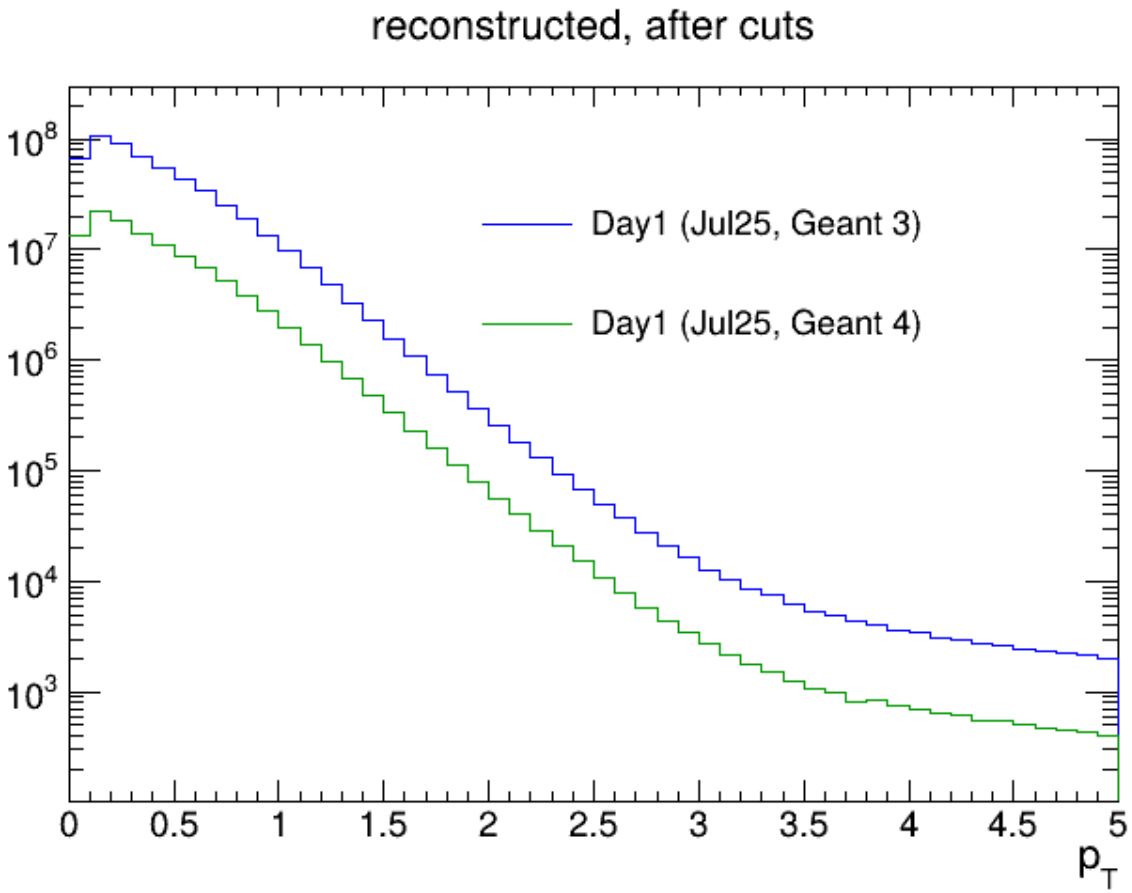
Distribution of transverse momentum

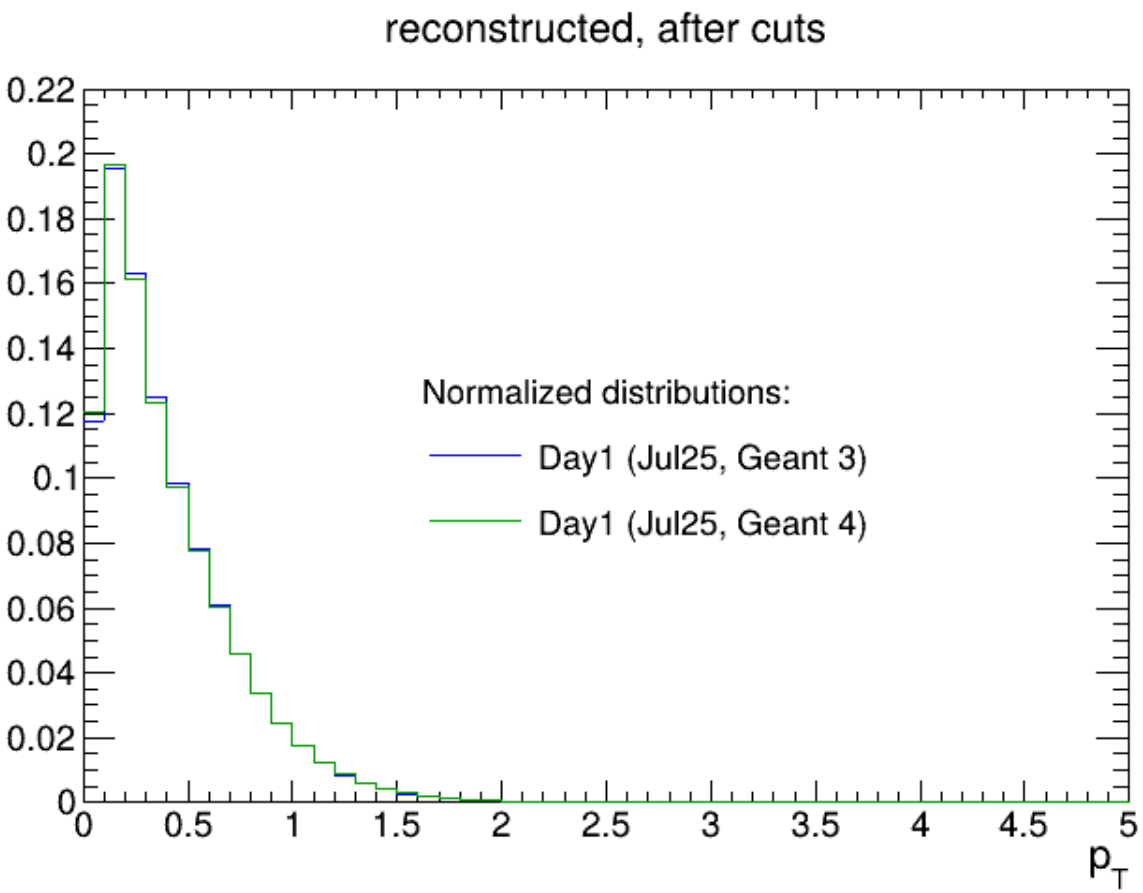
- Sizable discrepancy between the two configurations for all p_T



Distribution of transverse momentum

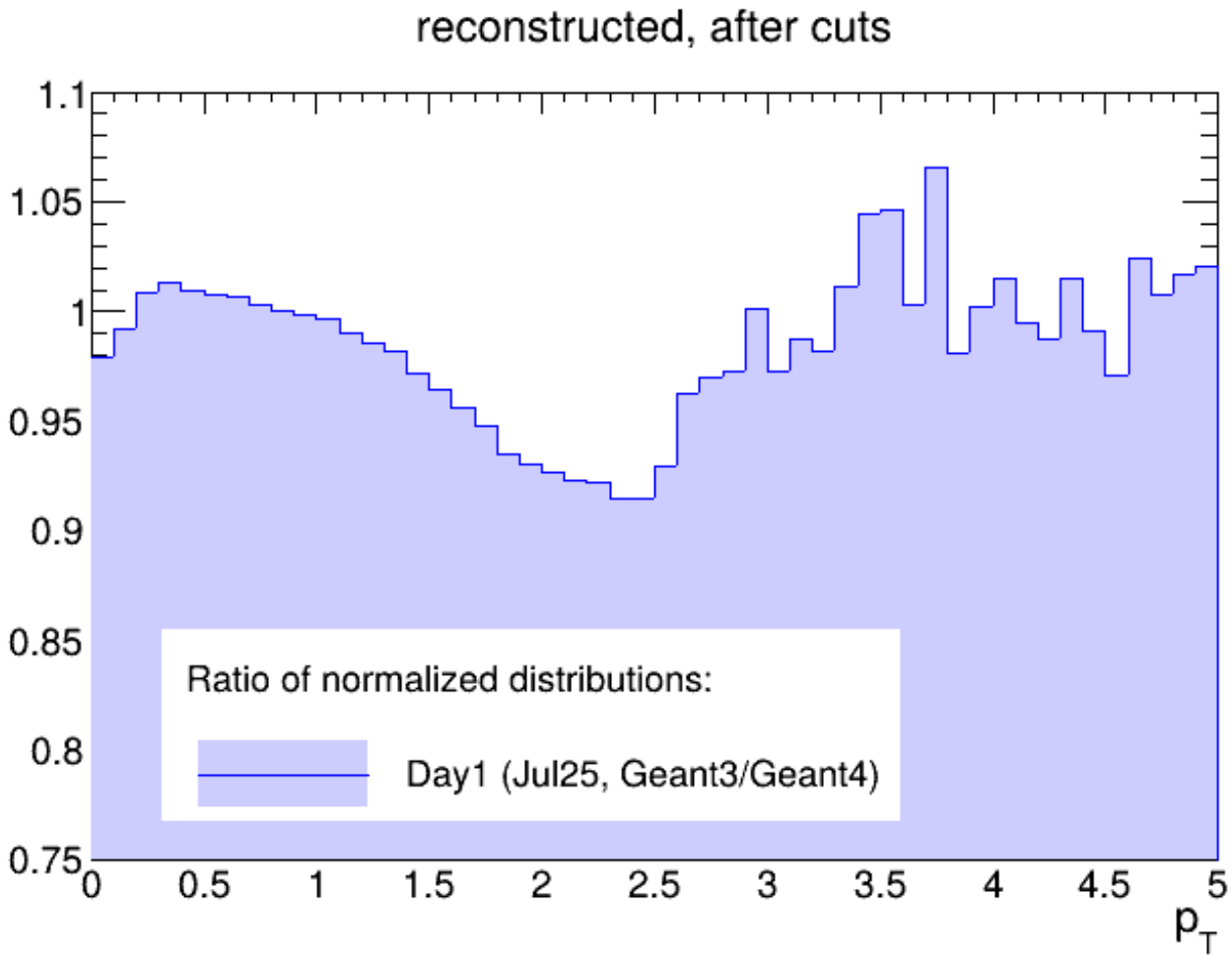
- Check for Geant version





Distribution of transverse momentum

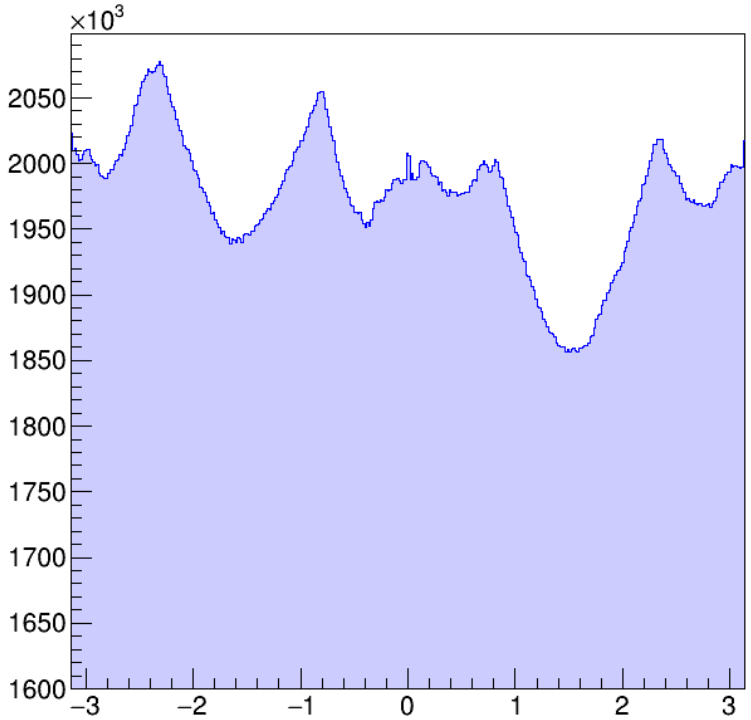
- Largest discrepancy at intermediate p_T (but within 10%)

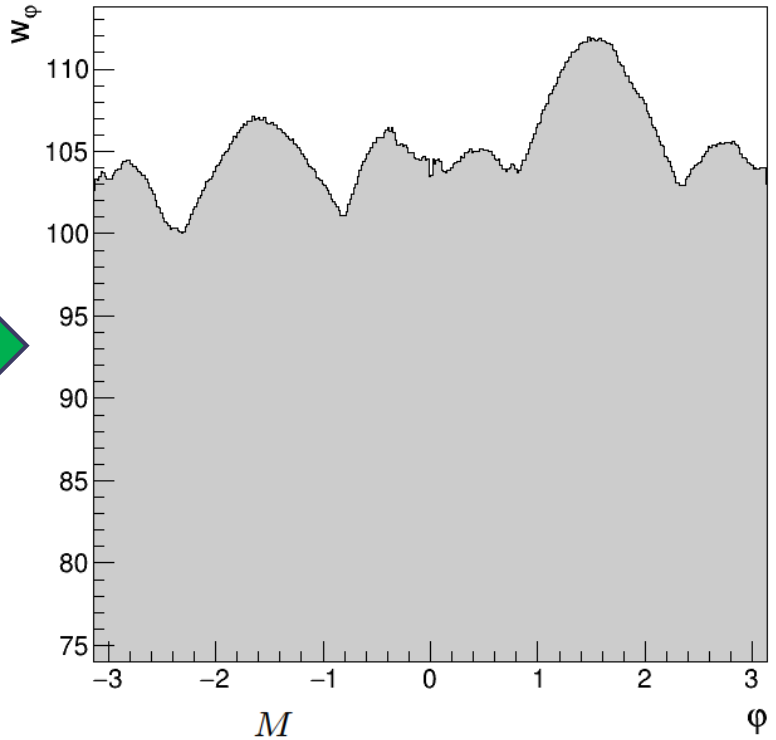


Reminder: Particle weights

- How can we correct for non-uniform azimuthal acceptance?
  - phi-weights

Section IV in Phys. Rev. C **89** (2014) no.6, 064904

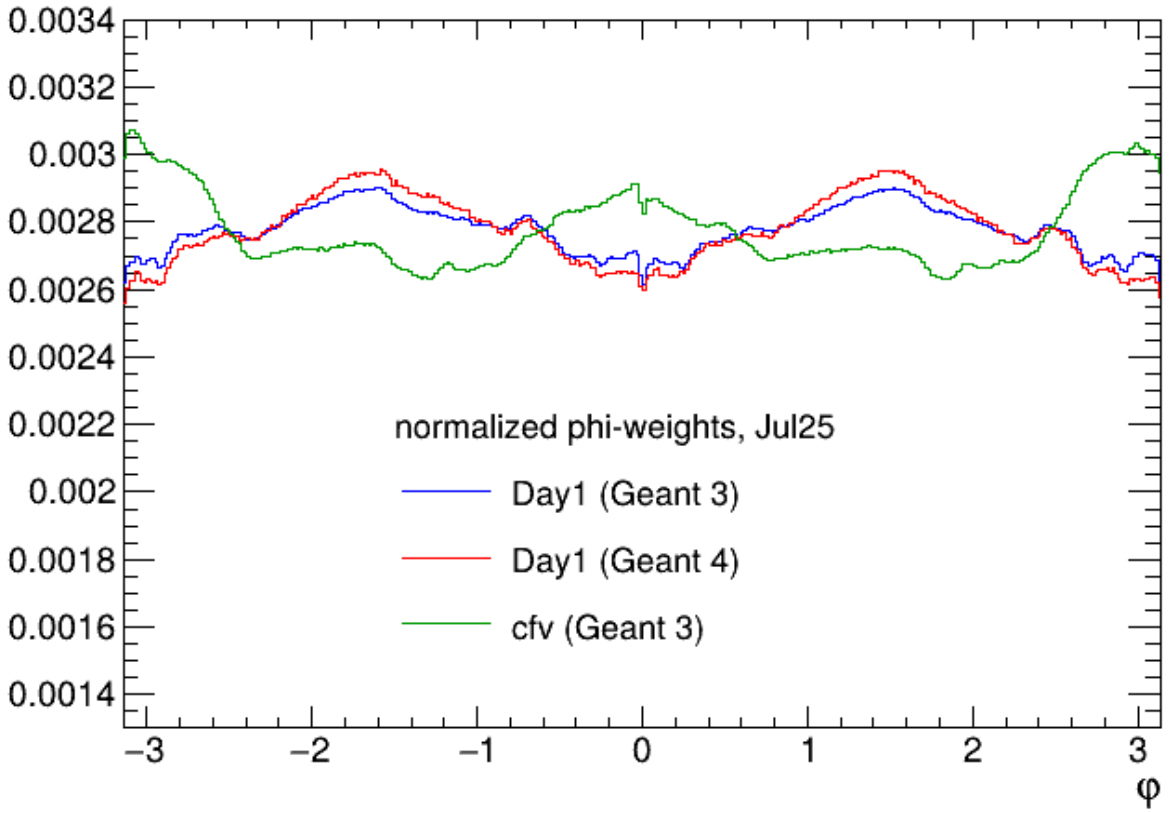


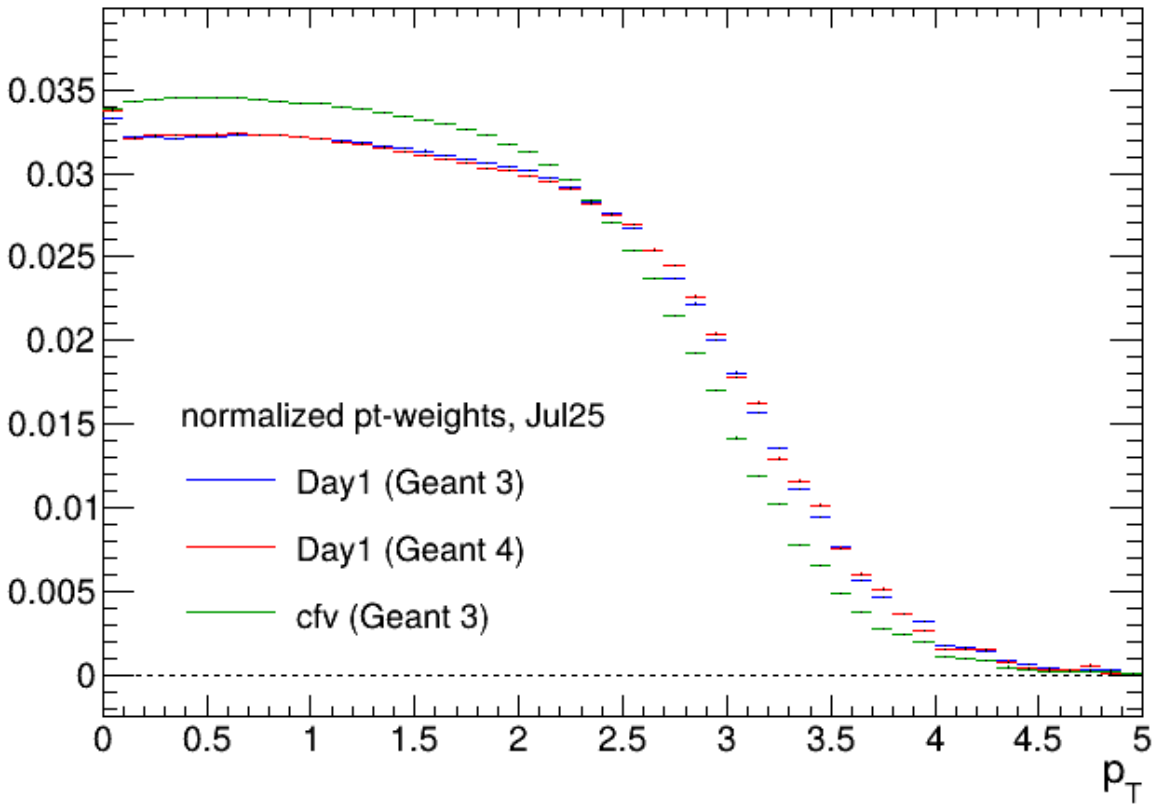


$$Q_n \equiv \sum_{k=1}^{M} e^{in\varphi_k} \qquad Q_{n,p} \equiv \sum_{k=1}^{M} w_k^p \, e^{in\varphi_k}$$

Particle weights

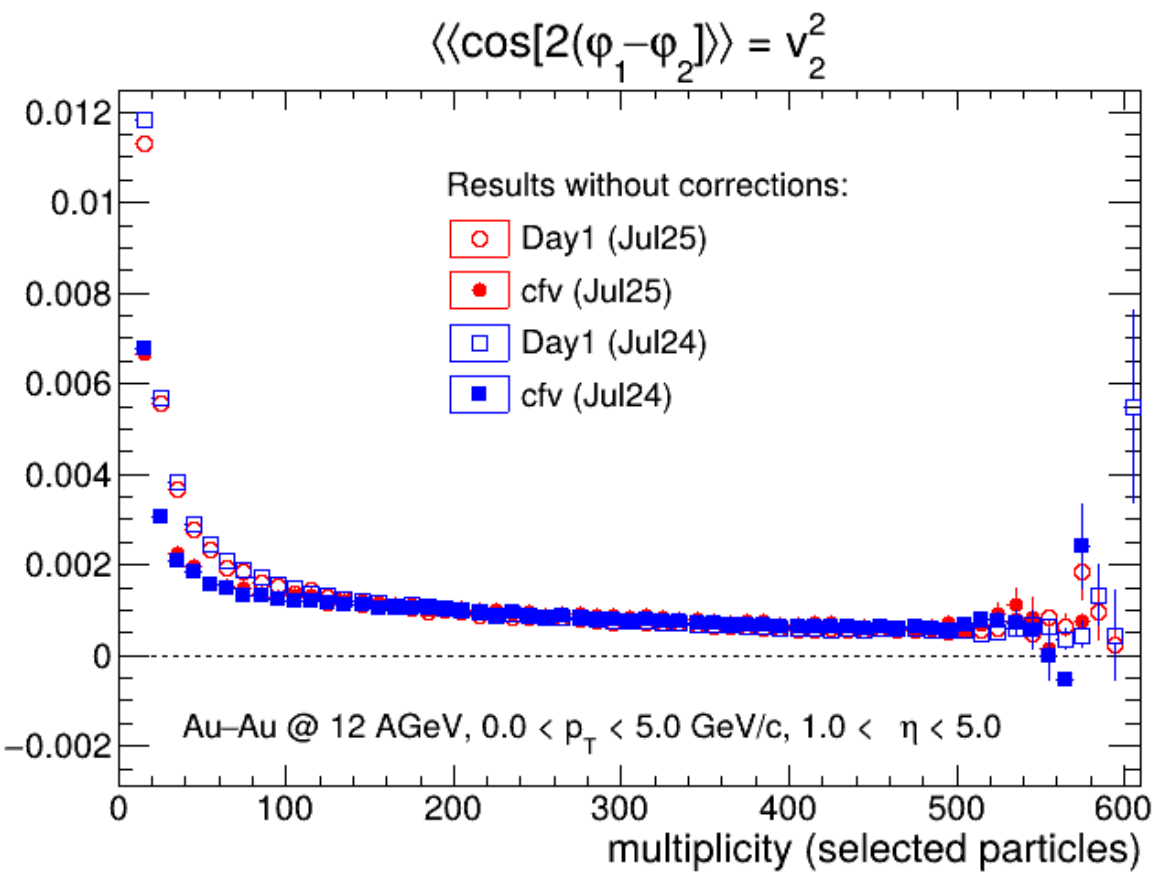
- phi-weights (LHS, data-driven) and pt-weights (RHS, from Monte Carlo)

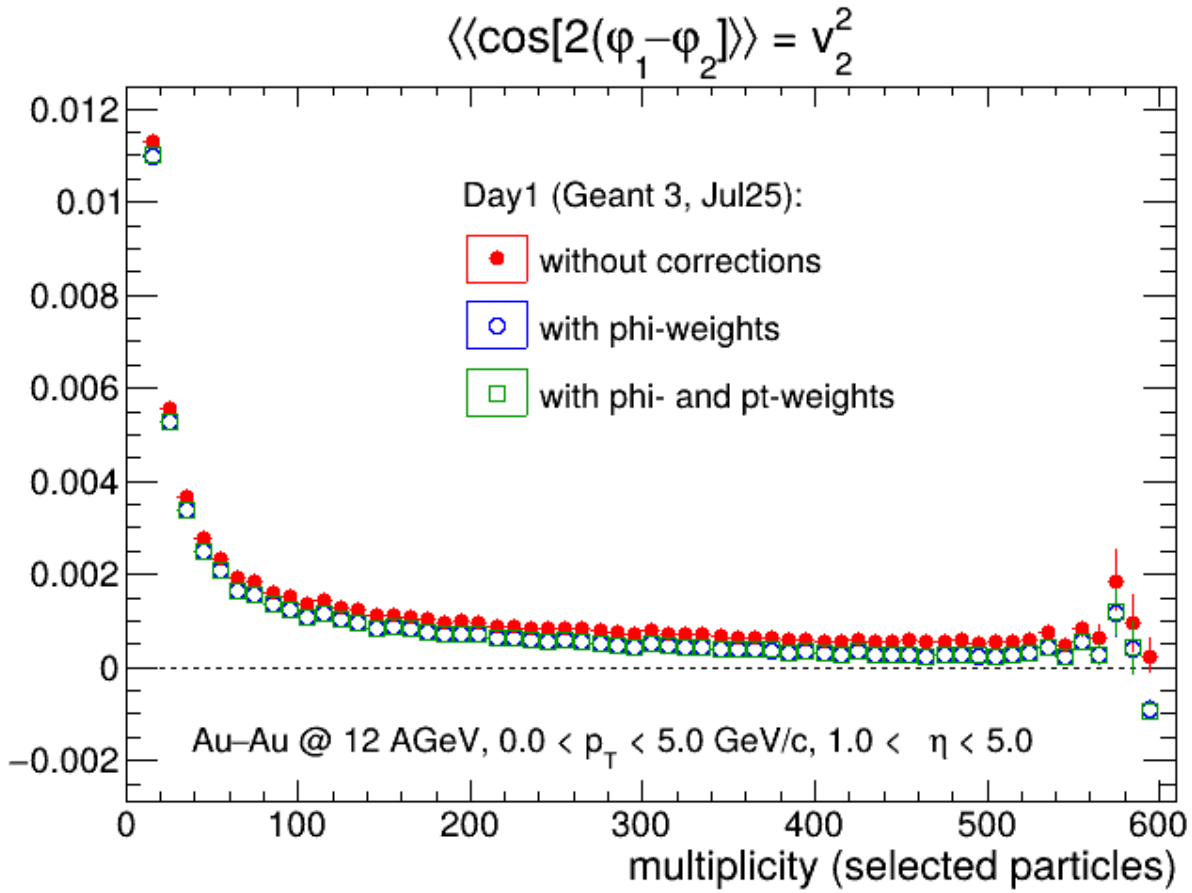




Results for 2-particle azimuthal correlations

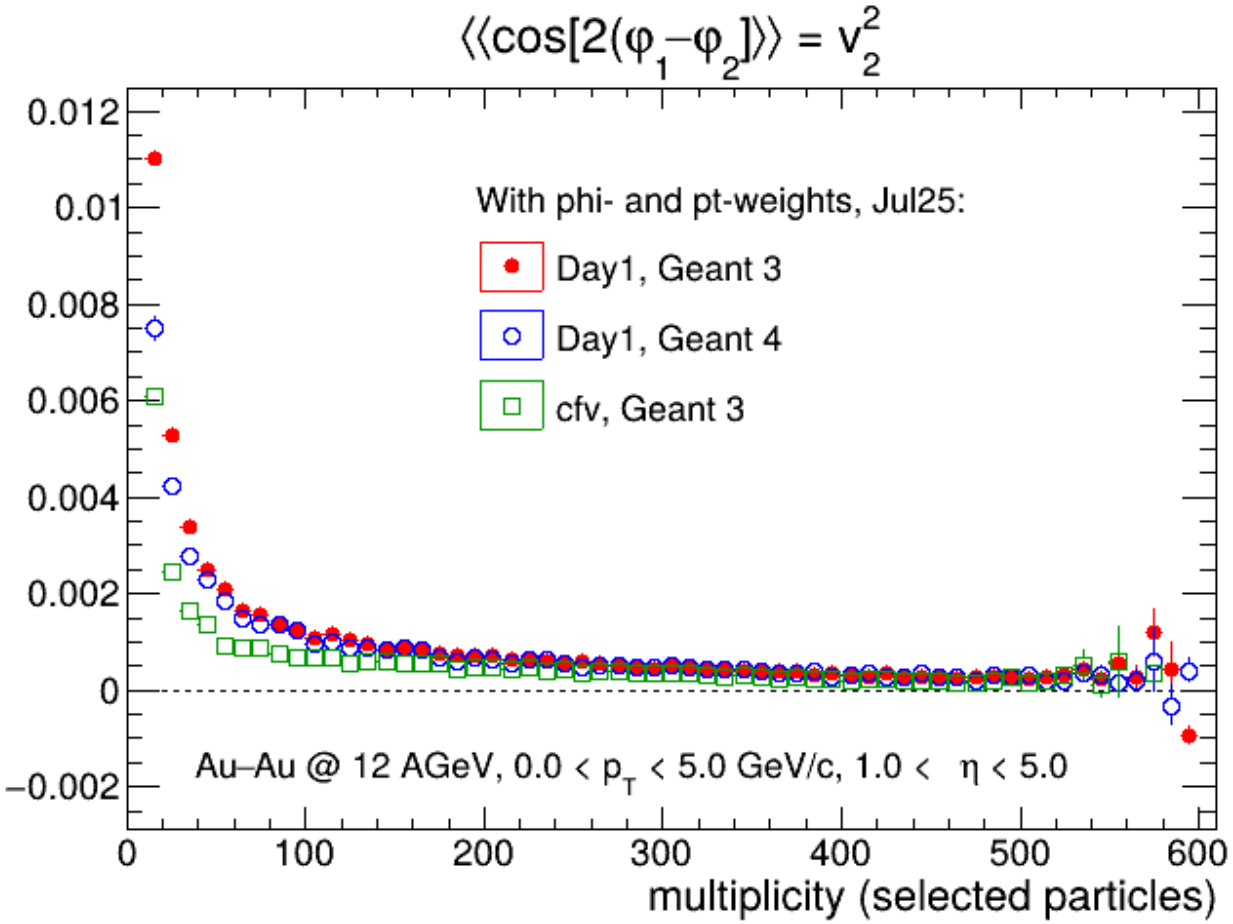
Elliptic flow vs. multiplicity



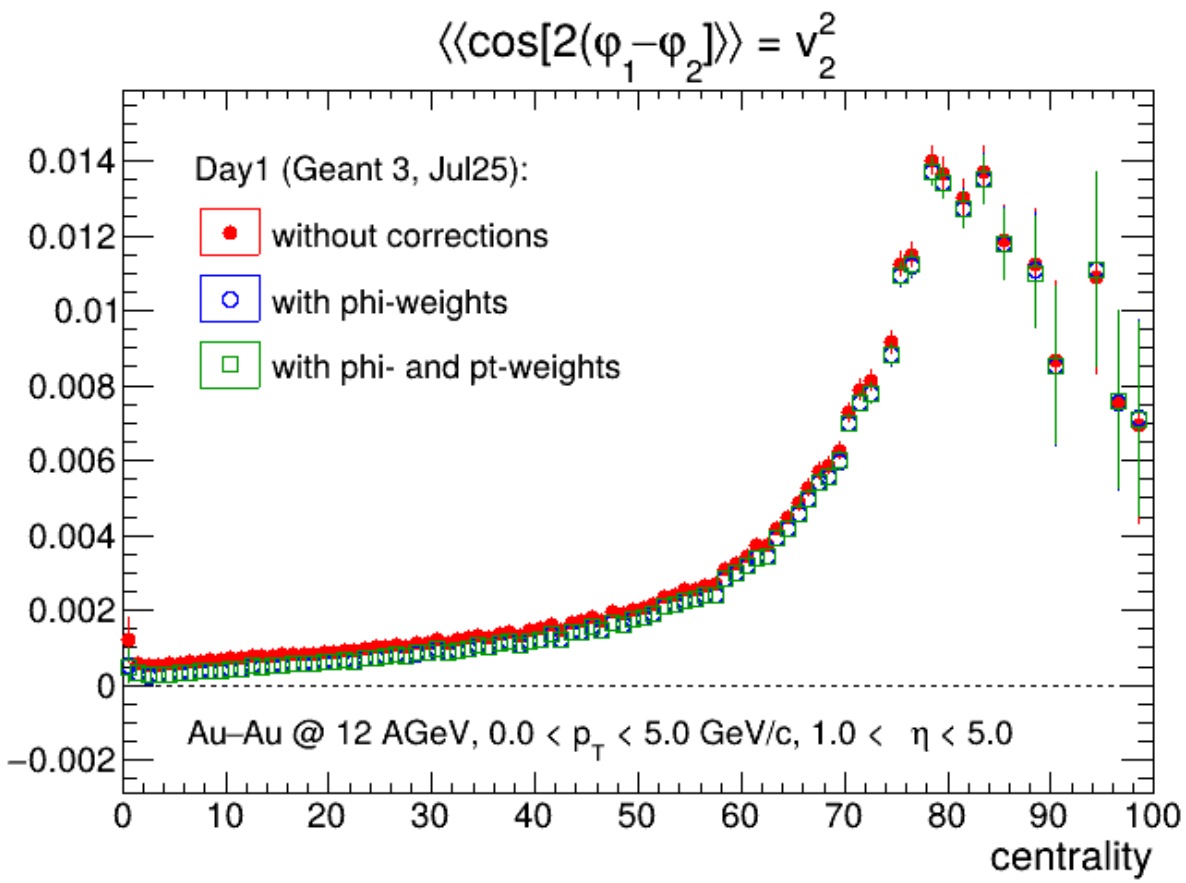


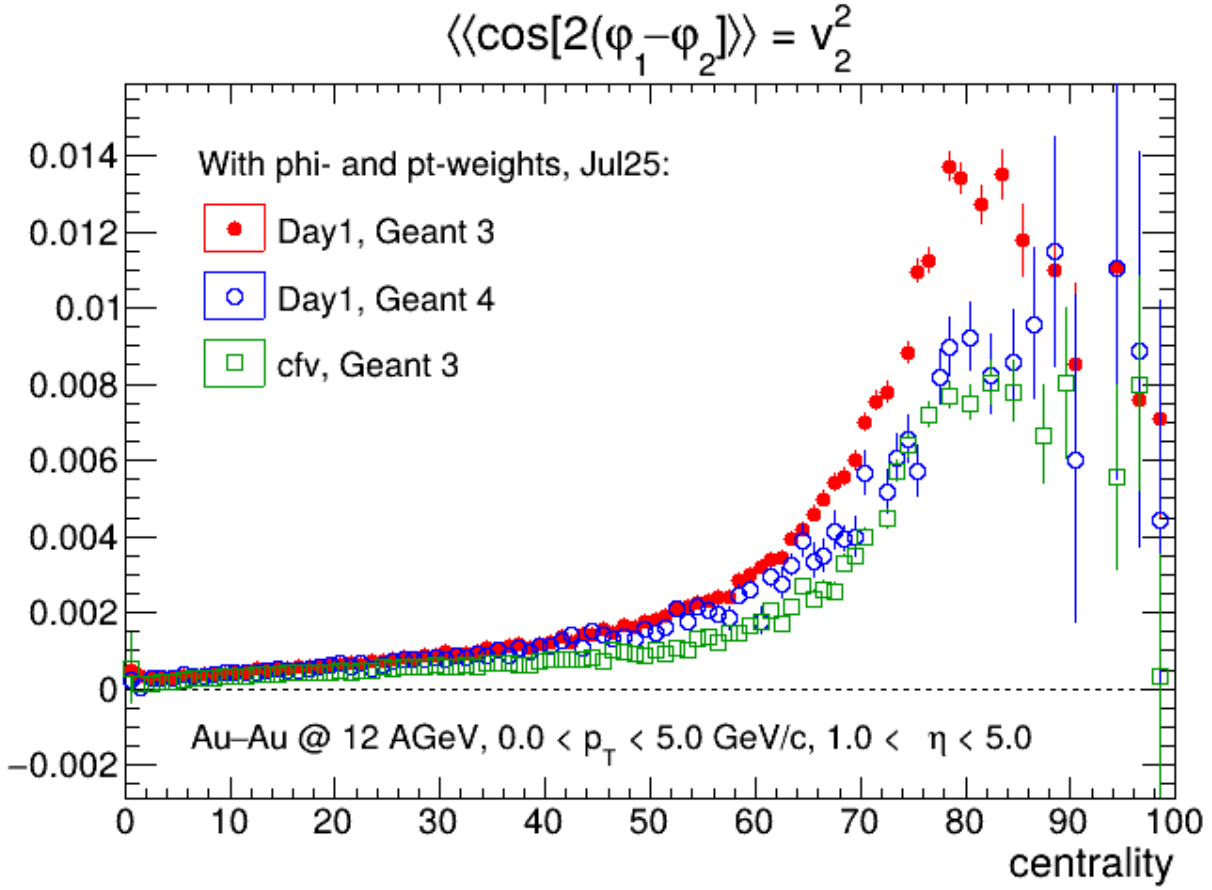
Elliptic flow vs. multiplicity

- Corrections (phi- and pt-weights) are applied



Elliptic flow vs. centrality





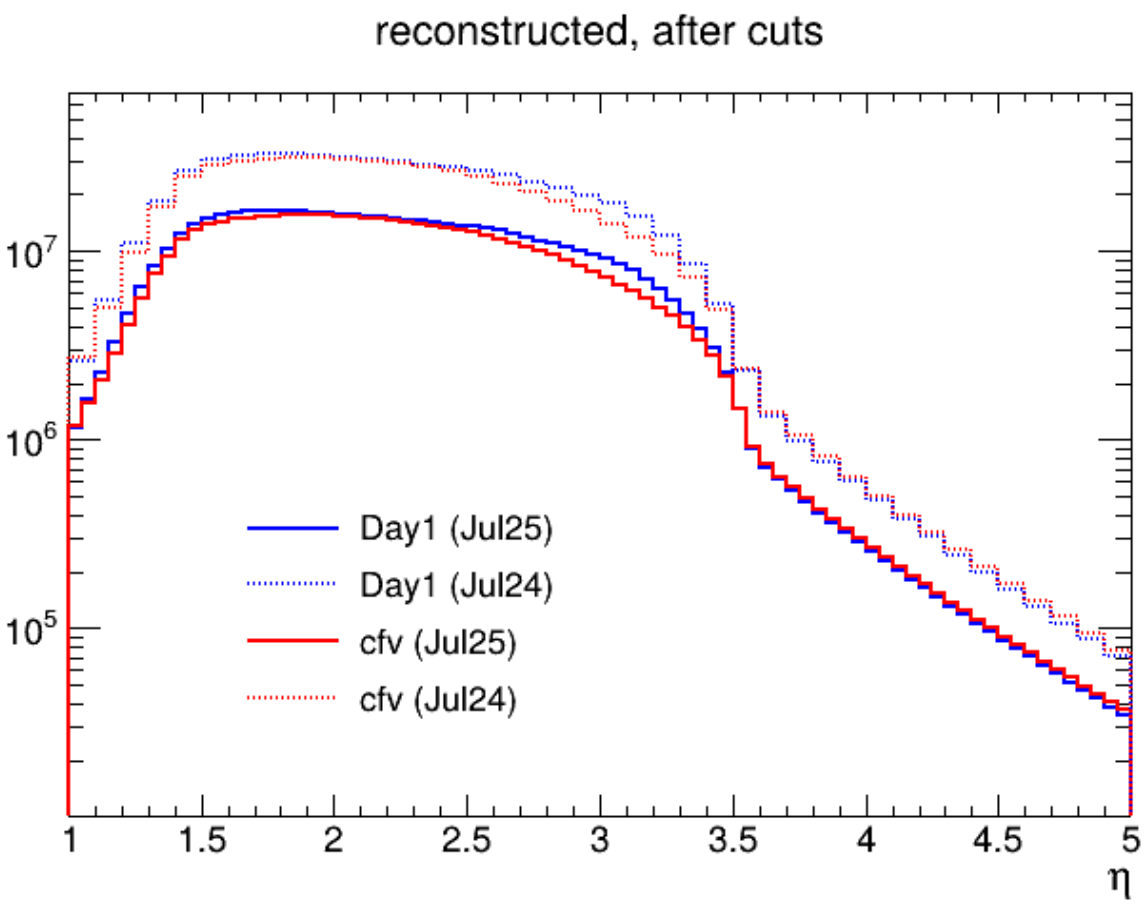
Summary & wishlist

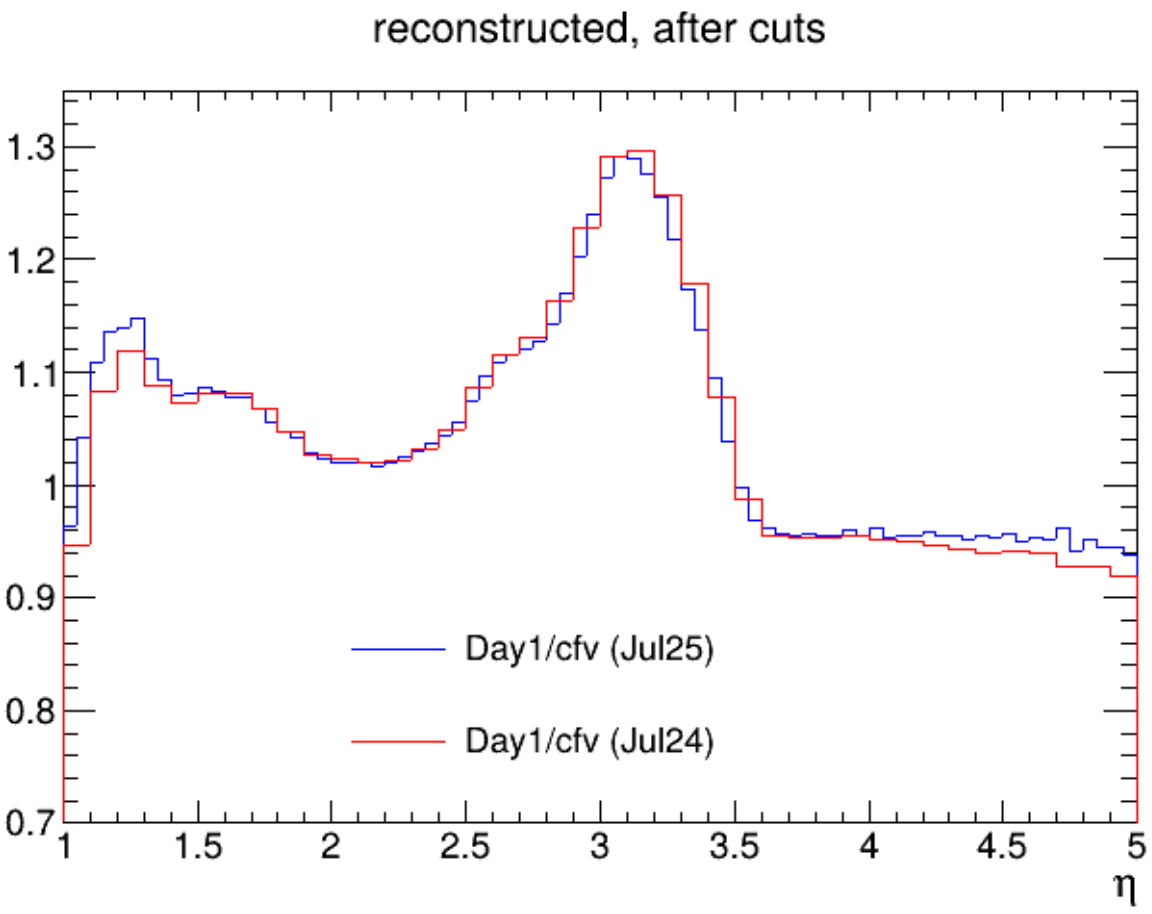
- Control histograms and results differ between the datasets
  - Additional differential corrections will be tested
- Wishlist for further information in the **AnalysisTree** output:
  - **Reference multiplicity** (as discussed in the last Physics Forum)
  - **Simulated centrality** calculated directly from the impact parameter
    - In the past, there was already the field “centrality_impactpar” in the branch “SimEventHeader”
    - We could use simple formula: **centrality(b) = Pi * b^2 / sigma_inel** (or something more profound)
    - It’s important that we all use the same value for “sigma_inel” for a given collision system and energy
  - **Run number**
    - Detector conditions change from one run to another
    - Trending plots as a part of QA (e.g. Average multiplicity vs. Run number, etc.)
    - Corrections will be different for different runs
    - There is a field “run_id” in the branch “SimEventHeader” => shall we add it to the branch “AnaEventHeader”?

Thanks!

Distribution of pseudorapidity

- Sizable differences





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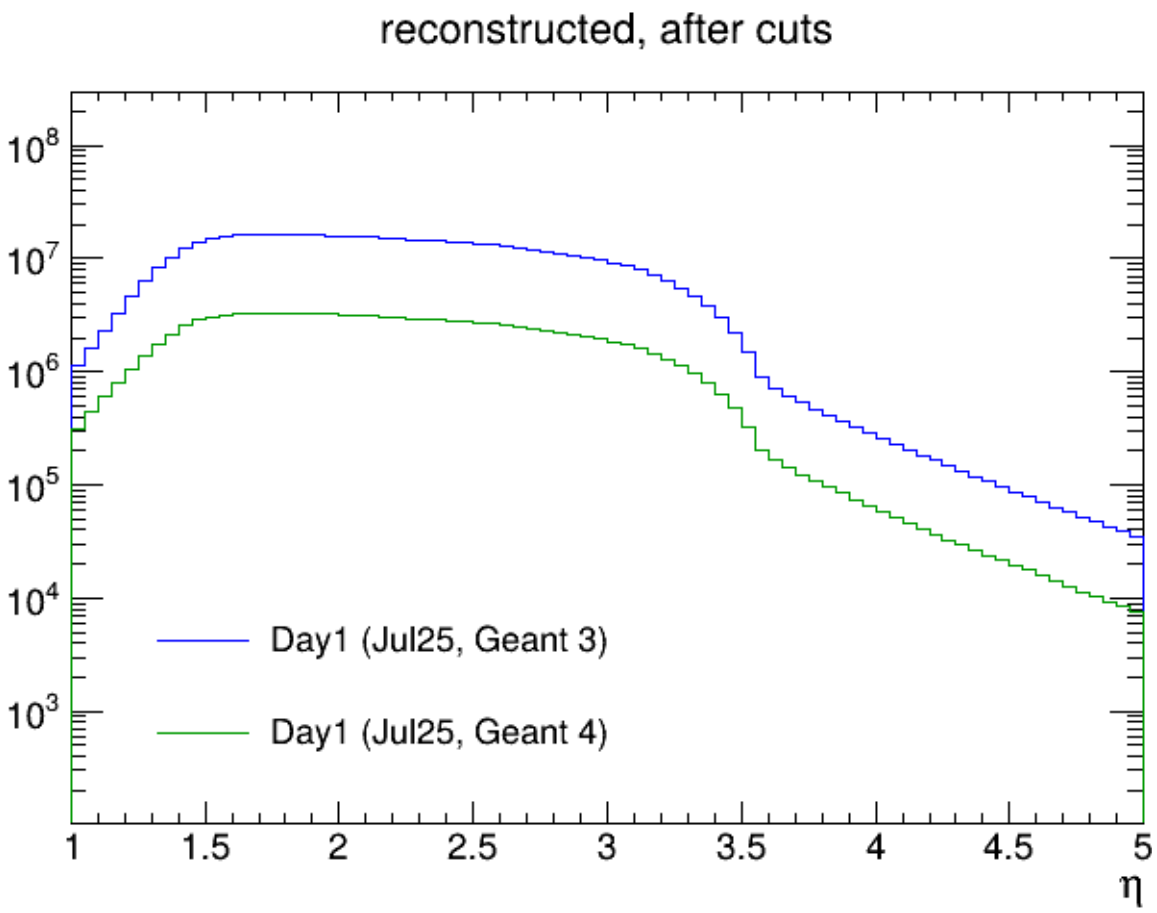

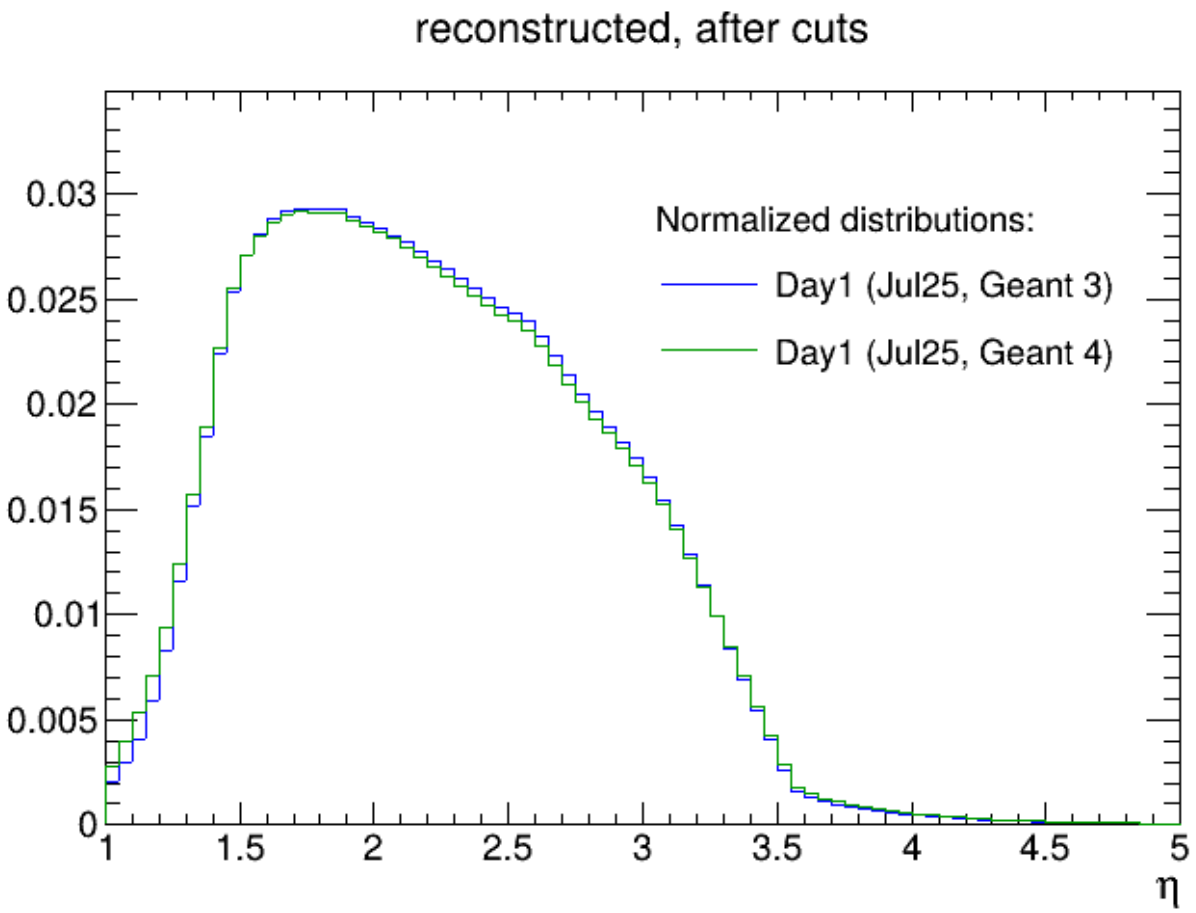

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