Simulation of heavy ion collisions in BBC detector (phase 0)

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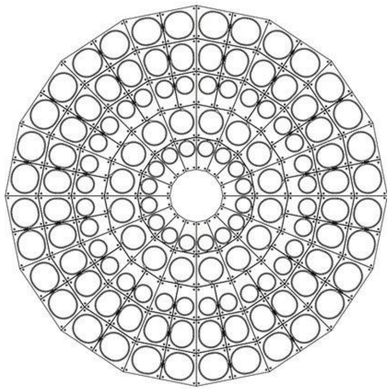
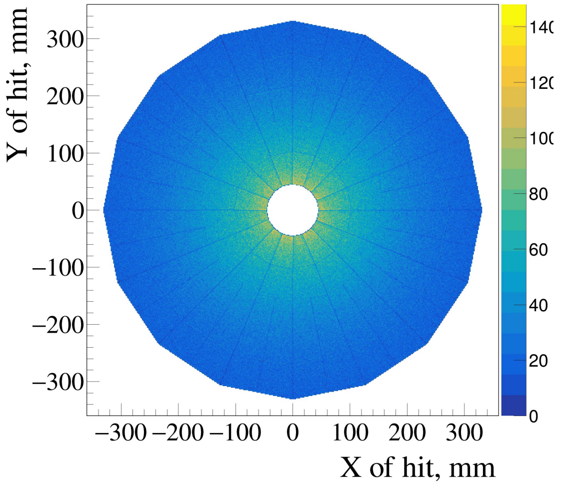
Motivation

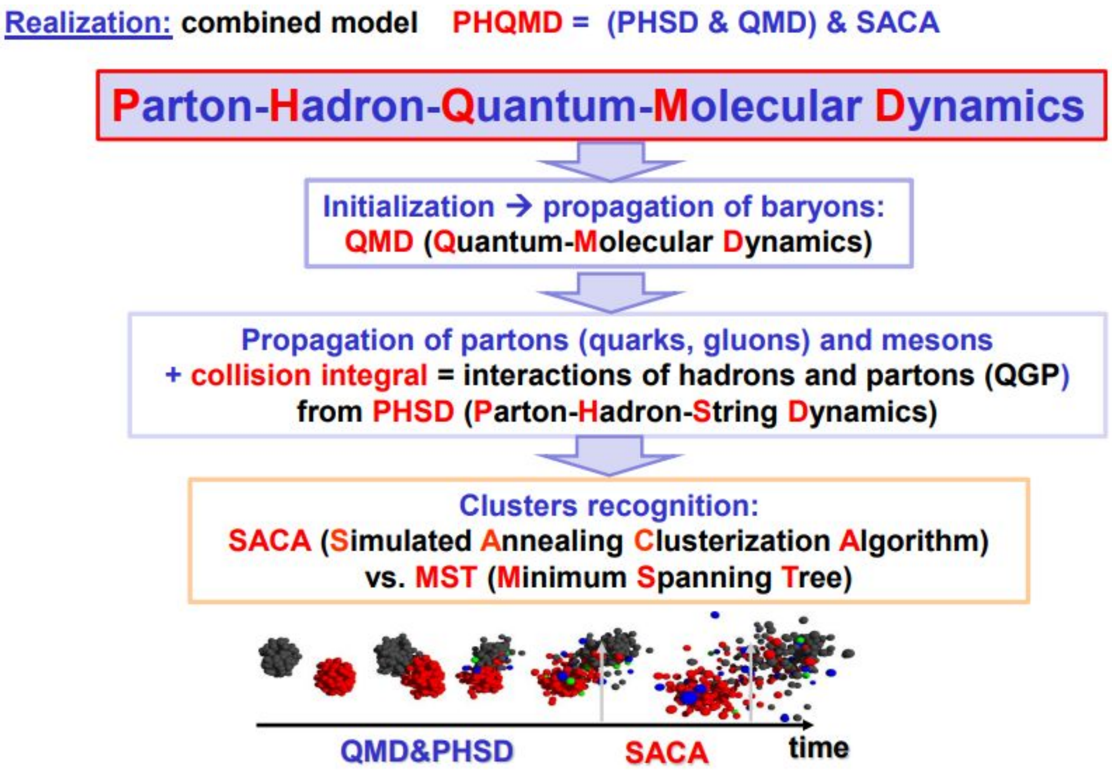
1. For **Phase 0** of the BBC detector, which employs a **^{124}Xe** beam scattering on a stationary **W** target, the **PHQMD** generator was chosen for its ability to simulate **clusterization** processes critical for modeling nuclear fragmentation and secondary particle production in heavy-ion **fixed-target** collisions.
2. **Geant4** was preferred over **SPDRoot** because it fits better for **BBC Phase 0** conditions with **simplified setup**.





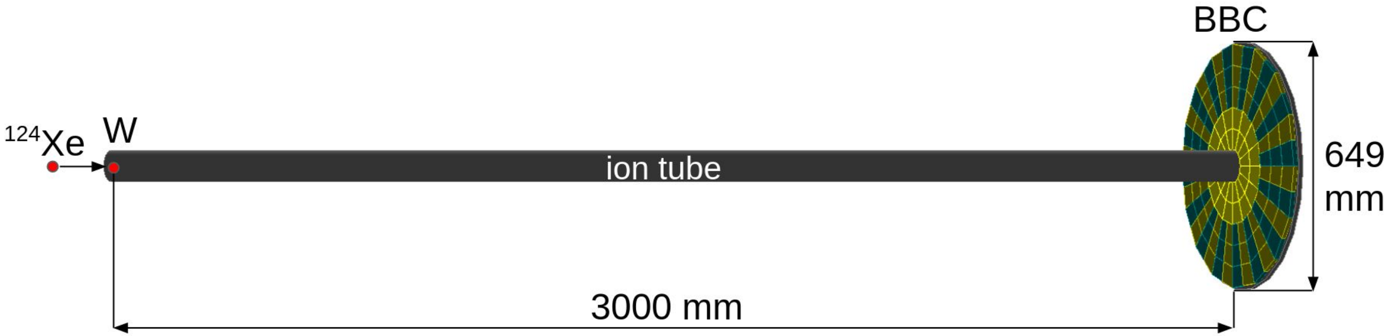
PHQMD generator

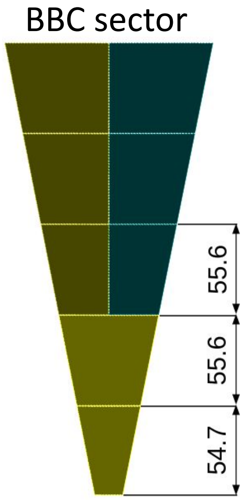
Transport approach that designed to provide a microscopic description of nuclear cluster and hypernucleus formation as well as of general particle production in heavy-ion reactions at relativistic energies. The clusters are identified by the MST or the SACA algorithm which finds the most bound configuration of nucleons and clusters. Collisions among hadrons as well as Quark-Gluon-Plasma formation and parton dynamics in PHQMD are treated in the same way as in the established PHSD transport approach.



Condition of the simulation in Geant4

^{124}**Xe** beam with energy **3 GeV/n** interacts with the fixed **W** target.
The detector is a wheel with an inner radius of **45 mm** and an outer radius of **324.5 mm**, which is divided into **16 sectors** and **5 rows**.
128 scintillators total, the **gap** between scintillators is **0.6 mm**, **thickness** is **10 mm**.
Distance from target to detector is **3m**.





environment - **vacuum**

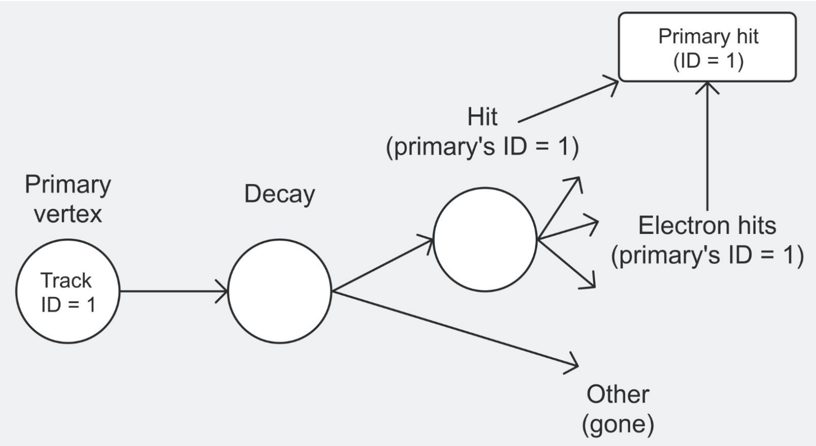
detector material - **polystyrene**

neglect particle scattering on the **ion tube**

scintillation - **off**

Hit-to-Primary Association Algorithm

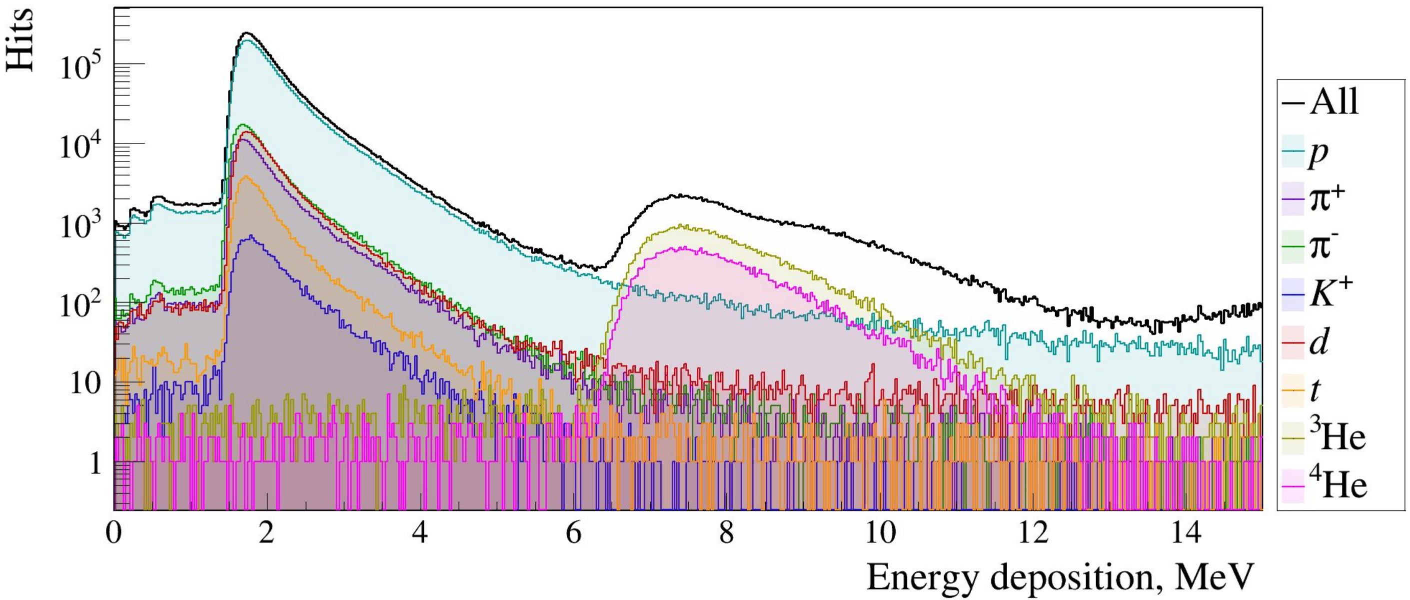
- **Algorithm purpose is**
  to trace the origin of hits in the detector back to their corresponding primary particles from the generator, even if the hit was produced indirectly (e.g., by secondary decay products or scattering). This may provide critical insights for validating generator models and physics processes by isolating the direct and indirect impacts of primary particles on detector signals.



- **Implementation in Geant4:**
  - Uses inheritance from **G4VUserTrackInformation** to save the parent track information into the current track.
  - Saves important information about **primary** track (parent track ID = 0), **parent** track, and **current** track in each hit.
  - Merges all hits in the entire detector based on primary particle ID.
  - Hit of particular primary: time and position from most young hit, E_{dep} is sum of all hits.

Energy deposition of primary particles

Distribution differentiated by particle type

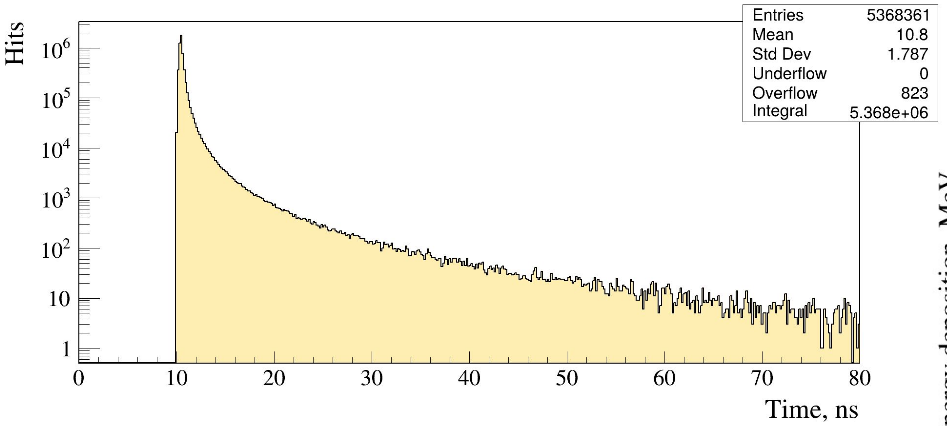


Particle	%
p	76.38
π^+	4.13
π^-	6.34
d	5.35
t	1.31
^{3}He	1.03
^{4}He	0.55
K^+	0.30
other	4.61

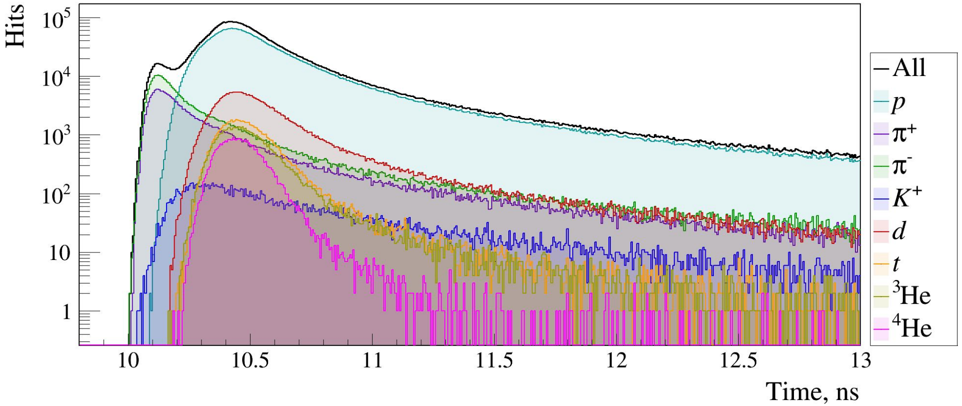
Mesons ~11%, Ions ~13%.

Time-of-flight

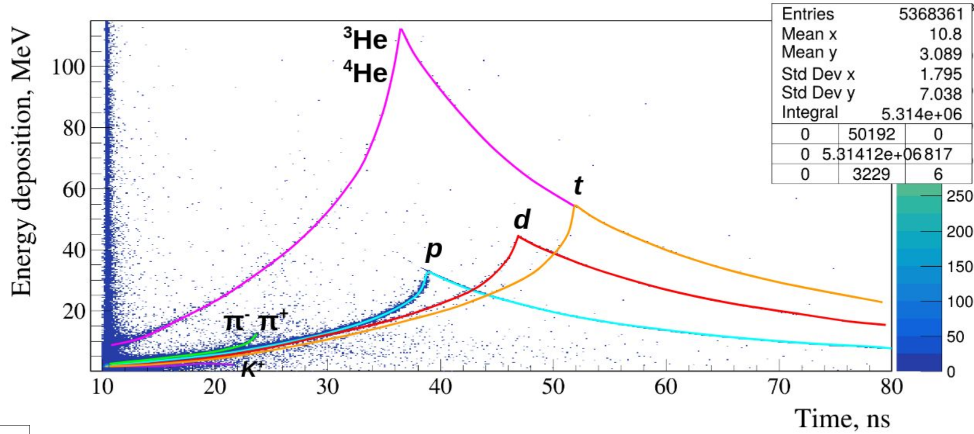
Time of arrival for all particles in entire detector



Time of arrival by particle type (close scale)



Dependency of energy deposition by time of arrival

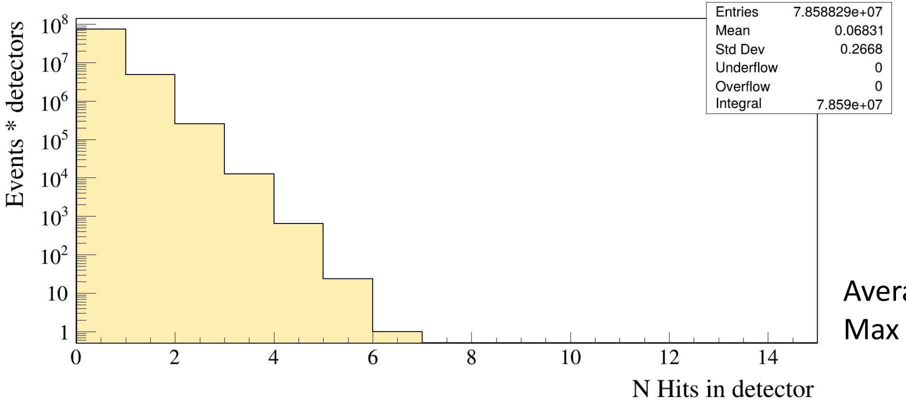


There is no guarantees that we could identificate particles using E_{dep}-Time distribution due to real time and energy uncertainties.

The difference of time-of-flight (ToF) for most fast particles of different types is too small for our detectors.
Required a dedicated ToF system.

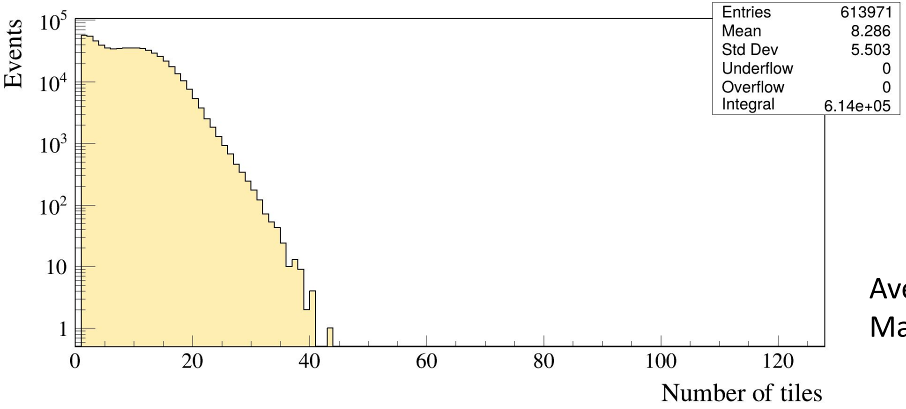
Multiplicity of primaries in detector

The number of particles that hit the tile in one event



Average particles in one tile - 0.07
Max particles in one tile - 7

Number of detectors triggered in one event

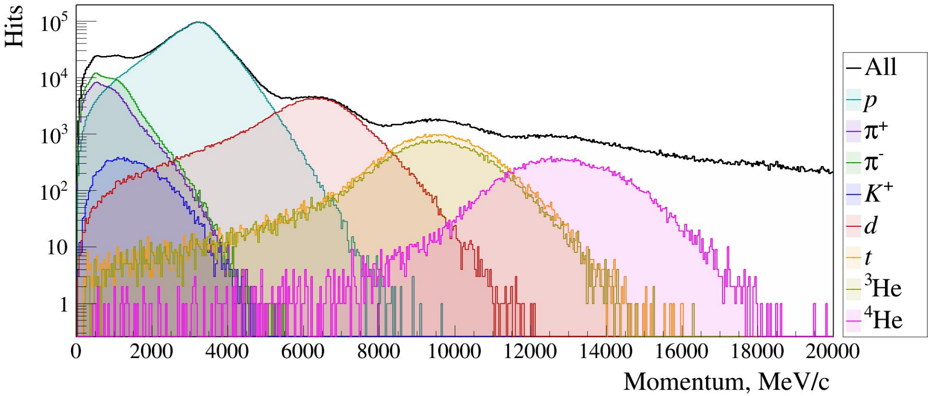


Average tiles hitted in one event - 8
Max tiles hitted - 43

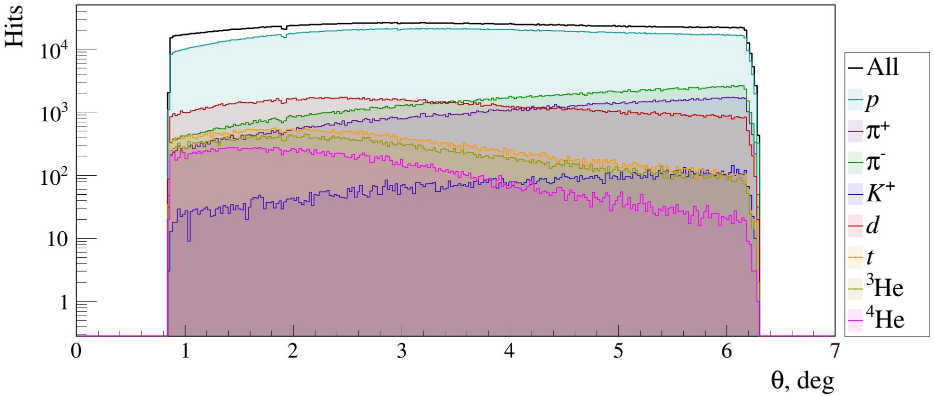
Particle	Average multiplicity
p	6.68
π^+	0.36
π^-	0.55
d	0.47
t	0.11
^{3}He	0.09
^{4}He	0.05
K^+	0.03

Momentum and angular distributions

Momentum of primaries differentiated by particle type



Angle of hit differentiated by particle type



Clearly visible differentiation of primary particles by full momentum.

The loads change slightly as the scattering angle increases

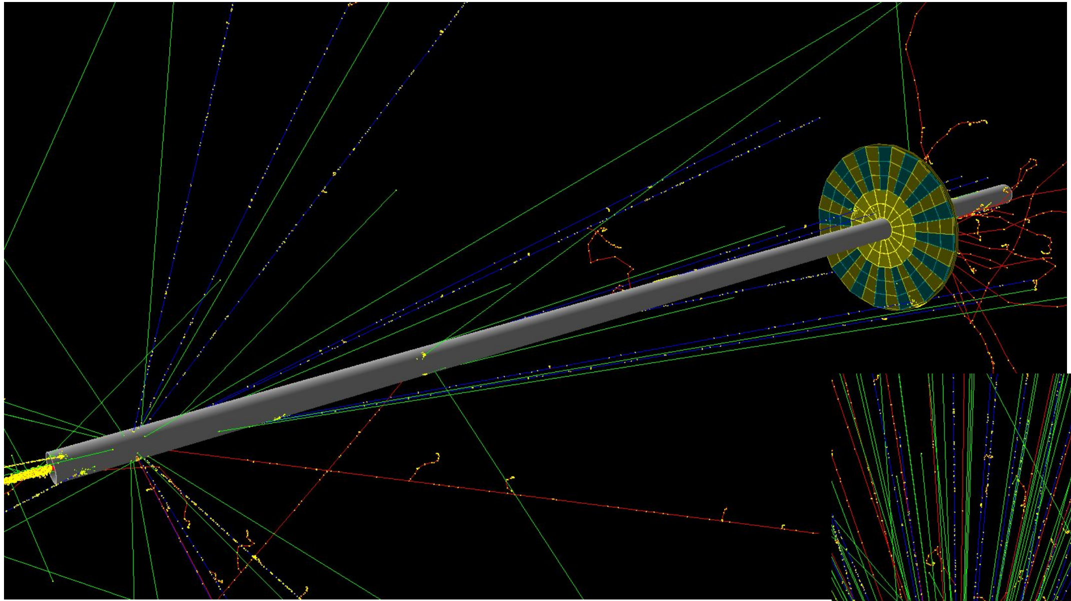
Conclusions

- Simulation of interactions between ^{124}**Xe** beam and fixed **W** target at **3 GeV/n** using the **PHQMD** generator was performed.
- **Multiplicity in tile**, **loading by angle** and **number of hitted tiles** were **estimated**.
- A quite **large number** of nuclear **fragments** was **observed**.

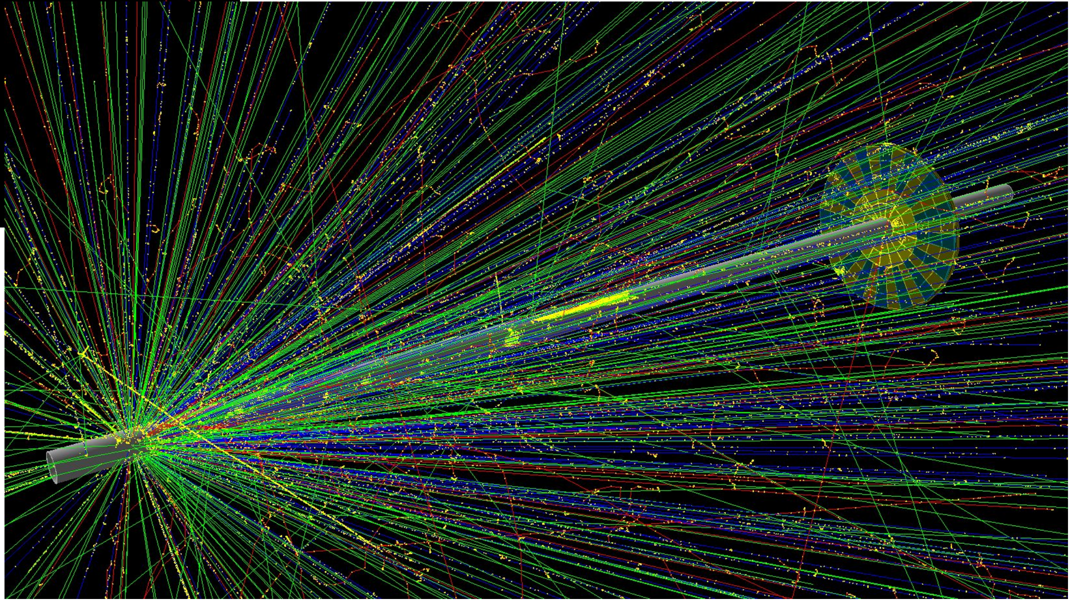
Future plans:

- **Improve the algorithms for processing of simulated data**
- **Integrate the beam pipe and detector support** into the simulation framework to **evaluate the impact of secondary particles**
- **Incorporate realistic time and energy resolution parameters of the detector** into simulations
- **Investigate spatial and temporal correlations between** detector **tiles** for potential detection of angular multiparticle correlations using our detector
- **Perform** dedicated **studies of Xe+Xe collisions** in **collider mode**
- **Add a second BBC wheel** to the **simulation** and explore correlations between two wheels

Preliminary!

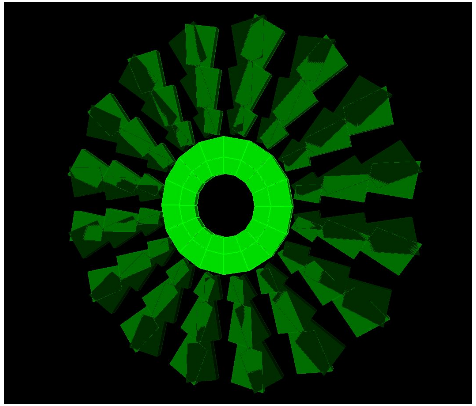


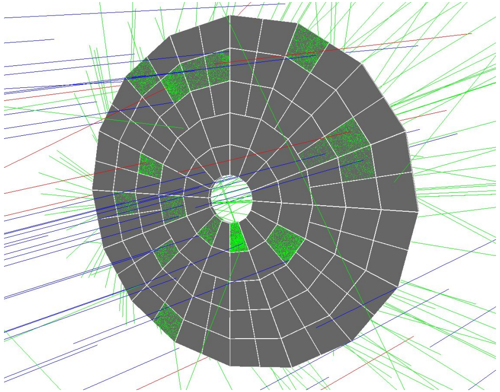
Large
impact factor



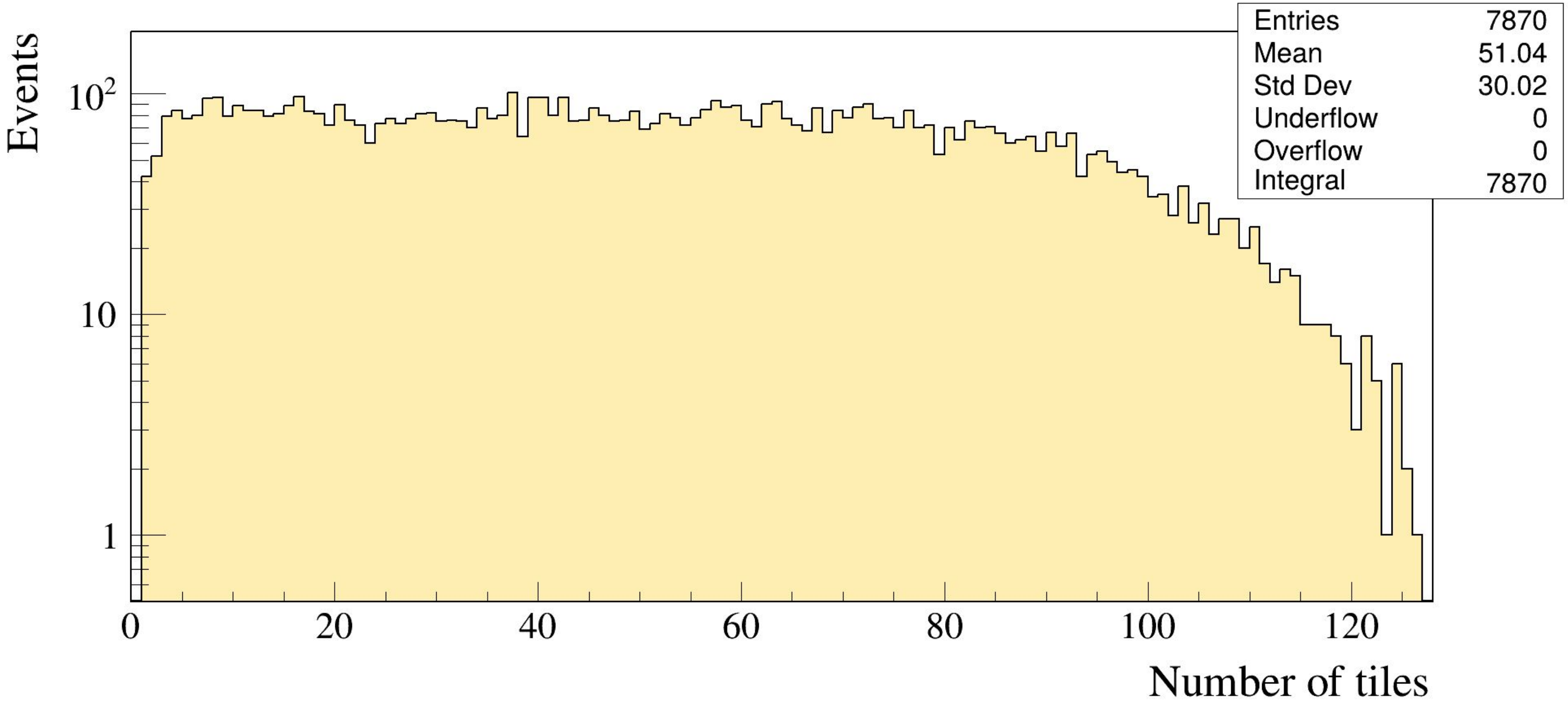
Small
impact factor

Thank you for your attention!

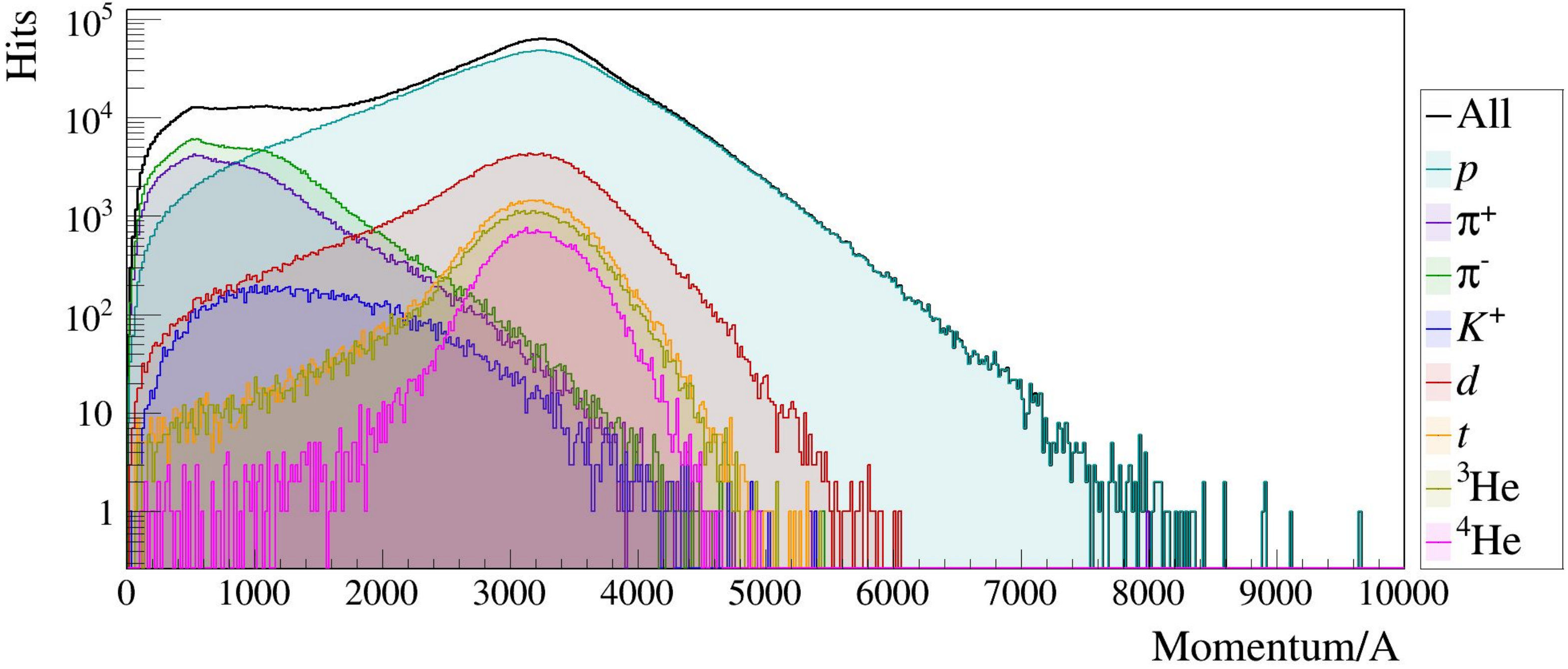




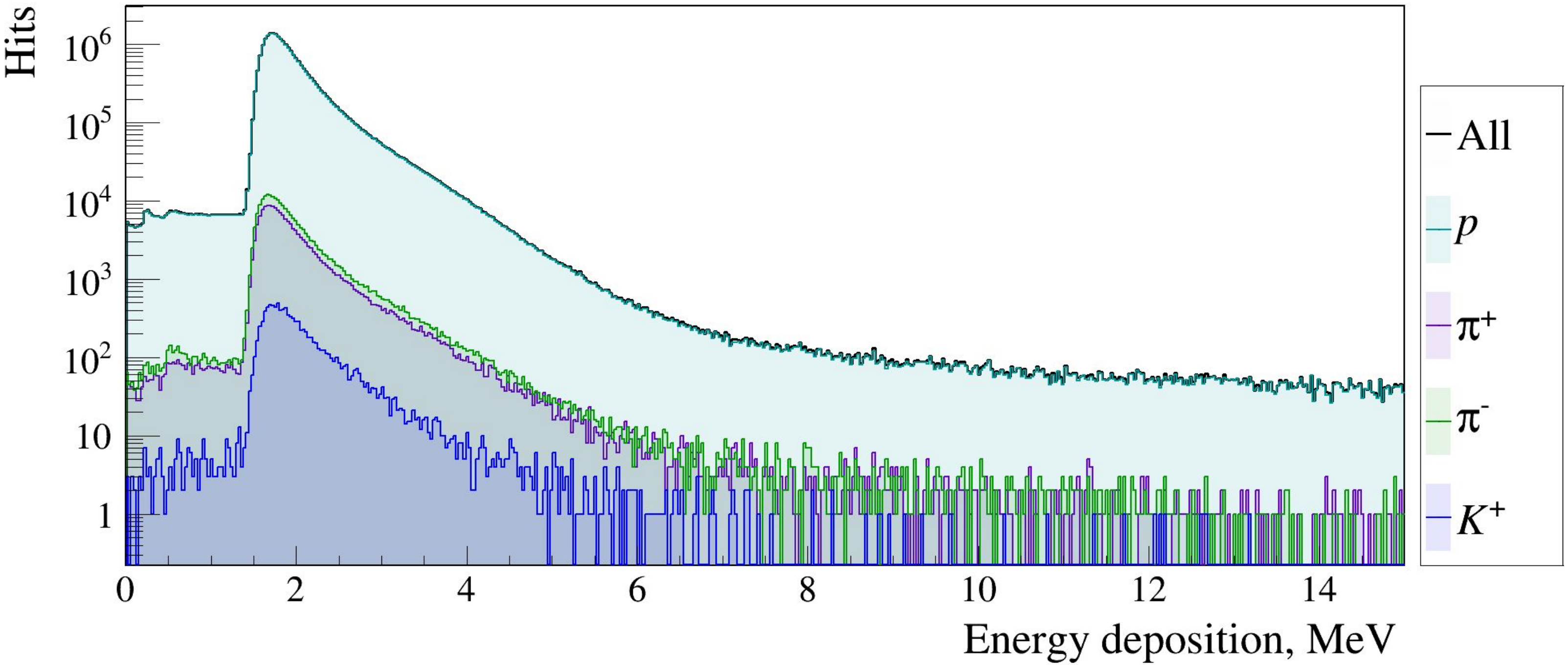
PHQMD: Preliminary realistic loading in the detector



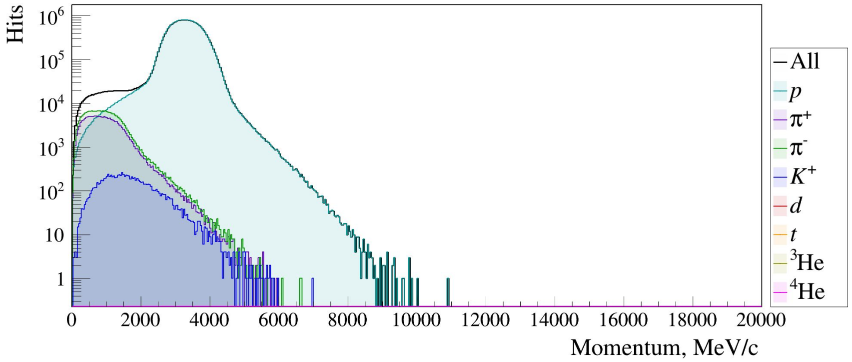
PHQMD: Momentum on atomic mass



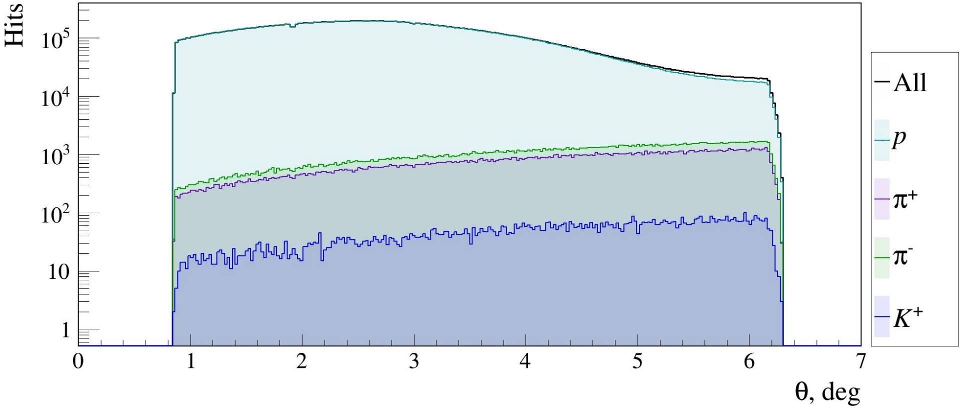
UrQMD: Energy deposition



UrQMD: Momentum and angular distributions



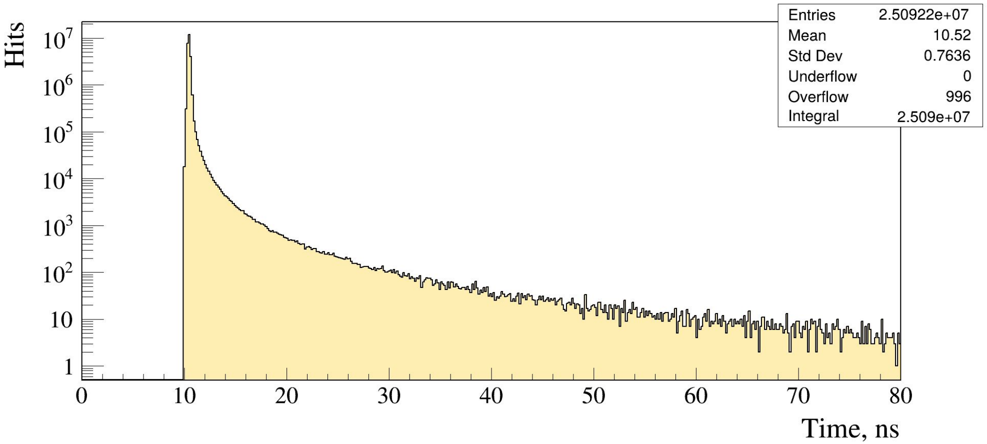
Particle type segregation at hit

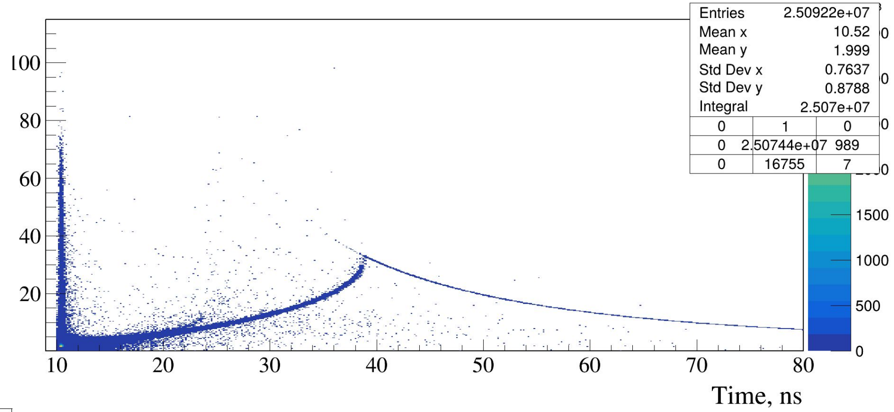


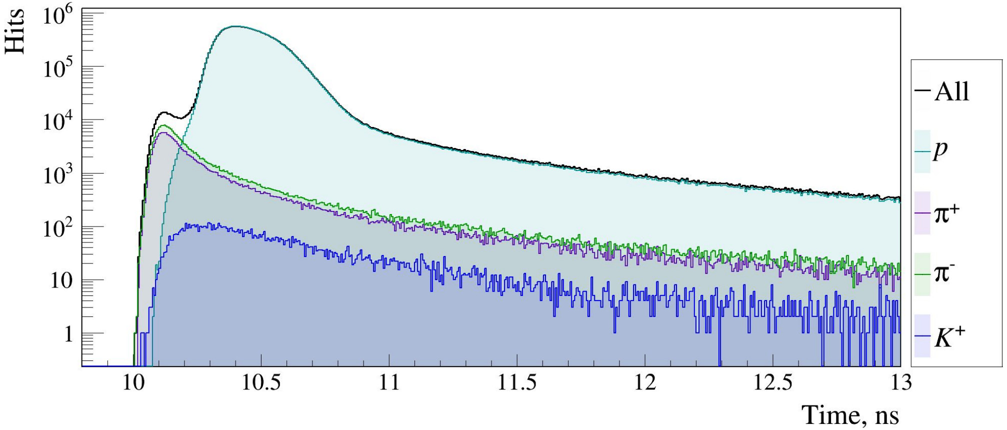
Proton peak with bump.
Slightly different shape for pions.

Proton peak with bump.
Slightly different shape for pions.

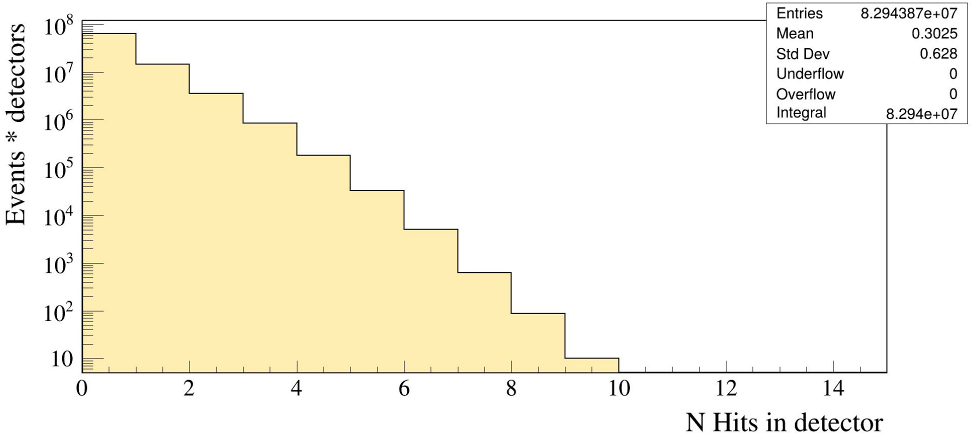
UrQMD: Time of flight

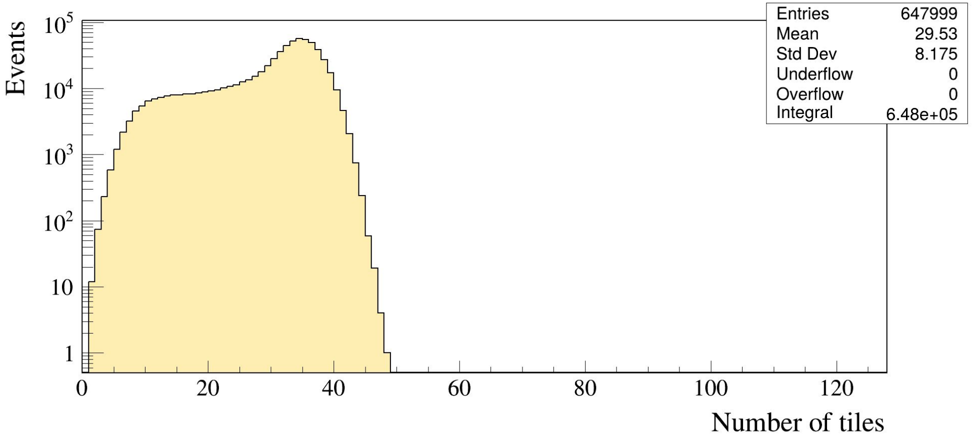






Almost the same as PHQMD



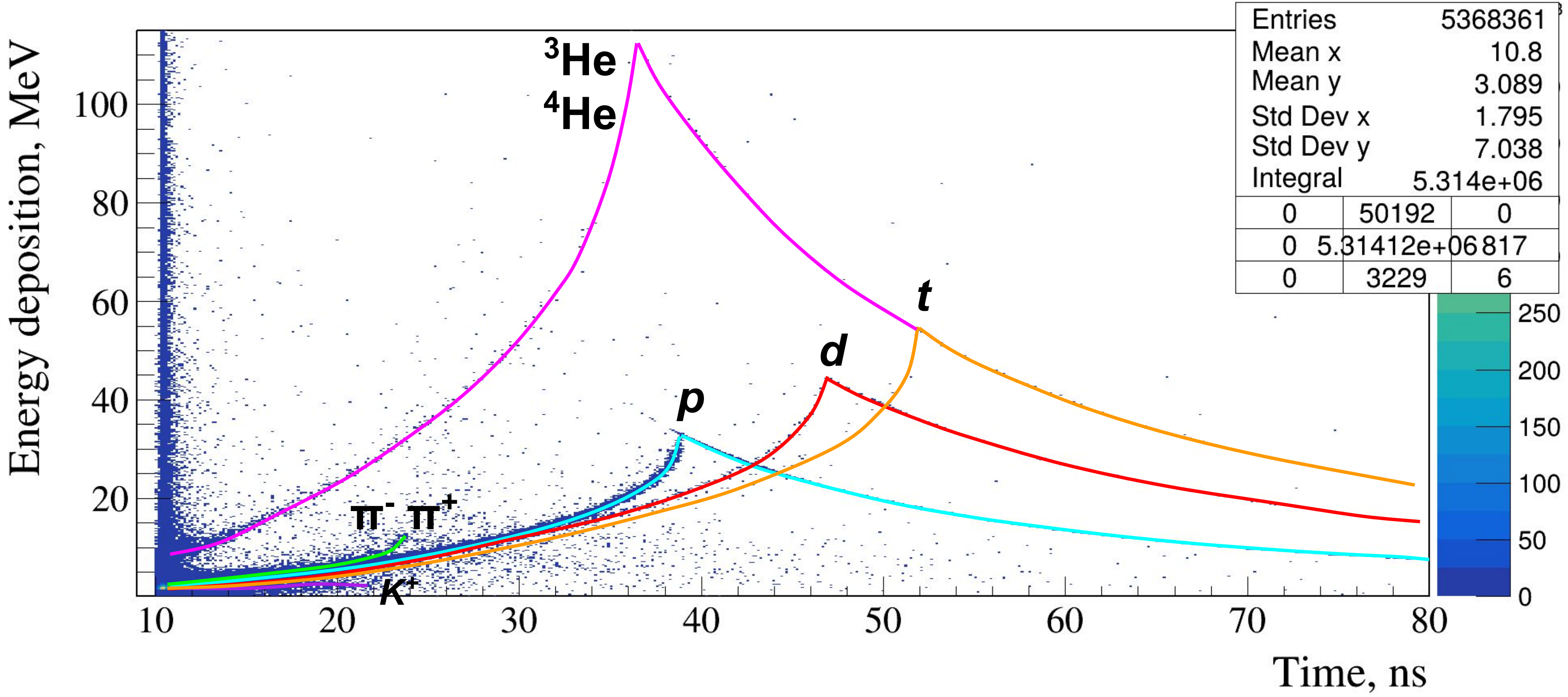


UrQMD: Multiplicity in detector

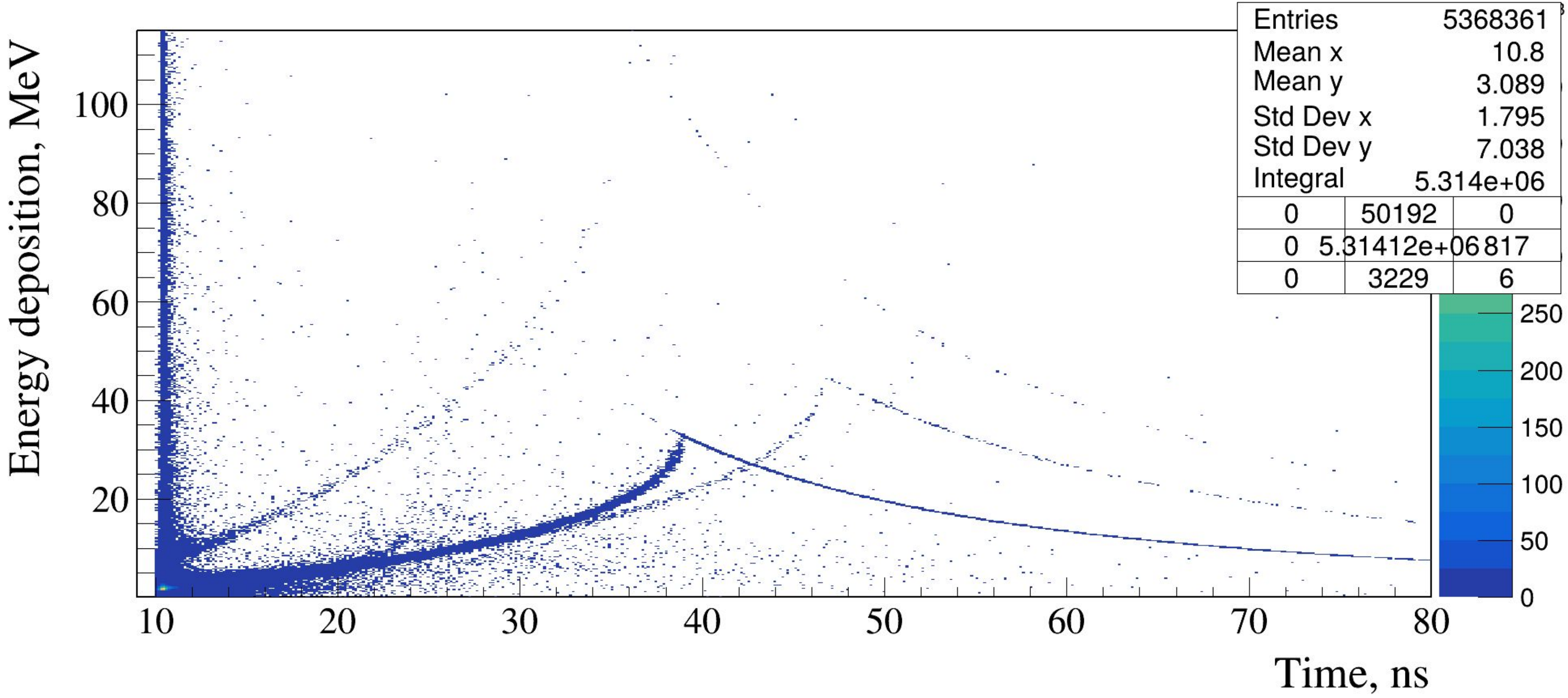
More particles hitted one tile on average.
More tiles hitted in one event on average.

Particle	Average multiplicity
p	38.07
π^+	0.27
π^-	0.36
K^+	0.02

Dependence EDep on Time by type of particles

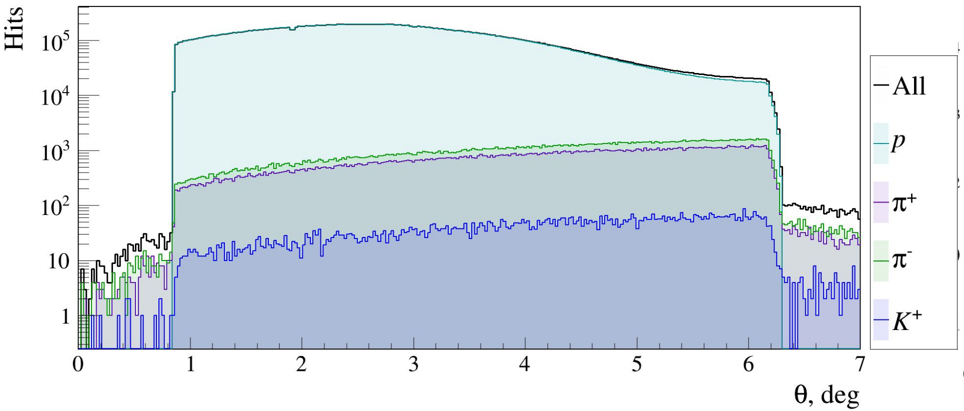


Dependence EDep on Time by type of particles (clear)



Particle type differentiation at primary vertex

UrQMD



PHQMD