SMASH 1.7: new features and some remarks

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Content

1. SMASH model
2. Some features of generator – old and new (1.6 vs 1.7)
3. Catching particles-spectators
4. Physical observables – before and after spectators removing
5. Some strange things with φ-distribution
6. Impact-parameter distribution – a little bit about it

Papers on SMASH

- arXiv:nucl-th/9803035 – description of transport model
- arXiv:1606.06642v2 [nucl-th] – description of the SMASH model especially
- https://smash-transport.github.io/ - the main page of the project
- http://theory.gsi.de/~smash/doc/1.7/index.html – technical documentation about SMASH and its settings and outputs

SMASH model: the notion

SMASH - **S**imulating **M**any **A**ccelerated **S**trongly-Interacting **H**adrons

Physical basement of SMASH is the hadronic transport model J. Weil et al, PRC 94 (2016)

Dynamics of system are described by relativistic Boltzmann equation

$$p^\mu \partial_\mu f_i(x,p) + m_i F^\alpha \partial_\alpha^p f_i(x,p) = C_{\text{coll}}^i$$

mass of particles of species i

the force experienced by individual particles

the single particle distribution for each species i

collision terms

SMASH model: particles collisions

Sequence of generation process:

1) Generating of nuclei with given geometry, atomic numbers and energies

2) Numerical calculating of Relativ. Boltzmann Eq. for many-particle system

3) If 2 particles are close enough, they can interact via one of the listed processes (elastic and inelastic scattering, resonance creating, strings…)

4) Calculating it until end, writing the particles characteristic in time moments which we want

5) Profit!

SMASH 1.7: what`s new?

- Input configuration of deformed nuclei has changed. Additional level of Orientation provided where the angles or a random rotation can be specified.
- Most outputs now specify whether the projectile collided with the target
- **ROOT output now includes charge and optionally the extended output**
- **New output content: Initial conditions output in ASCII, Oscar, Binary and ROOT format**
- New stochastic collision criterion (A. Lang et al. J. Comp. Phys. 106, 391 (1993)) is available
- Fermi motion for deformed nuclei
- Random rotation of custom nuclei
- Automatic deformation parameters for ruthenium and zirconium
- Option to add net-baryon density dependence to symmetry potential
- And other (not so important for present work) changes

https://github.com/smash-transport/smash/releases

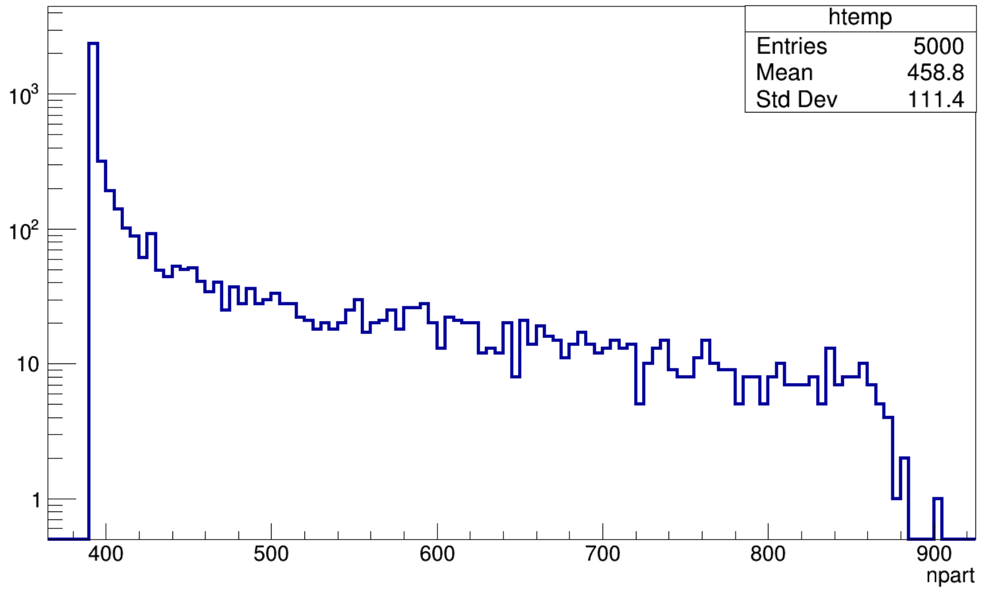
The main settings of SMASH event generator

- **Delta_Time:** 0.1 **– time step of numerical calculations of rel. Bolzman equation**
- **End_Time:** 150.0 **– moment** until SMASH calculates a solution or rel. Bolzman eq. At each time step
- **Nevents:** 5000 **–** Number of generating events
- **Output_Interval:** 150.0 – the period of intermediate output
- **Format:** [Root] **– preferred format to save results of generating**
- **Only_Final:** True – will we save final particles only or intermediate particles also?
- **Strings:** True **– will we turn on Lund string model? (via Pythia8)**
- **Force_Decays_At_End:** True **– Force_Decays_At_End:** True
- **Projectile:**
  Particles: {2212: 79, 2112: 118}
  – The number of proton and neutrons in projectile and target nuclei
- **Target:**
  Particles: {2212: 79, 2112: 118}
- **Sqrtsnn:** 4 **– energy in CMS per NN-pair (in GeV)**
- **Fermi_Motion:** on **– will we include Fermi-motion in nuclei or not?**
- **Impact:** **– form and range of impact parameter distribution**
  Sample: quadratic
  Range: [0.0, 20.0]

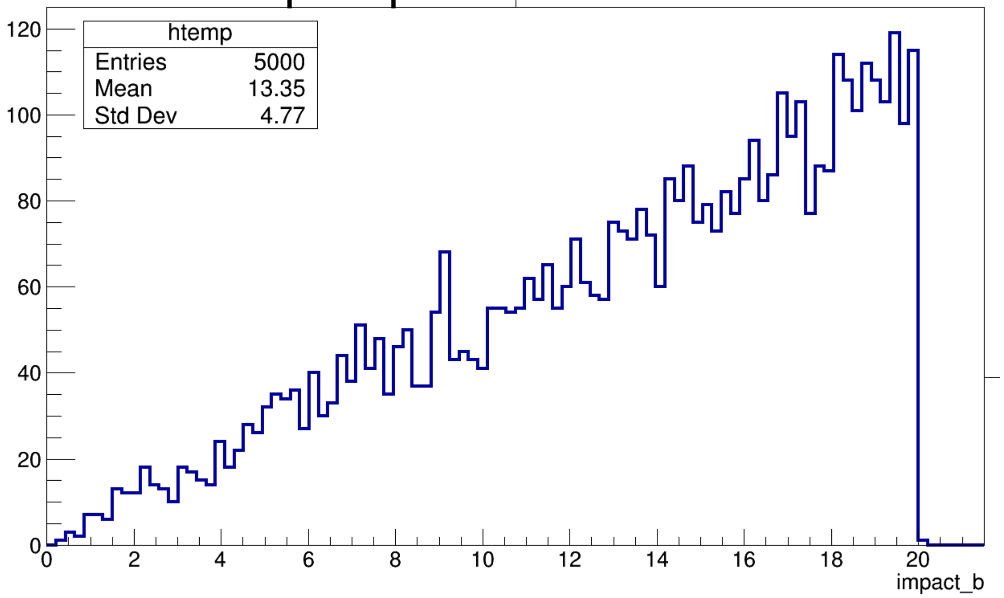
SMASH output: ROOT

Au+Au, 4 GeV/pair

Final particles Multiplicity distr.



Impact par. distr.

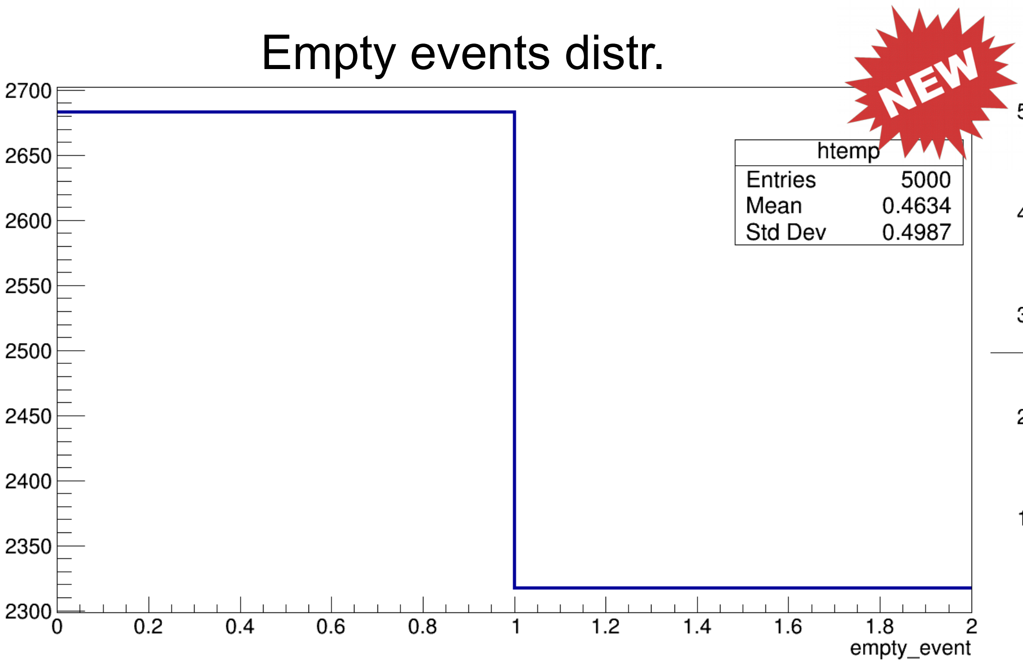


Number of particles in system in final time (150 fm/c here)

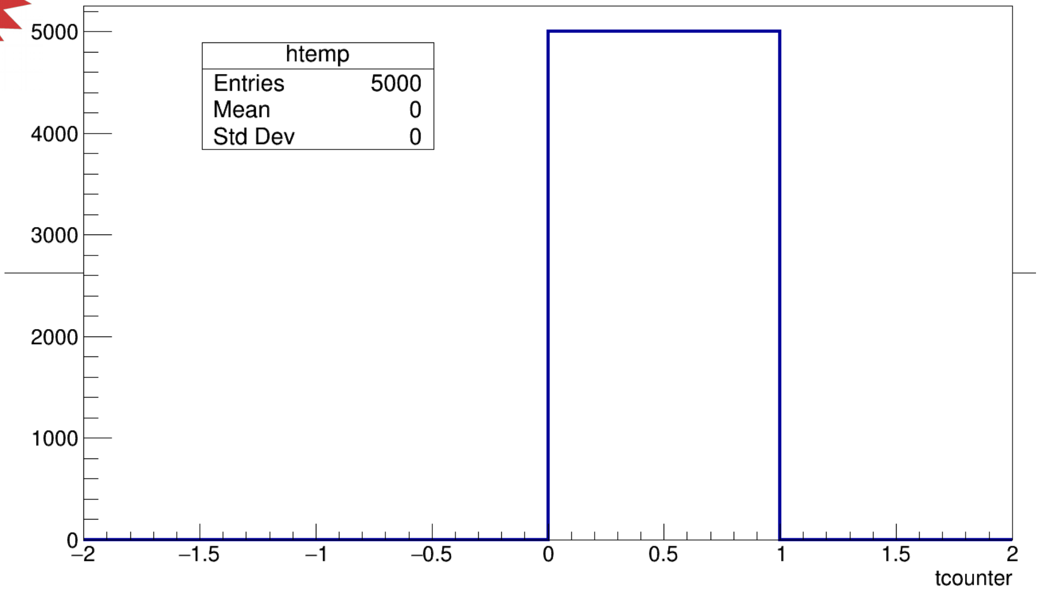
Event is recorded even there was no collision; dP(b) = b db

SMASH output: ROOT

Empty events distr.



Output blocks

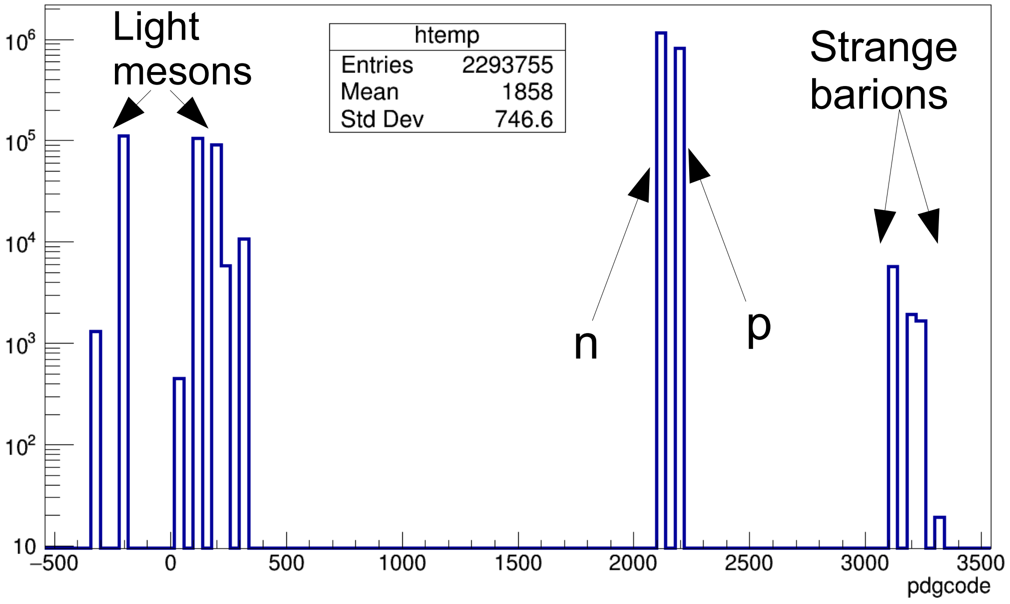


empty_events = 0 if there was a collision (minimum interaction even) and 1 if there was no

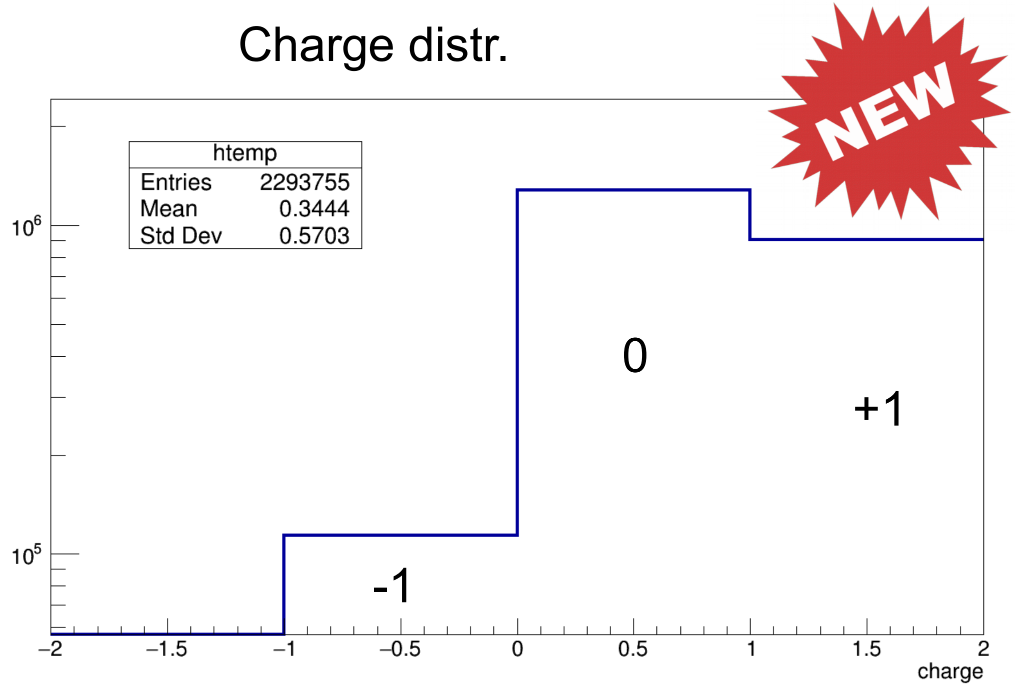
Number of output block (“snapshot”) in a given event

SMASH output: ROOT

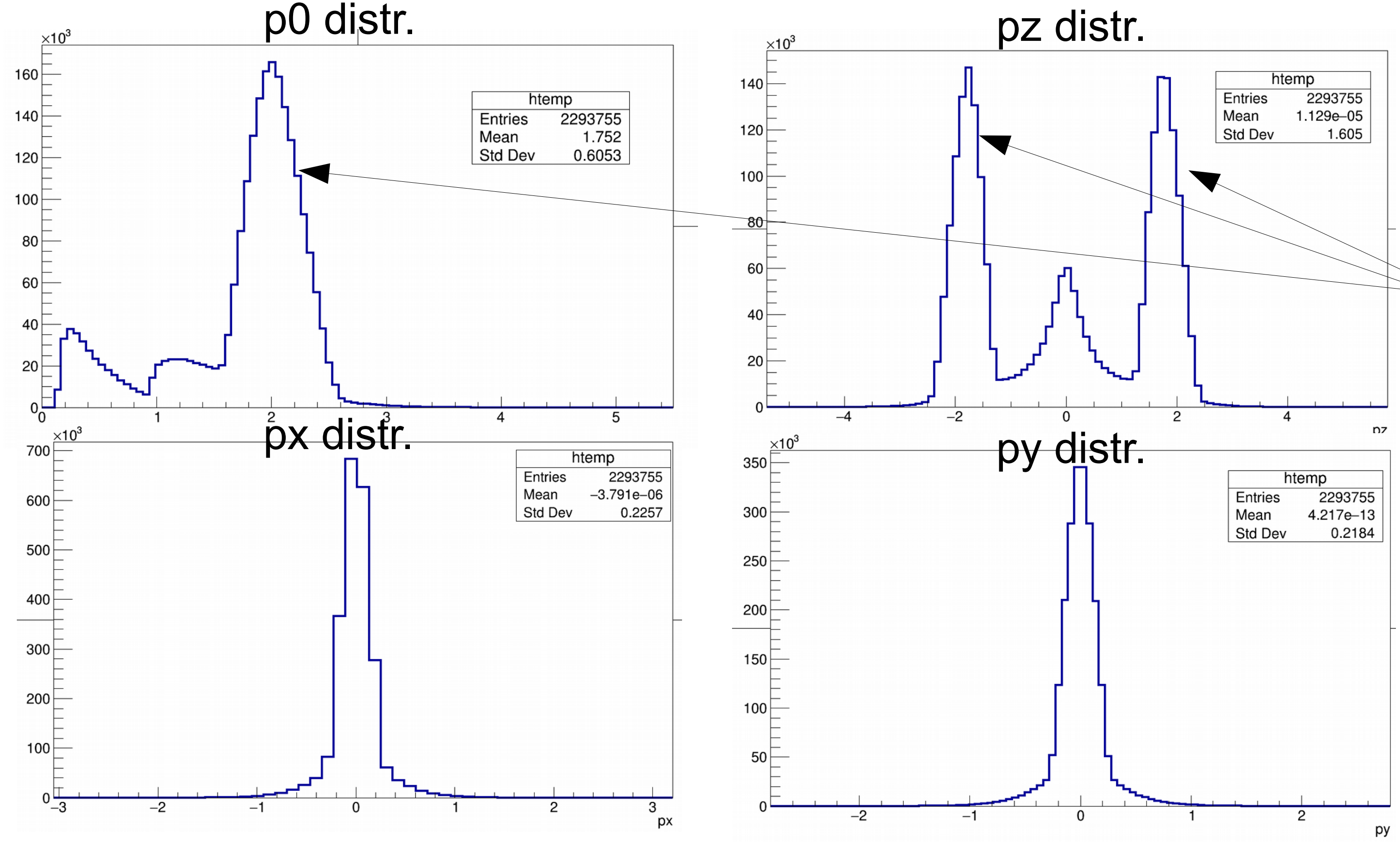
PDG distr.



Charge distr.



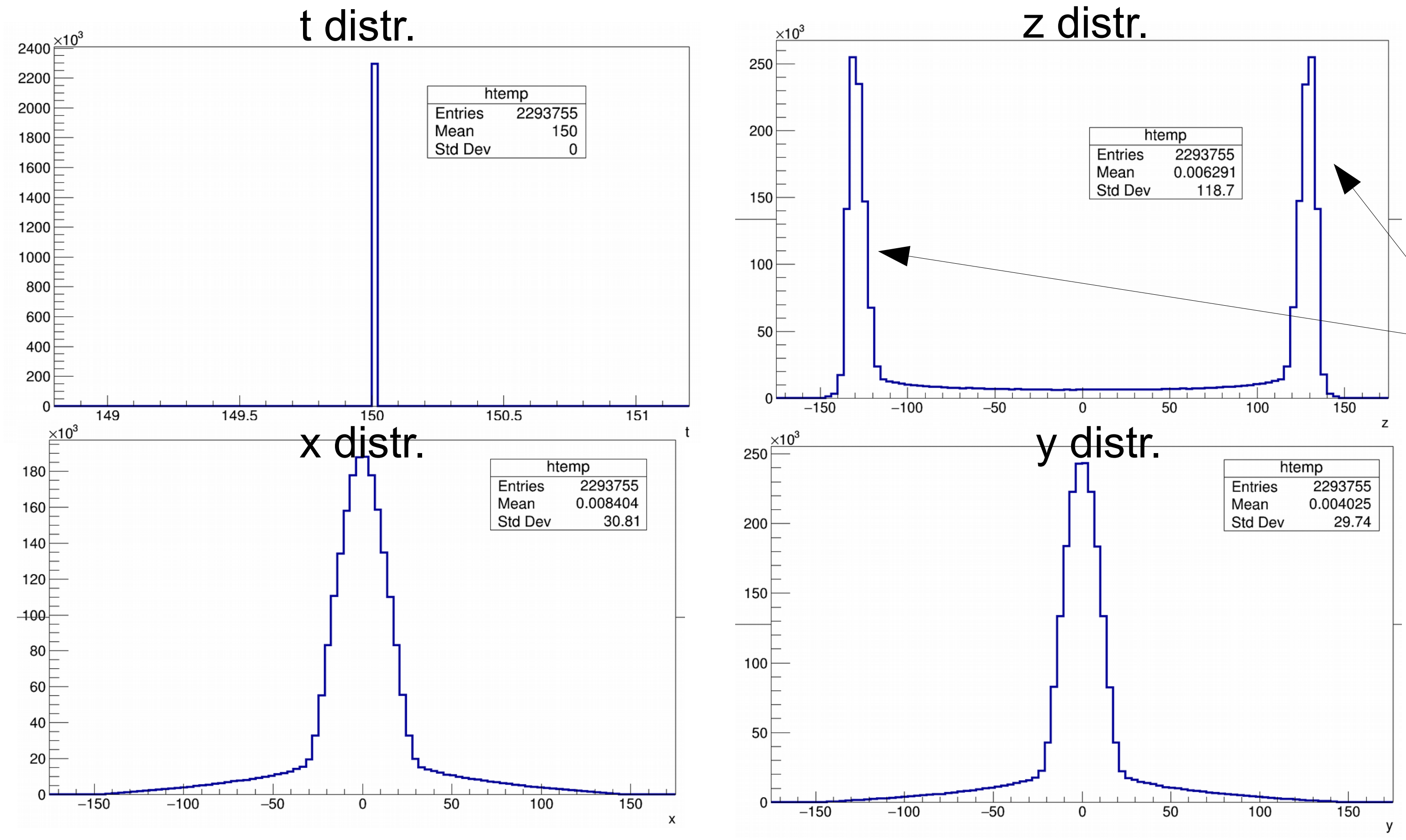
SMASH output: ROOT



Momentum-space distributions of final particles

spectators

SMASH output: ROOT

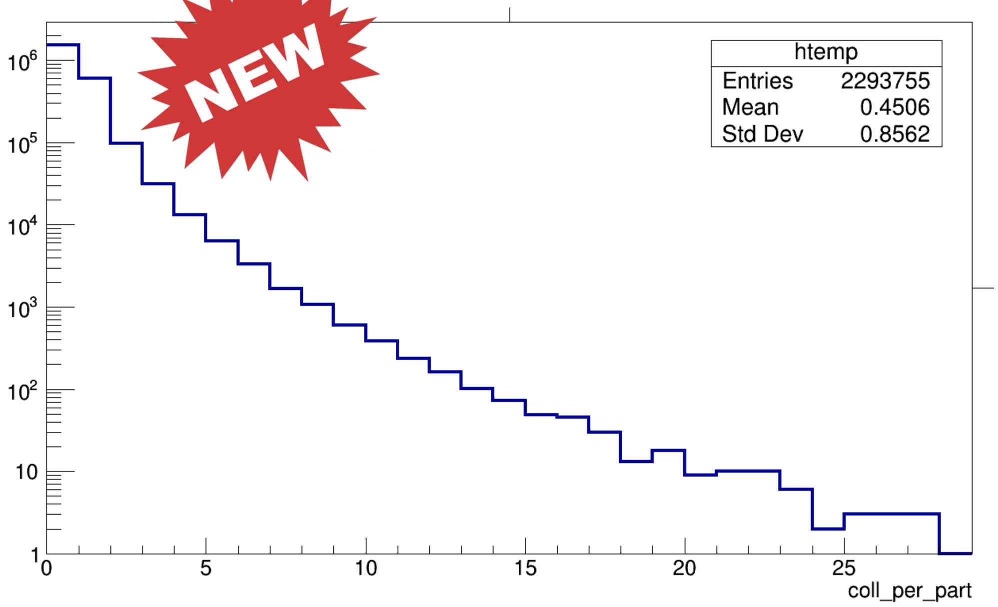


Space-time distributions of final particles

spectators

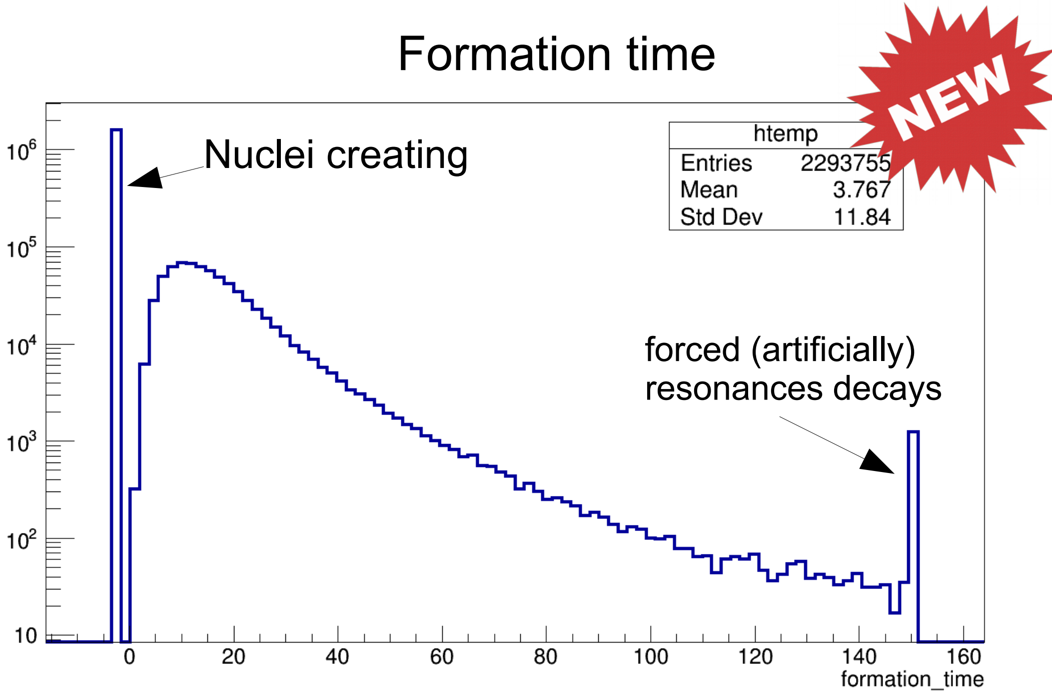
SMASH output: ROOT

Collisions per particle



Number of collisions the particle has undergone

Formation time

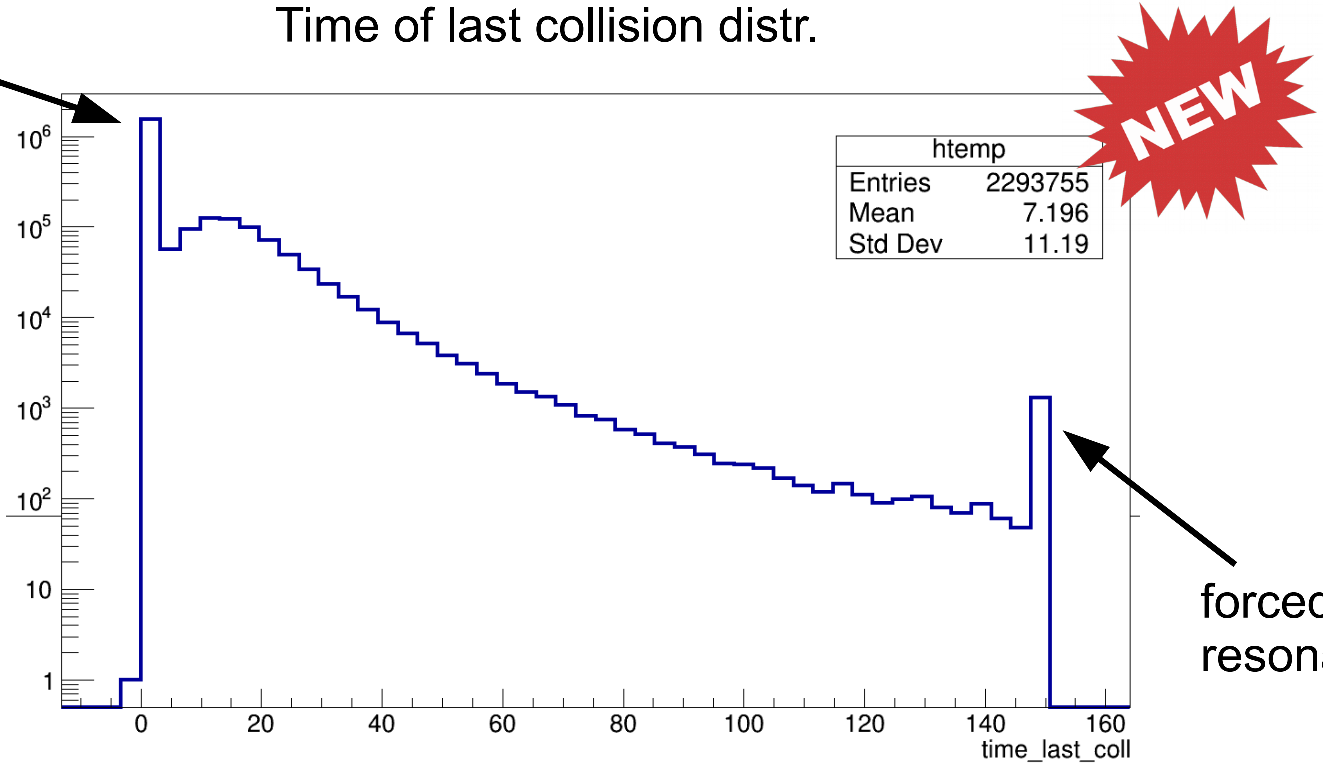


Formation time of the particle

SMASH output: ROOT

Nuclei creating

Time of last collision distr.

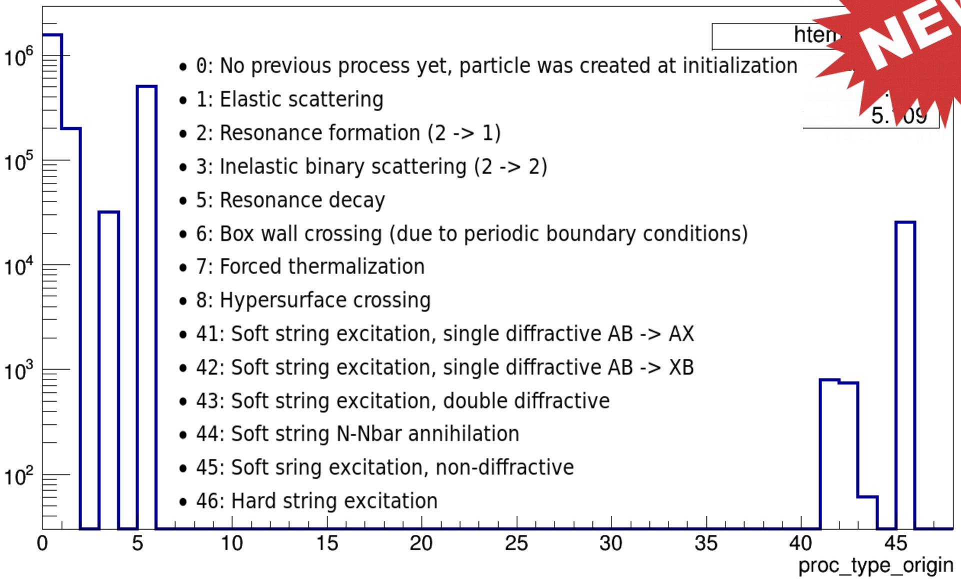


forced (artificially) resonances decays

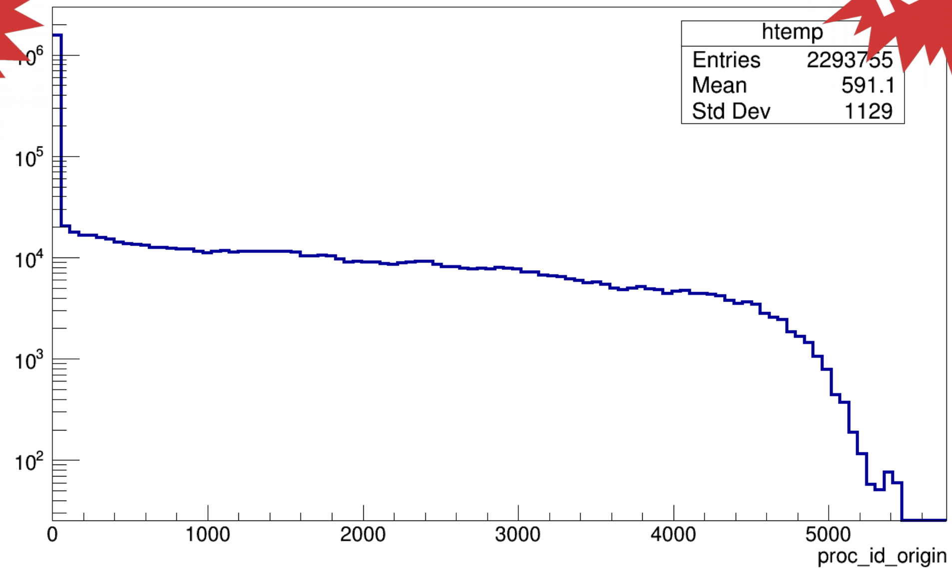
It is time of the (final) particle's last interaction distr.

SMASH output: ROOT

Origin process types



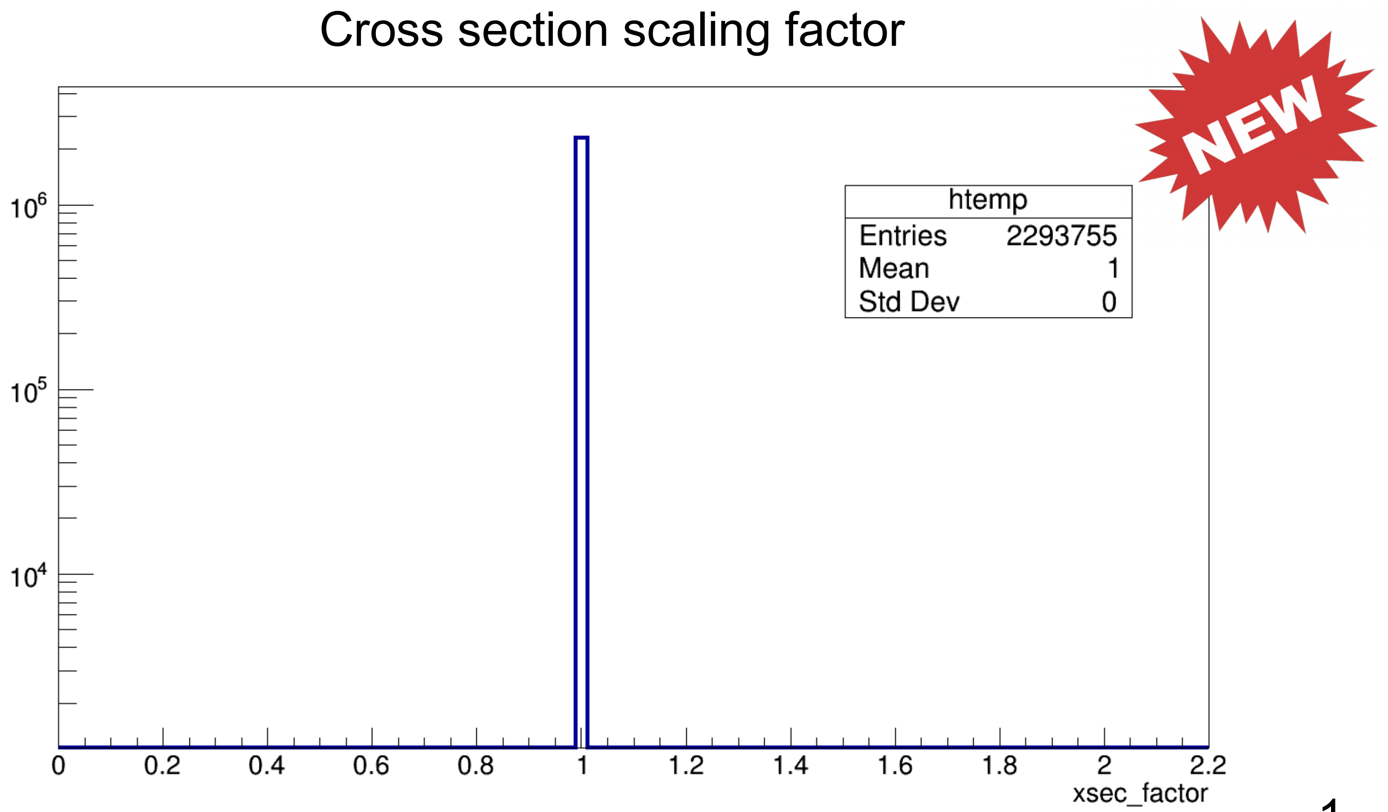
Origin process ID



Type of the last process the particle has and ID of the process of the particle's last interaction

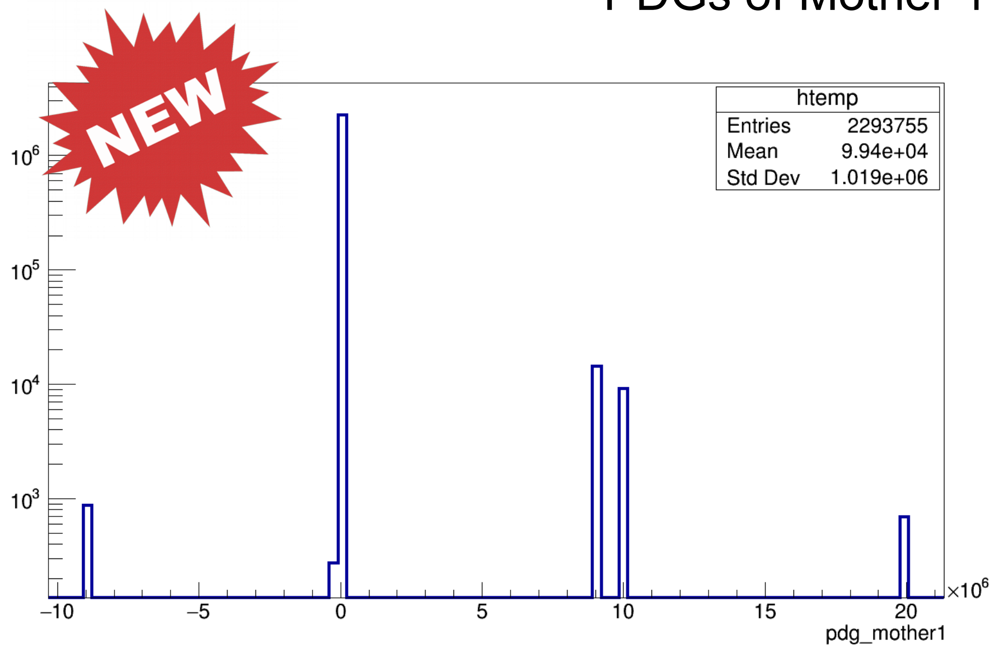
SMASH output: ROOT

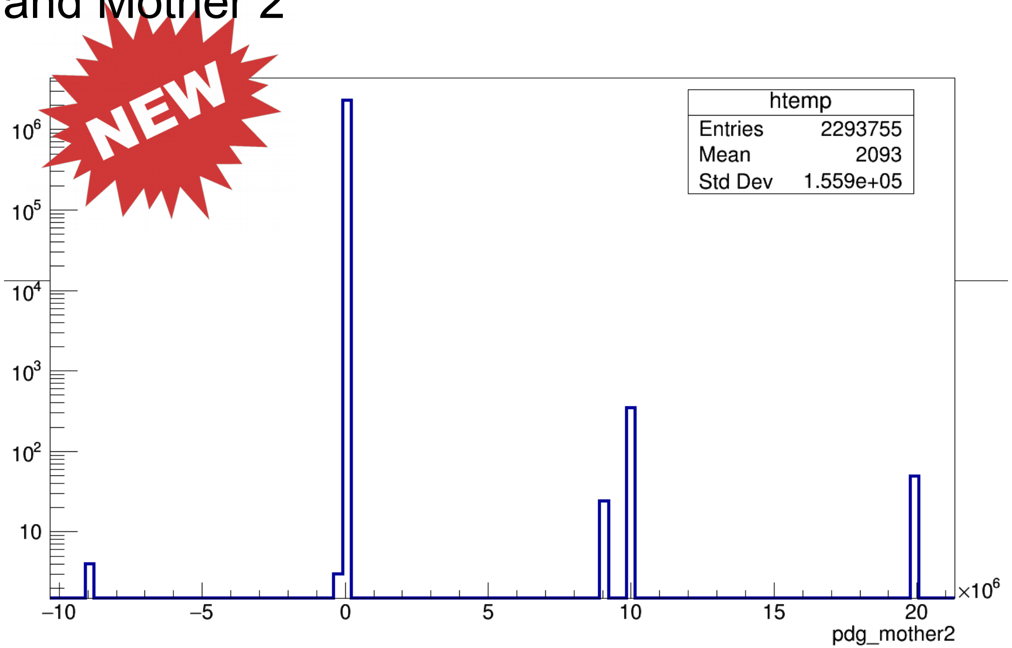
If the particles are not yet fully formed at the time of interaction, the cross section for the underlying process is scaled down by the cross section scaling factor



SMASH output: ROOT

PDGs of Mother 1 and Mother 2

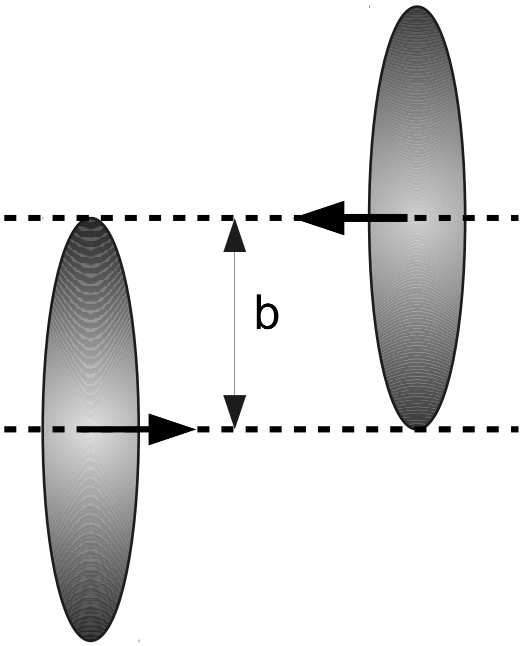


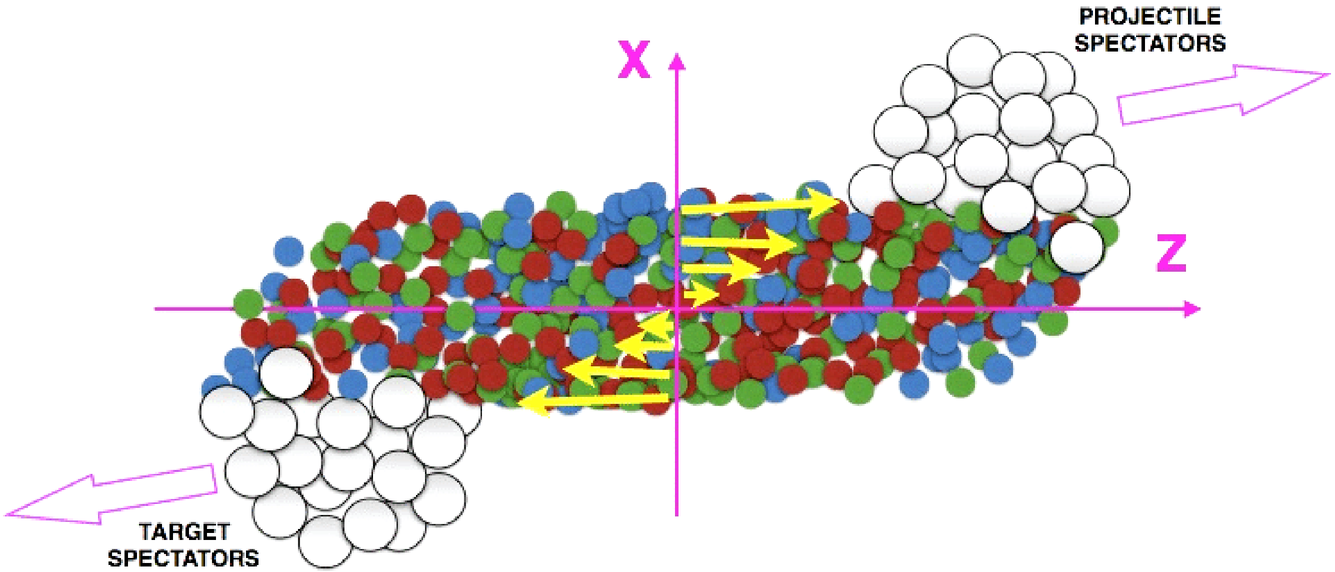


0 in case the particle is sampled in a thermal bubble. It is not updated by elastic scatterings.

0 in case the particle results from the decay of a resonance or the appearance of a thermal bubble. In the former case, pdg_mother1 is the PDG code of this resonance. It is not updated by elastic scatterings

Who is the spectators?





S. Voloshin. 10.1051/epjconf/201817107002

Who is the spectators?

There is few ways to determine which final particles we will assume as spectators:

1) Spectators is particles which formation time < -2 (was emerged before collision) **“FormTime”**

2) Spectators is particles which was not collided with other particles (coll_per_part = 0) **“CollPerPart”**

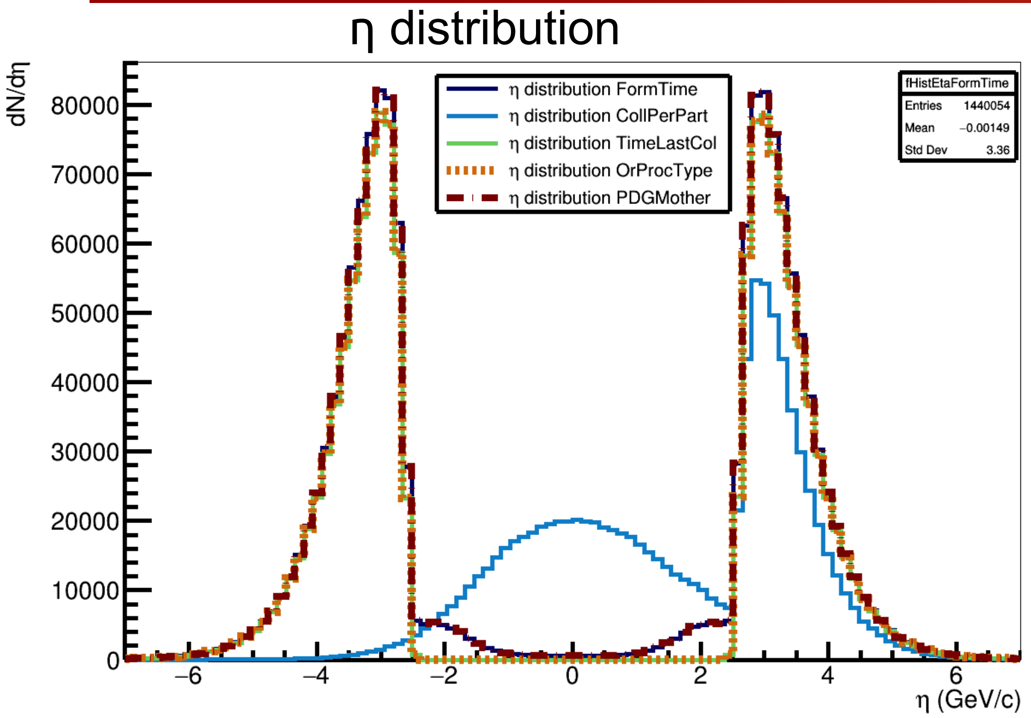
3) Spectators is particles which time of last collisions < 0 **“TimeLastColl”**

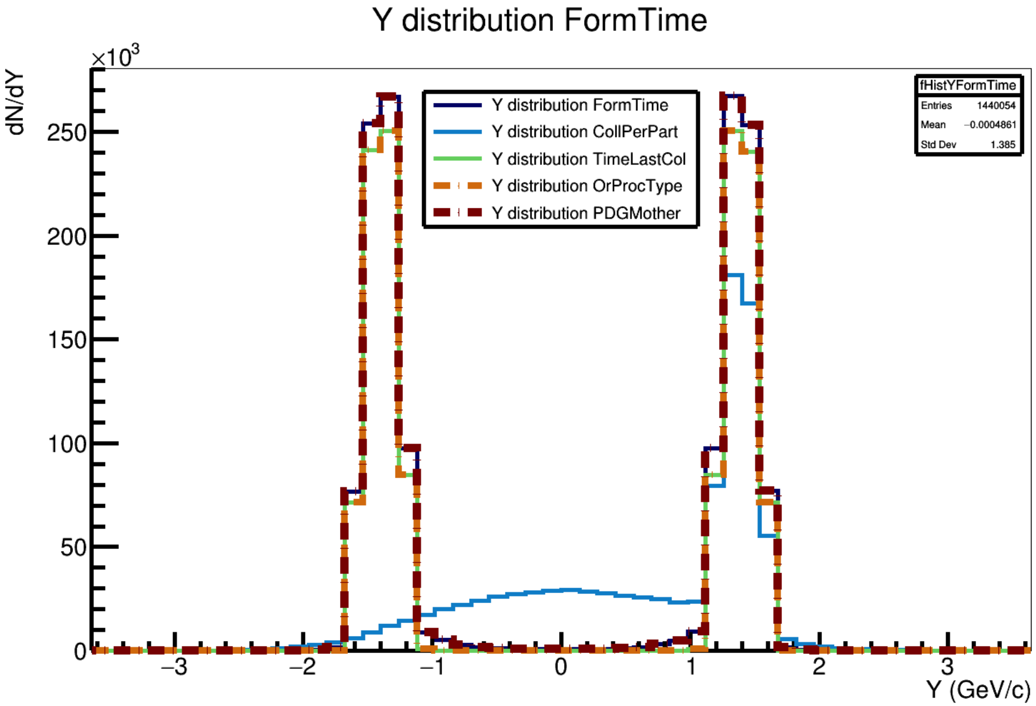
4) Spectators is particles which origin process type = 0 **“OrProcType”**

5) Spectators is particles which pdg_mother1 = 0 and pdg_mother2 = 0 **“PDGMother”**

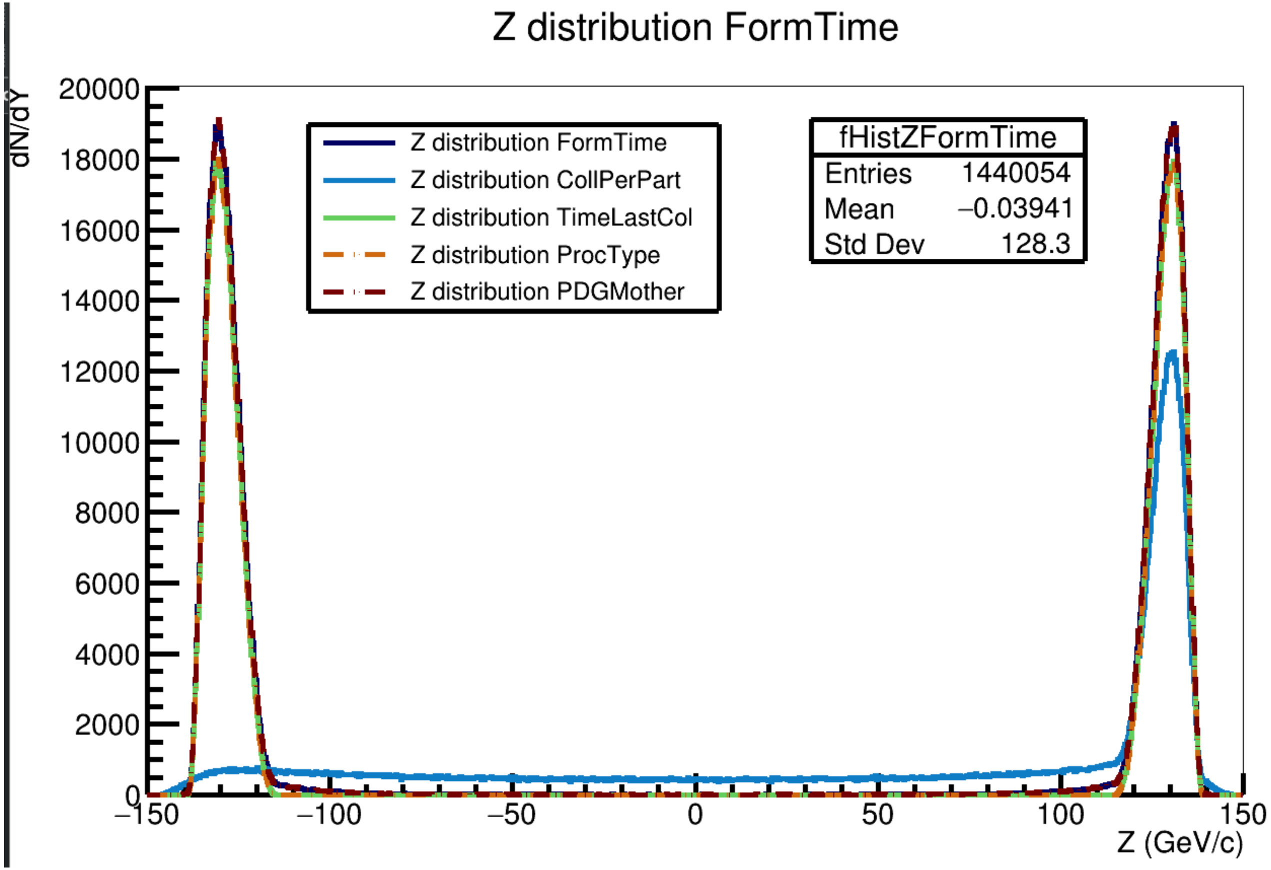
6) One of aforementioned variants + cuts on (pseudo)rapidity

Who is the spectators?

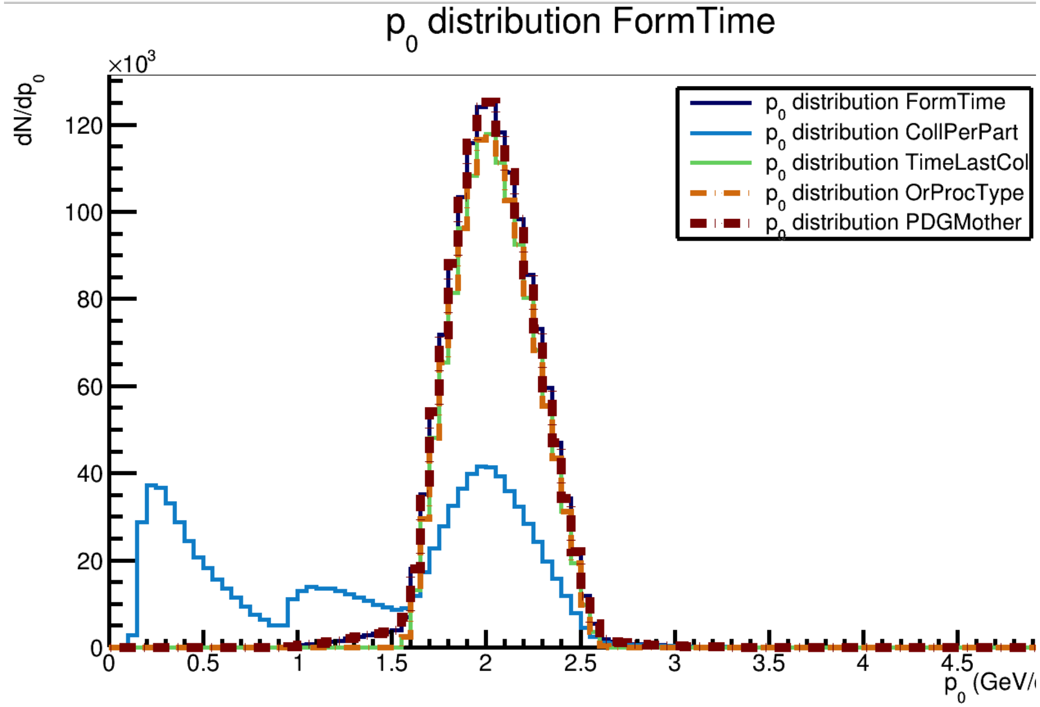


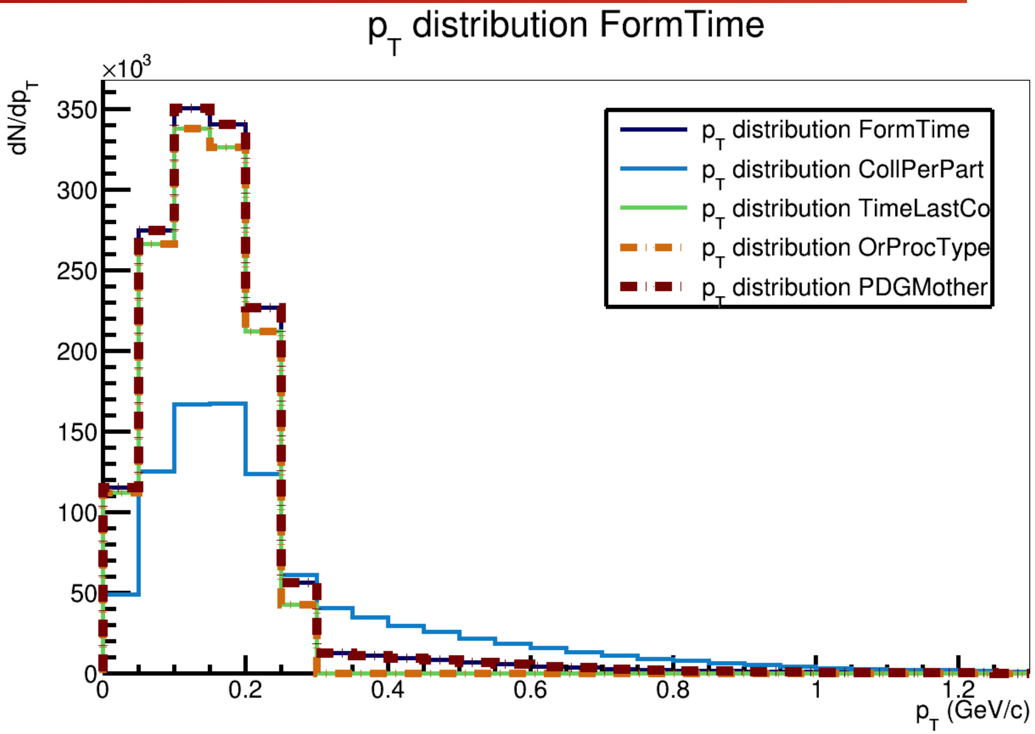


Who is the spectators?

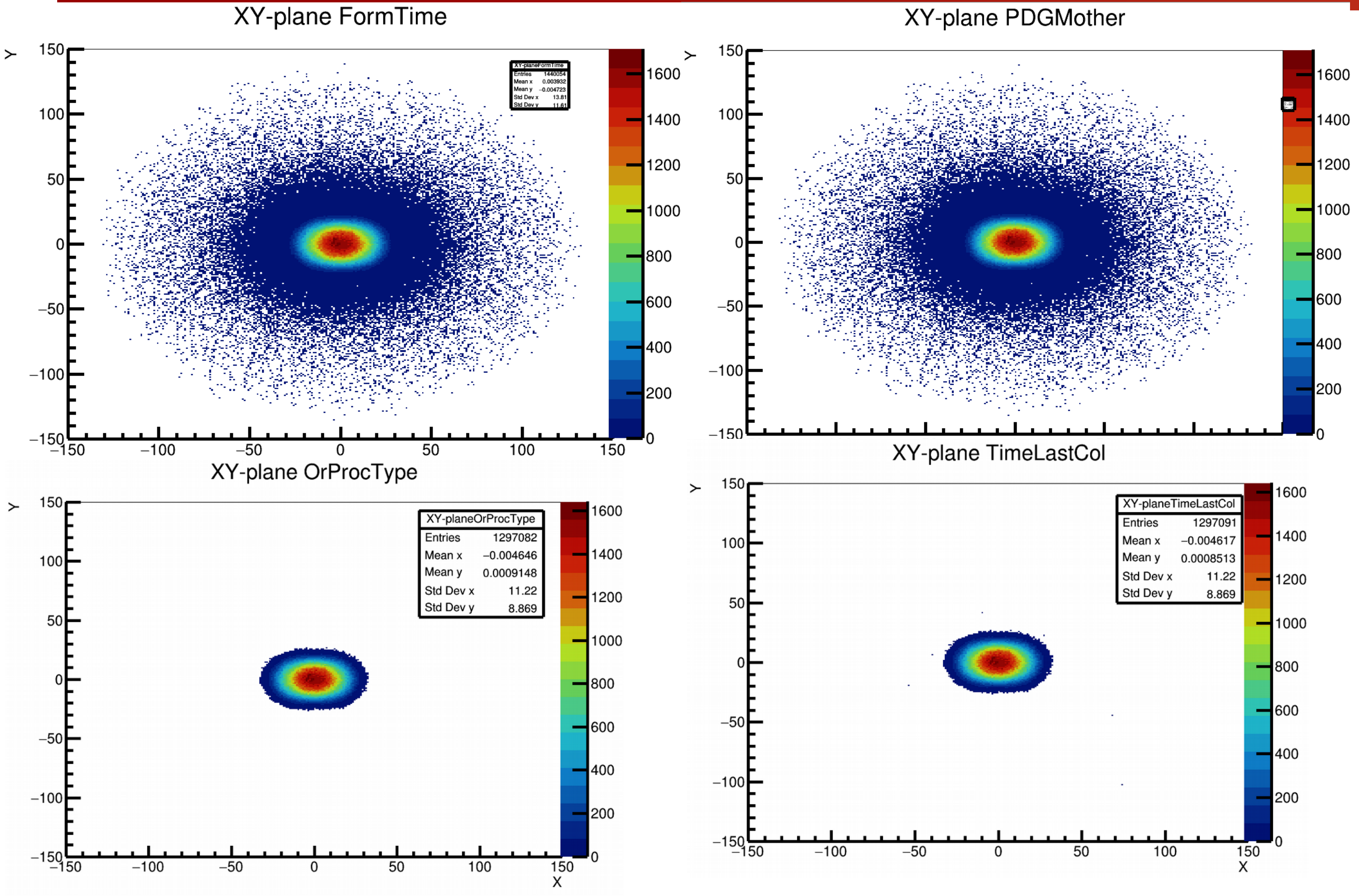


Who is the spectators?





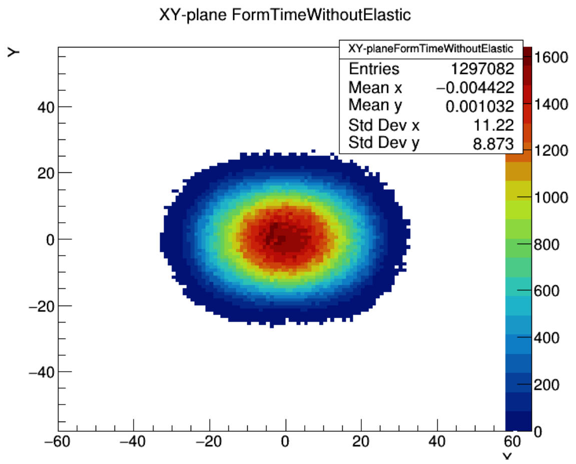
Who is the spectators?

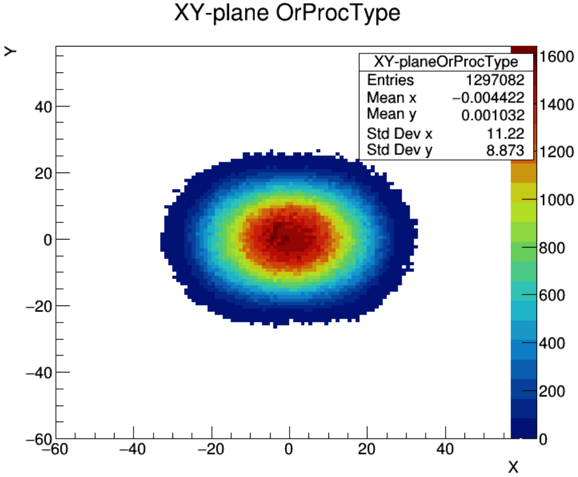


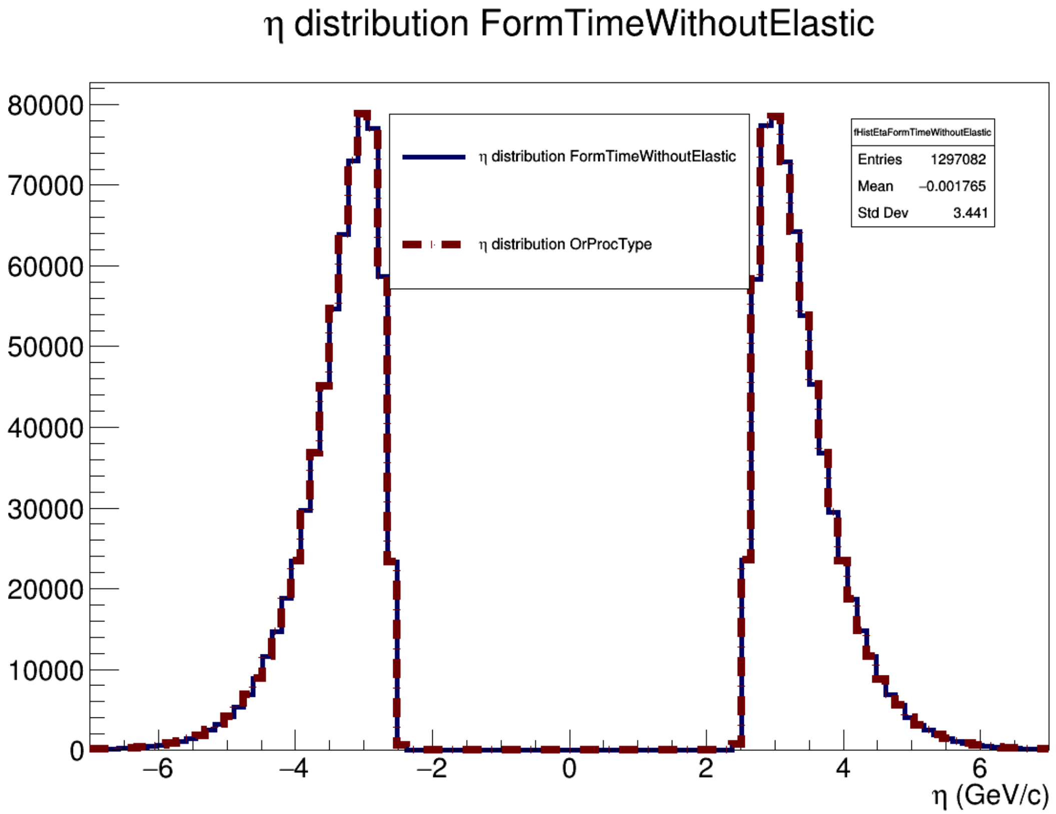
First 2 classes differs from the second ones by a lot of scattered particles

Maybe the only difference is a bunch of elastic scattered p and n, which taken into account or not??

Who is the spectators?







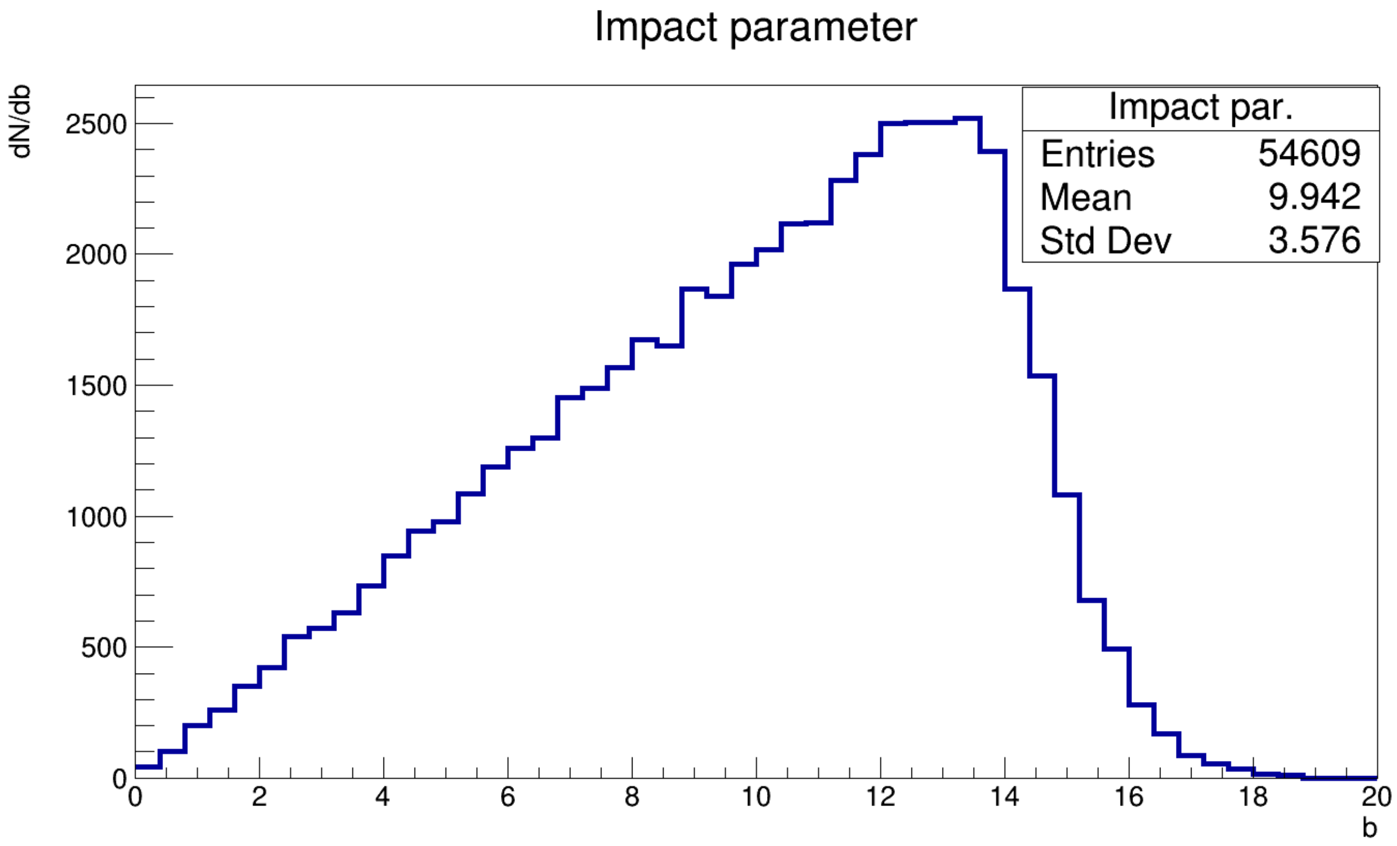
It was the right assumption – after removing elastic scattered particles from "FormTime" class there is no difference between this 2 classes

Who is the spectators? Conclusions

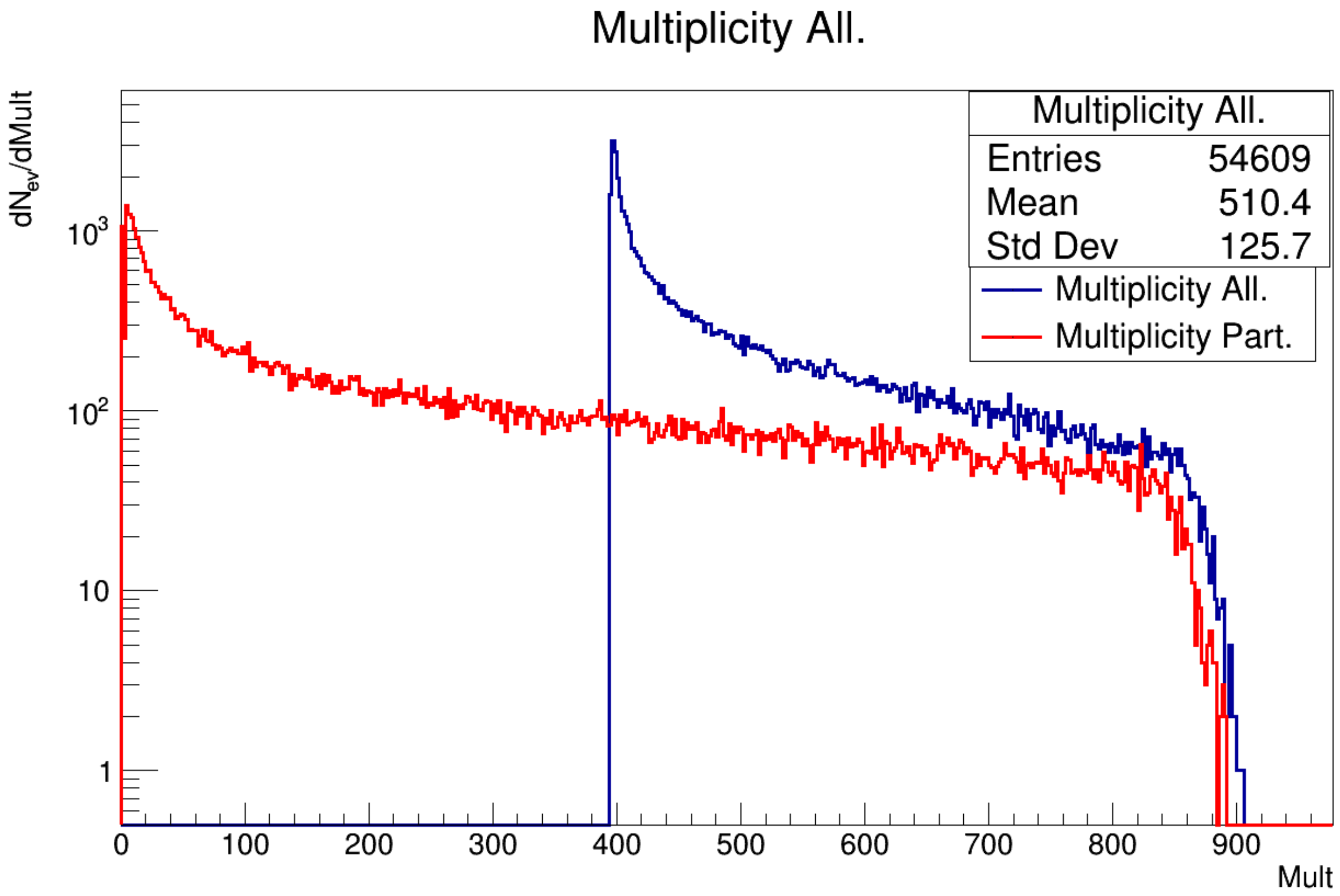
- Particles with **Form.Time = 0** and particles with **PDG Mothers = 0** is the *same particles* in SMASH frameworks
- Particles with **Time of Last Coll. = 0** and particles with **Origin Proc. Type = 0** is the *same particles* in SMASH frameworks
- The only difference between this two class of hypothetical particles-spectators is accounting of particles which has elastic scattering
- There is some strange Z-axis assymetry for particles with **Coll. Per Part = 0**
- Further in the work spectators is the particles with **Formation time < -2** (we assume that colliding nuclei was created in system in about -2.2 fm/c, and t=0 is time of the collision)

Physical observables: Impact-parameter

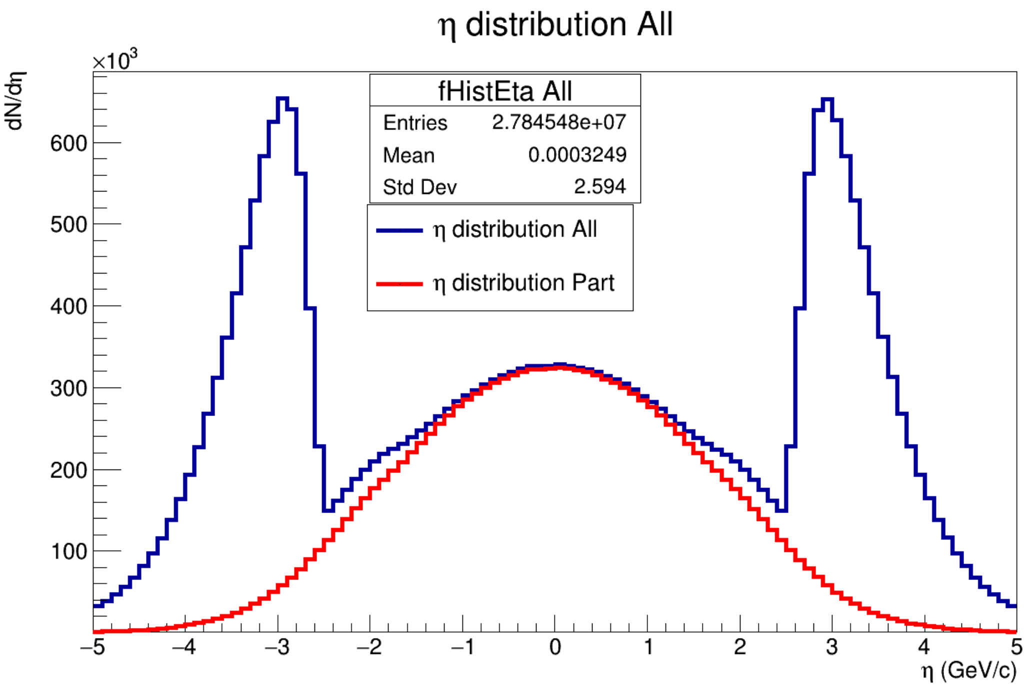
Au+Au, 4 GeV/pair

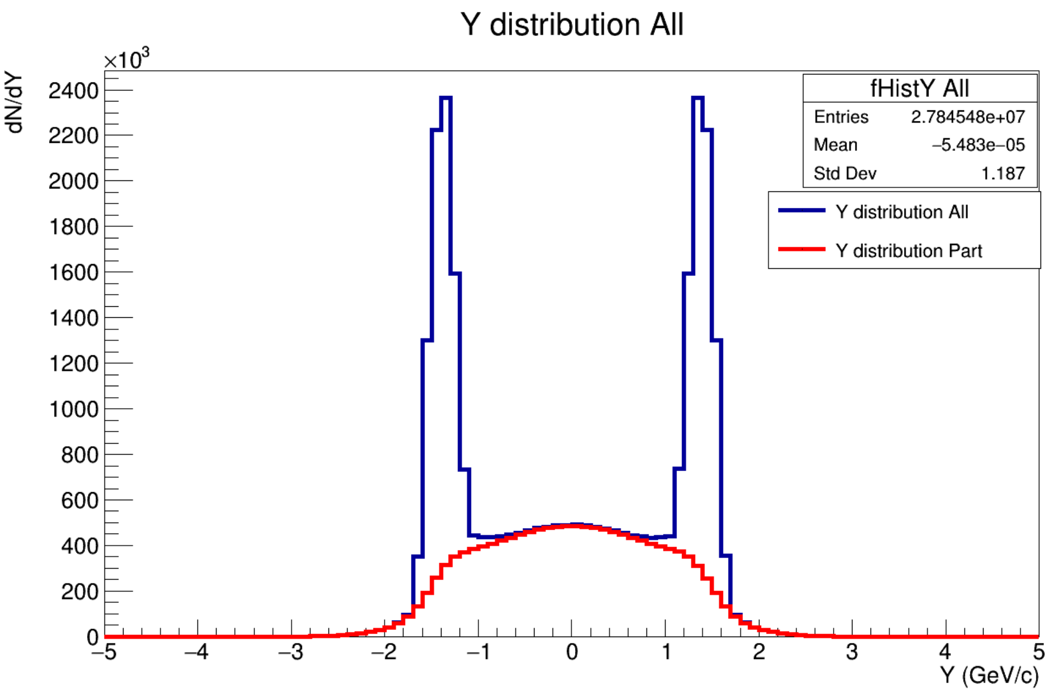


Physical observables: Multiplicity

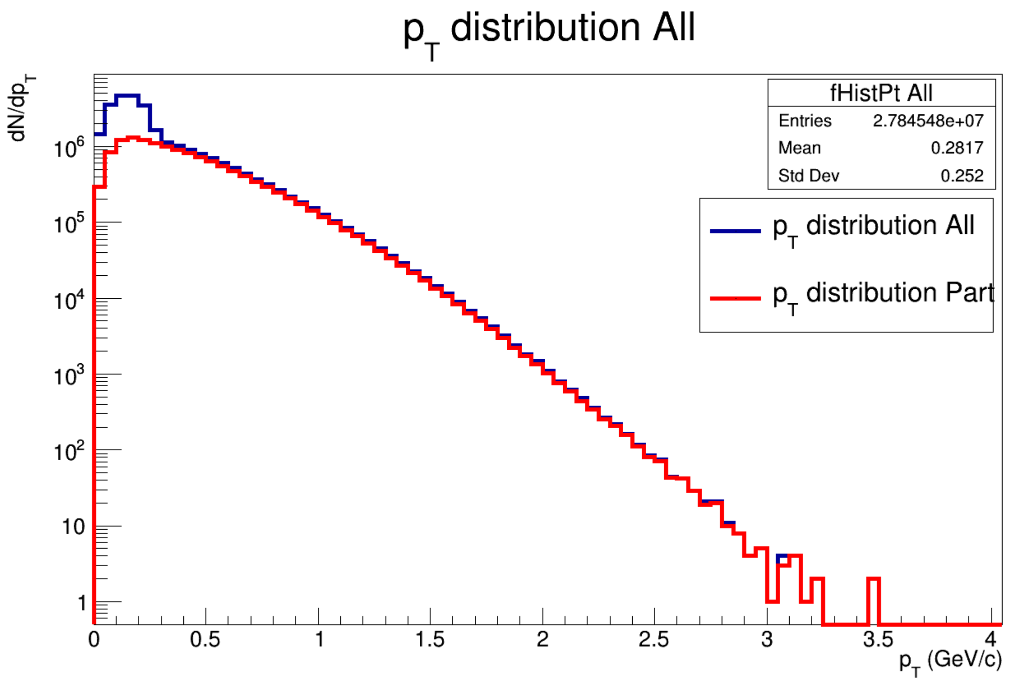


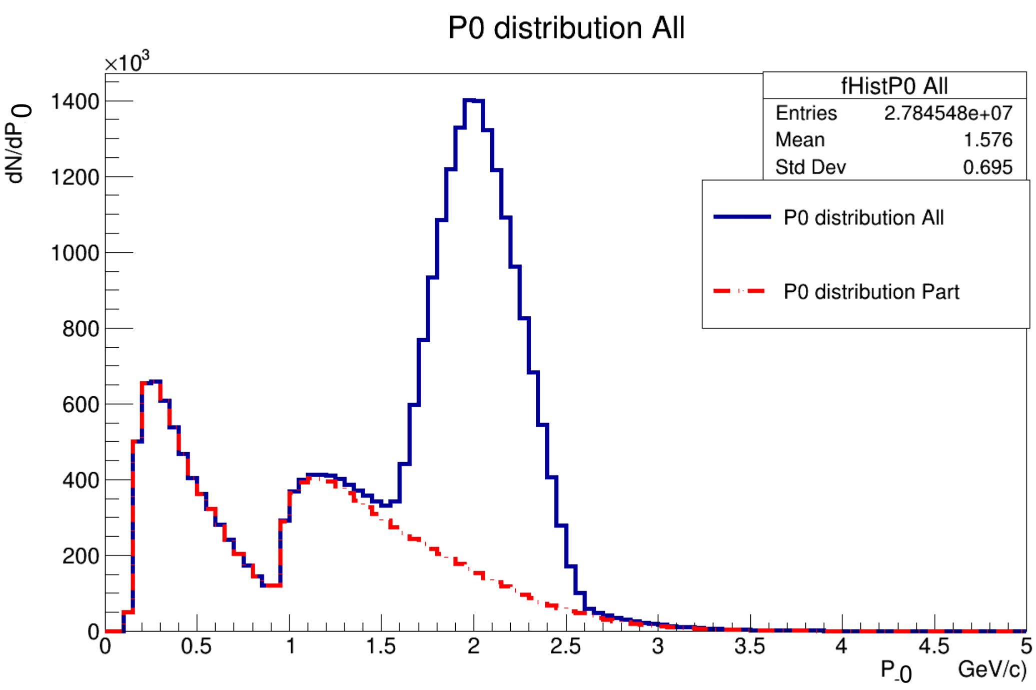
Physical observables: η and y distributions



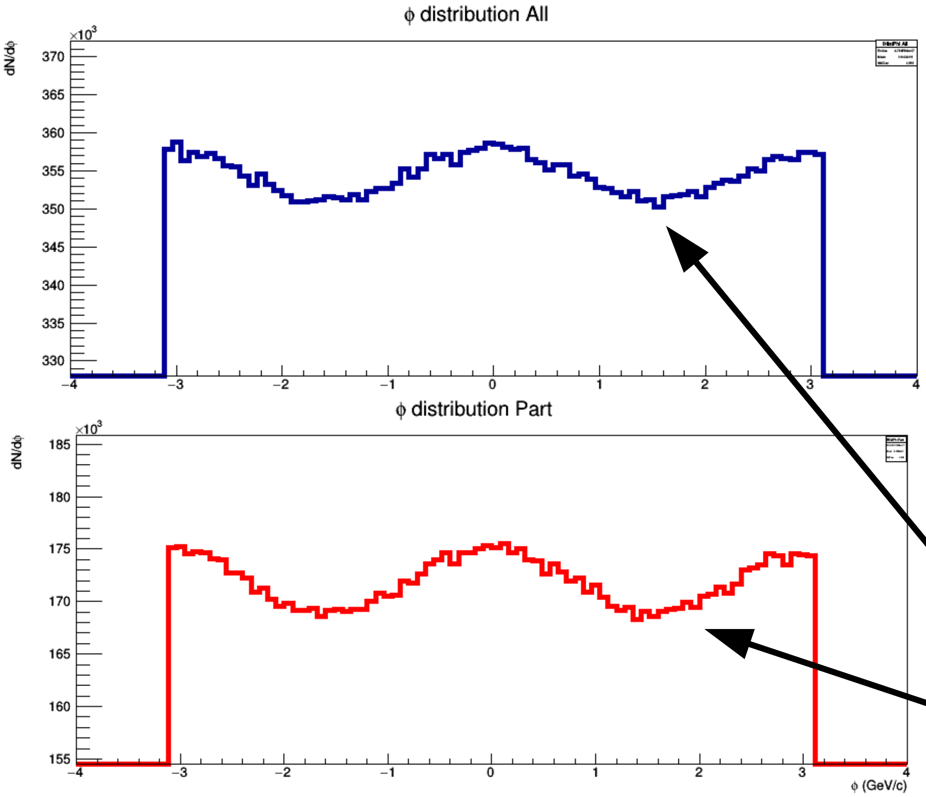


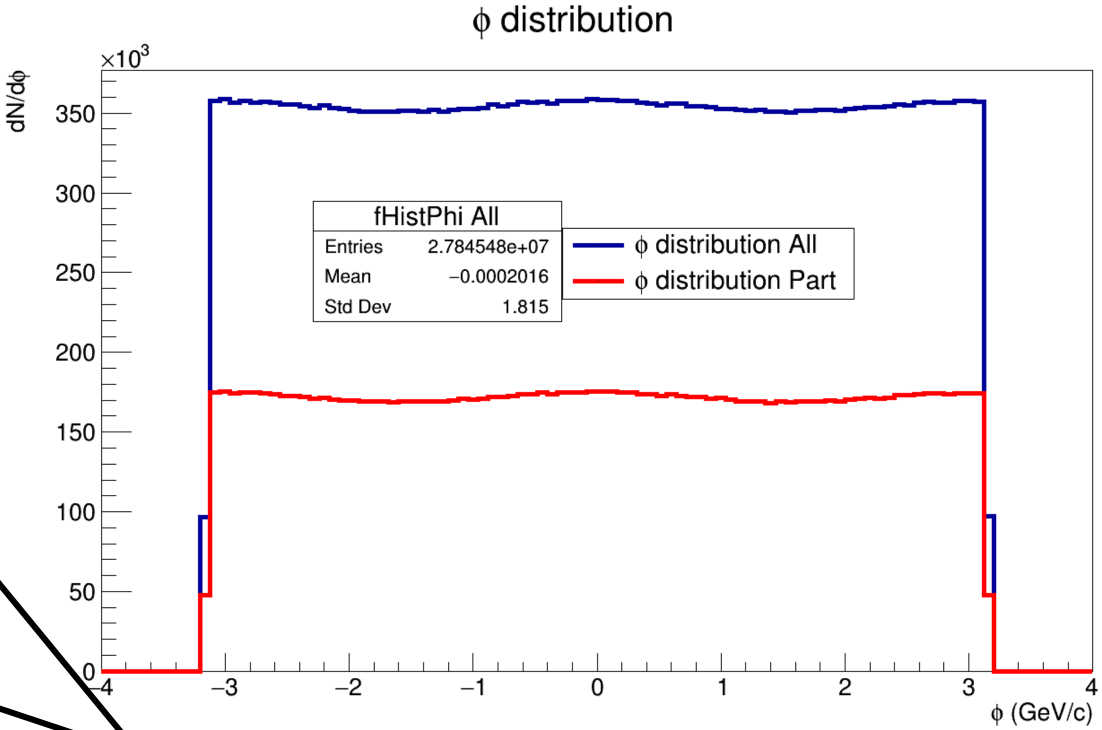
Physical observables: p_T and energy distributions





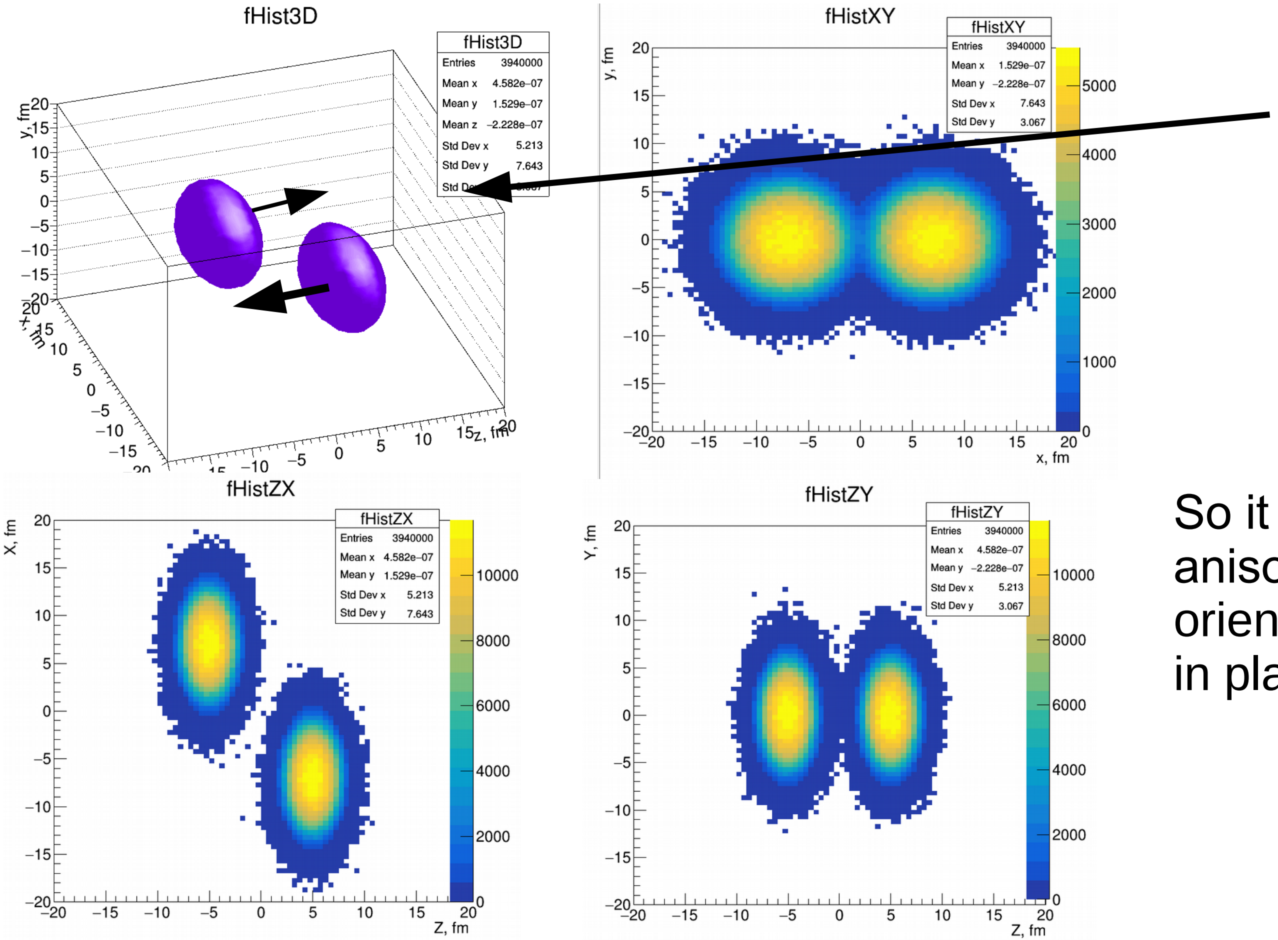
Physical observables: φ distributions





Some strange anisotropy in φ distributions – why?

Static impact parameter orientation

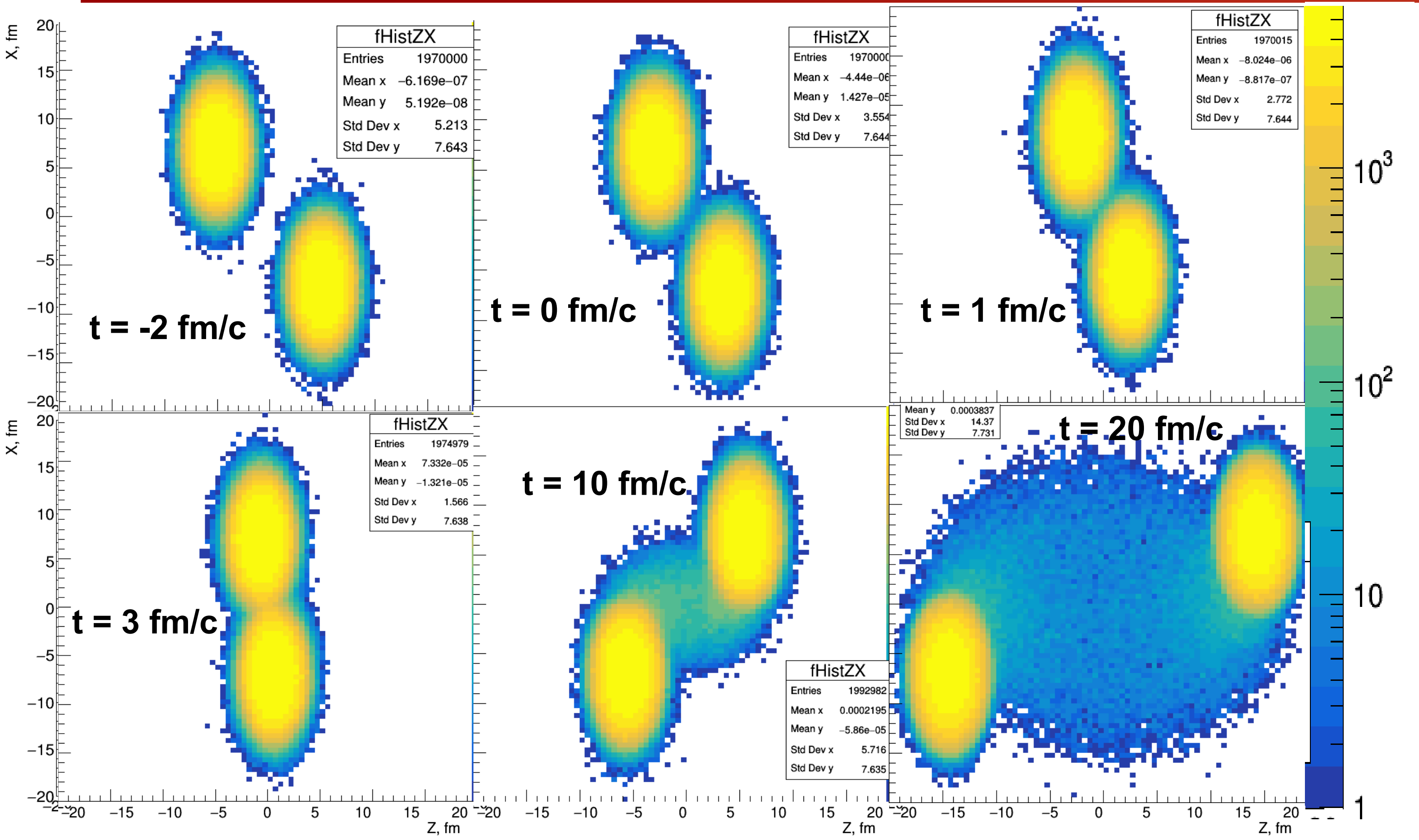


1 similar picture for 10000 events

Orientation of impact-parameter vector in space doesn't fluctuate or change

So it looks like the reason of anisotropy of φ distribution is constant orientation of impact-parameter vector in plane ZX

Evolution of collision system

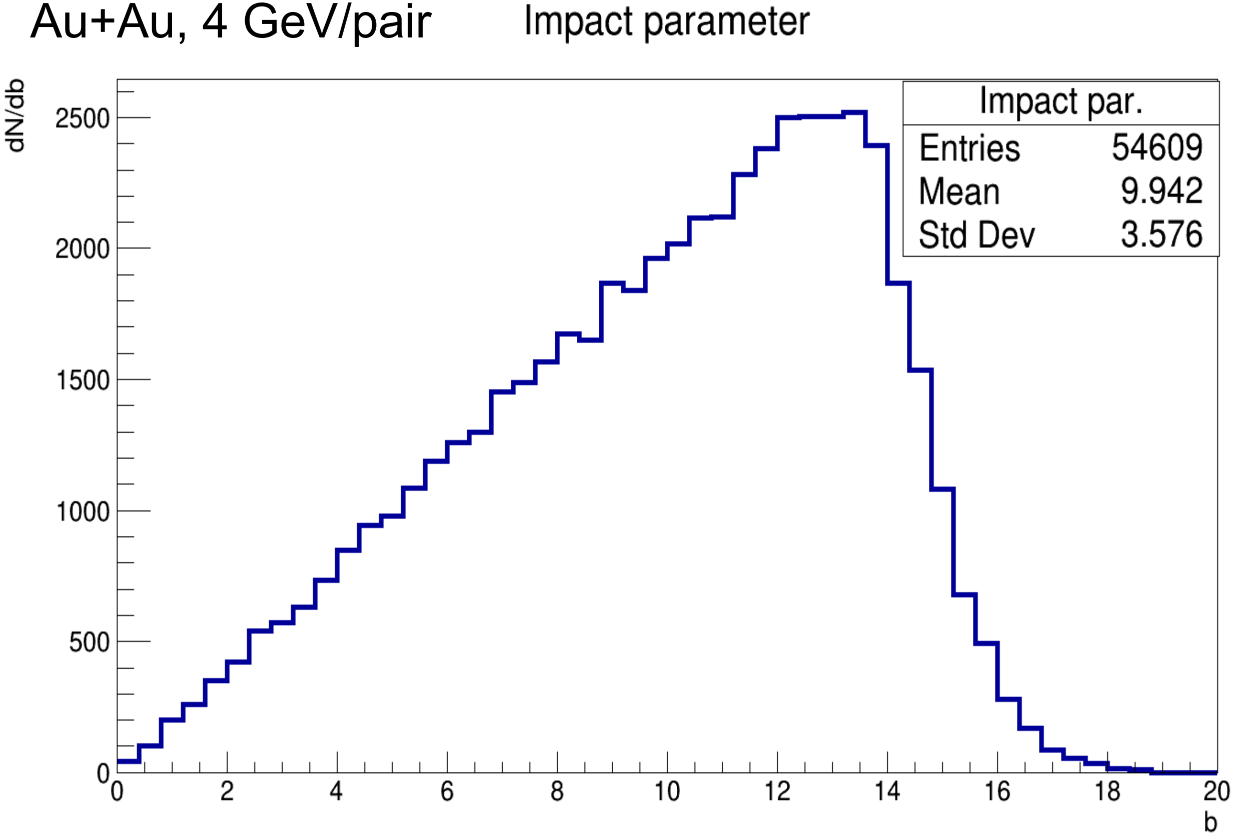


Au+Au, 4GeV/pair
|b|=14 fm (fixed)
5000 events

There is anisotropy of system on φ. In a common case this anysotropy is “blurred” by events with different impact-parameter orientation

Few words about impact-parameter

Au+Au, 4 GeV/pair



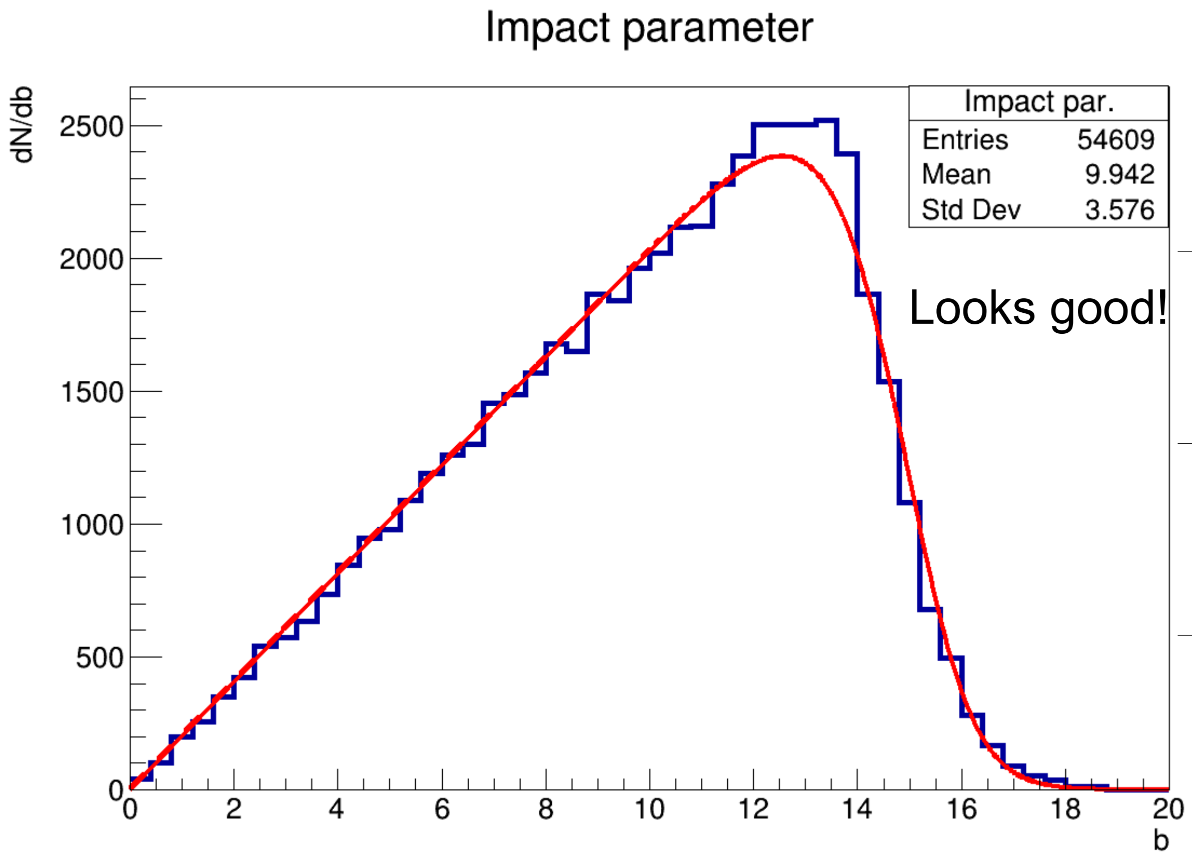
$$\sim \rho^2_{WS}(b) \qquad \sim b$$

$$P(b|inter) = \frac{P(inter|b)\cdot P(b)}{P(inter)}$$

$$\sim const$$

$$\rho(b|inter) \sim b\,\rho^2_{WS}(b)$$

Few words about impact-parameter



$$\frac{dN}{db} = \frac{A \cdot b}{\left(1 + e^{\frac{b-\alpha}{\beta}}\right)^2}$$ - approx. func.

$A = 203.6\,;\, \alpha = 15.43\,;\, \beta = 0.86$

$R = \alpha/2 = 7.7\ fm\,;\, a = \beta/2 = 0.43\ fm$

Radius of nuclei *Diffuseness*

It is in agree with simple estimations:

$$R = 1.3\, A^{1/3} = 7.56\ fm\,;\, a \approx 0.5\ fm$$

Honestly, Woods-Saxon distr. in SMASH a little more complicated – it considers an assymetry of nuclei

Conclusion

- New SMASH 1.7 allow us to extract information about charged particles and spectators and a lot of other information
- We have to choose what we exactly call “spectators”
- Anisotropy of φ-distribution is found. The reason is static (not event-by-event fluctuating) orientation of impact parameter in ZX – plane
- Does the formula $dN/db \sim b\,\rho_{PDF}^{2}(b)$ truthful?

Thank you for attention!