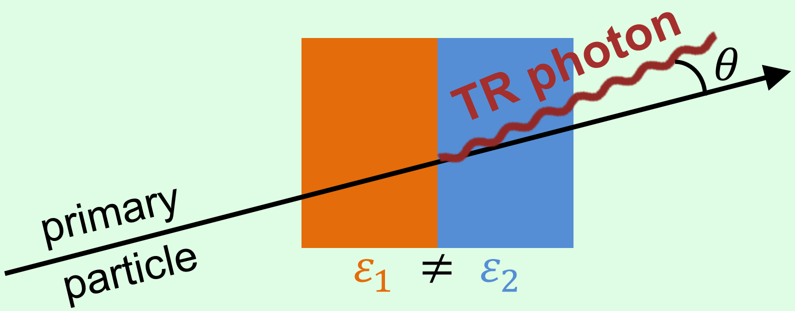
Measurements of angular distribution and spectrum of transition radiation with a GridPix detector

Yury Smirnov
(NRNU MEPhI, Moscow)

3rd International Conference on Particle Physics and Astrophysics
October 2-5, 2017

Transition radiation

- Transition radiation (TR) occurs when a charged particle passes through a boundary between two materials with different dielectric constants ε_1 and ε_2;
- TR emerges as soft X-ray photons at highly relativistic velocities;
- TR spectrum hardens with increasing Lorentz factor γ;
- $\theta \sim {}^{1}/_{\gamma} \rightarrow$ particle identification;



- Structures with many transition surfaces like layered foils, foams, fibers can be used to increase a probability of TR yield.

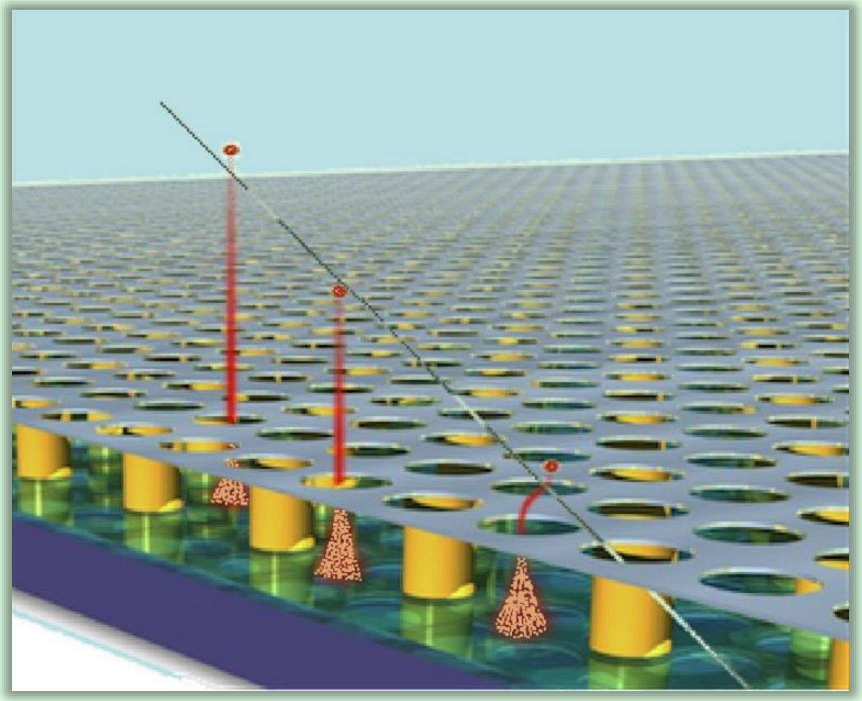
GridPix detector

- Combines the best properties of silicon and gaseous detectors;

- A specially treated pixel electronics chip is placed in the gas volume with a drift gap and an electron multiplication region;

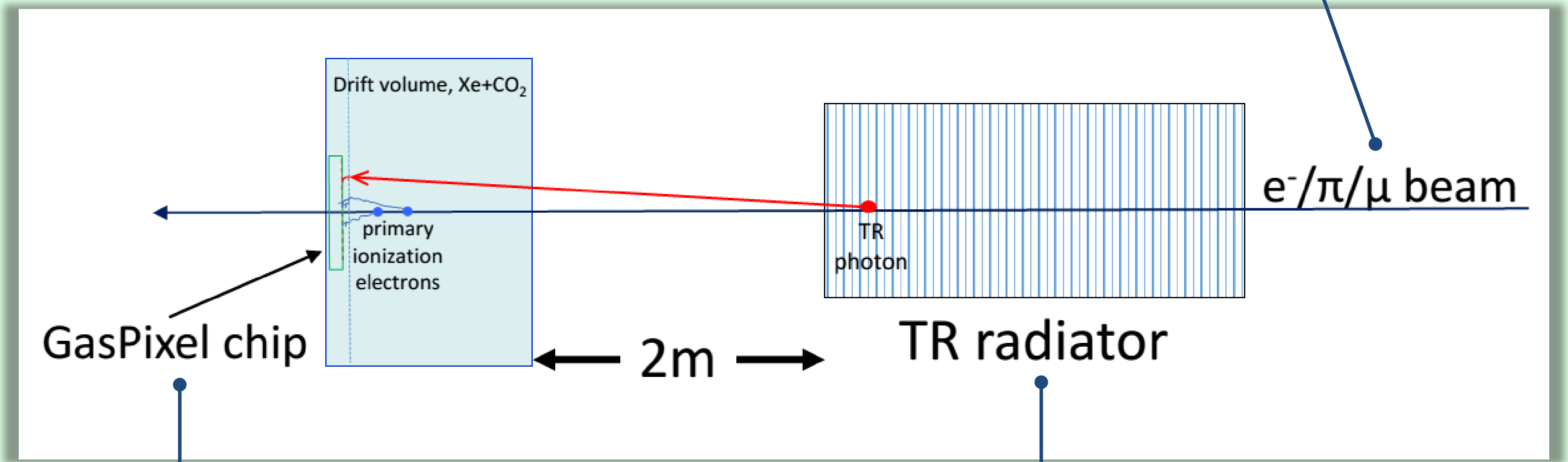
- Primary ionization electrons, produced by a charged particle, drift towards the pixel chip, focused into the grid holes, develop an avalanche in the multiplication region and finally are measured by the pixels of the chip;

- Based on a GEM and MicroMegas technologies.



Test beam setup at CERN SPS (July 2016)

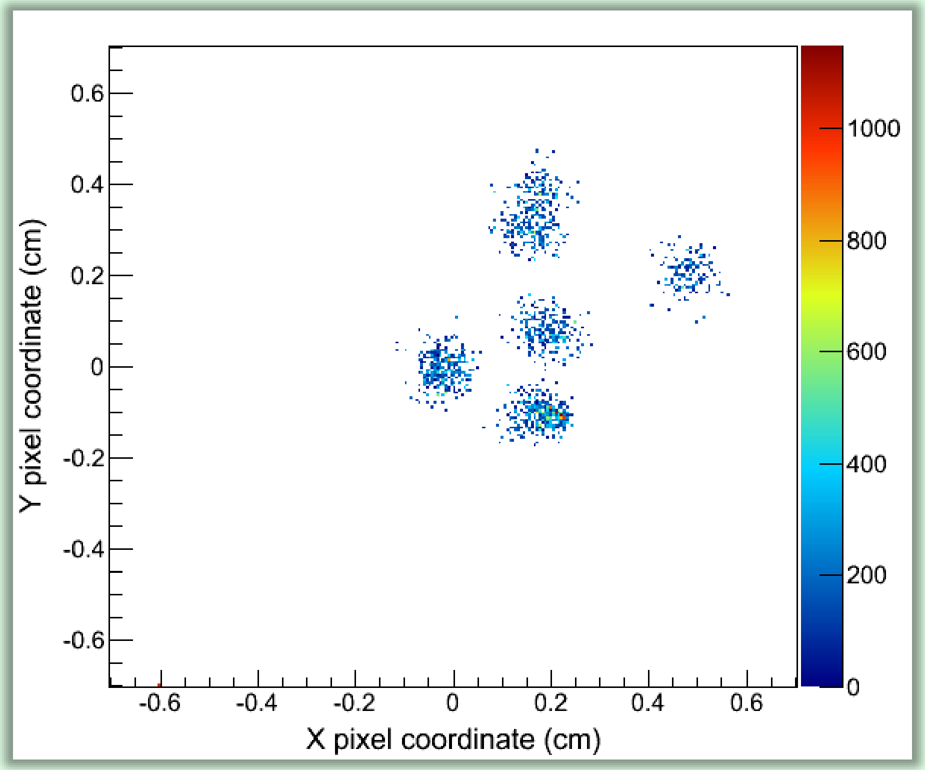
20 GeV electrons ($\gamma = 3.9 \times 10^4$) or
20 GeV pions ($\gamma = 1.4 \times 10^2$) or
180 GeV muons ($\gamma = 1.7 \times 10^3$)



14×14 mm^2 overall sensitive area

150 foils, with 2 mm separation; each foil consists of 4 layers of polypropylene films, 15.5 μm thick each

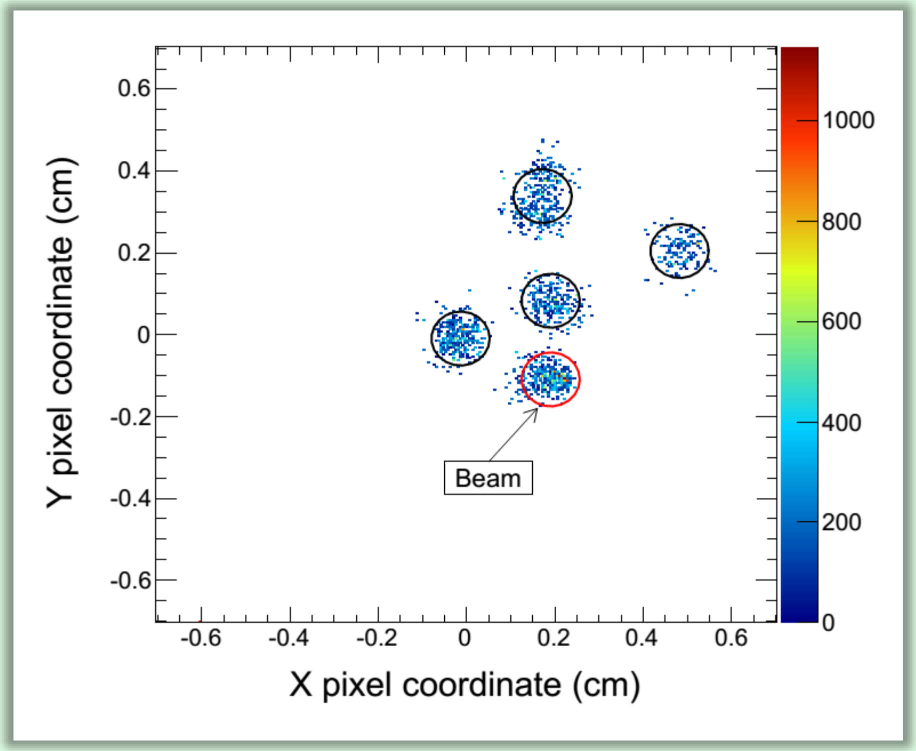
Representation of a typical event



- Every small point is a fired pixel, 55×55 μm² in area;
- The pixels collect primary ionization electrons → two coordinates of a fired pixel and a signal amplitude (in nanoseconds along the z-axis);
- Fired pixels usually form clusters → event displays show beam particle clusters, TR photon clusters, δ-electron clusters etc.

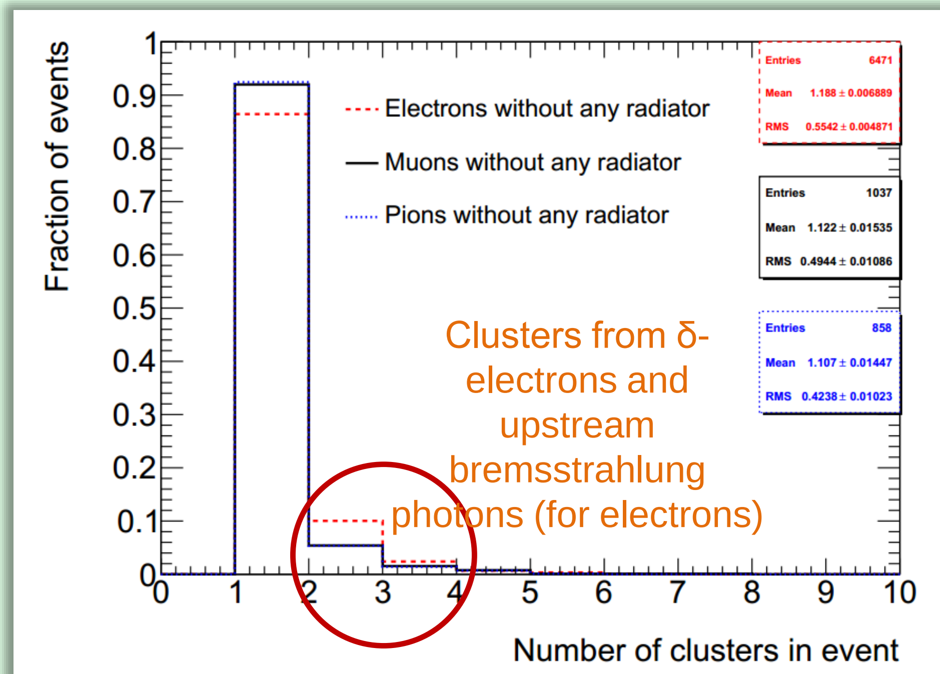
Cluster searching algorithm

- A dedicated cluster searching algorithm was developed in ROOT;
- The underlying idea is to project the 2D distribution onto each axis, then to automatically look for groups of adjacent bins with high bin content (threshold is defined iteratively: has to be high enough to reject noise, has to be low enough to identify as many peaks as possible) on each projection;
- Identifies clusters: cluster center and its radius;
- Tells apart clusters from beam particles (“primary clusters”) and those from TR photons/δ-electrons (“secondary clusters”) based on a cluster position, sum of pixels energy values, cluster asymmetry and width.

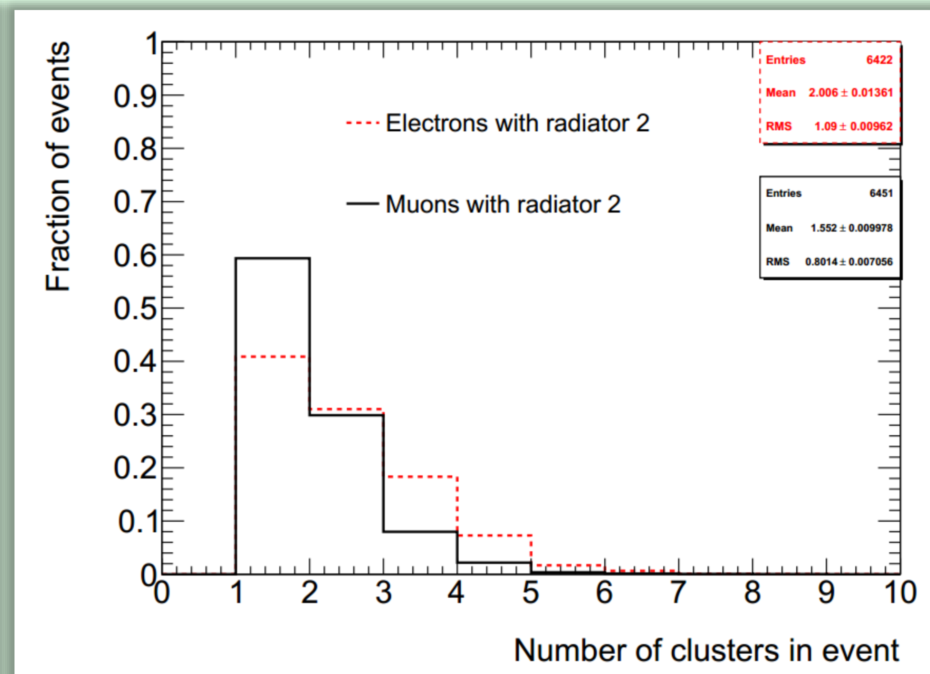


Clusters multiplicity

Without radiator



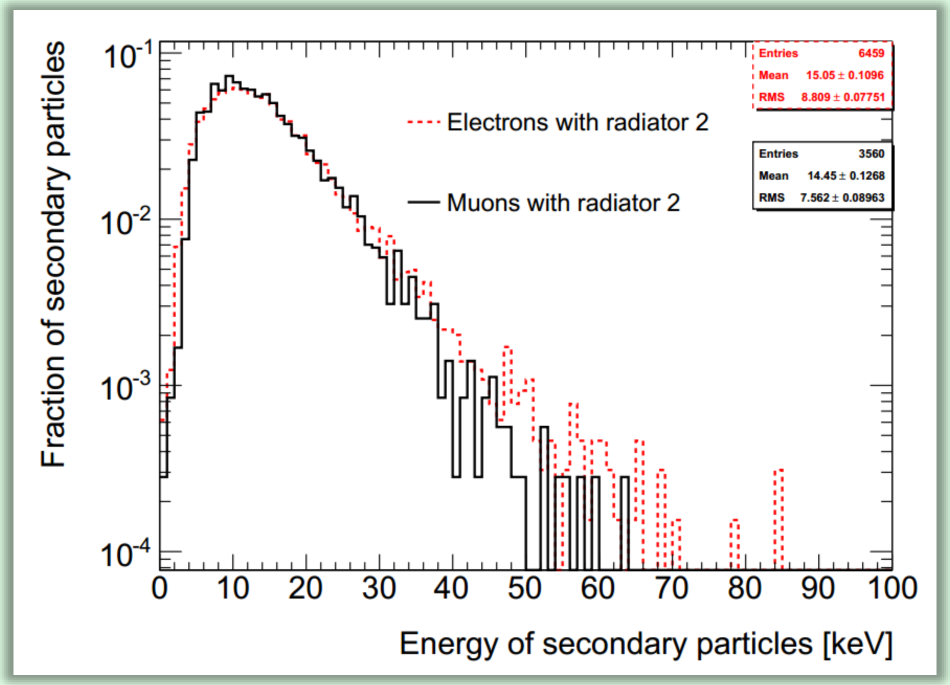
With radiator



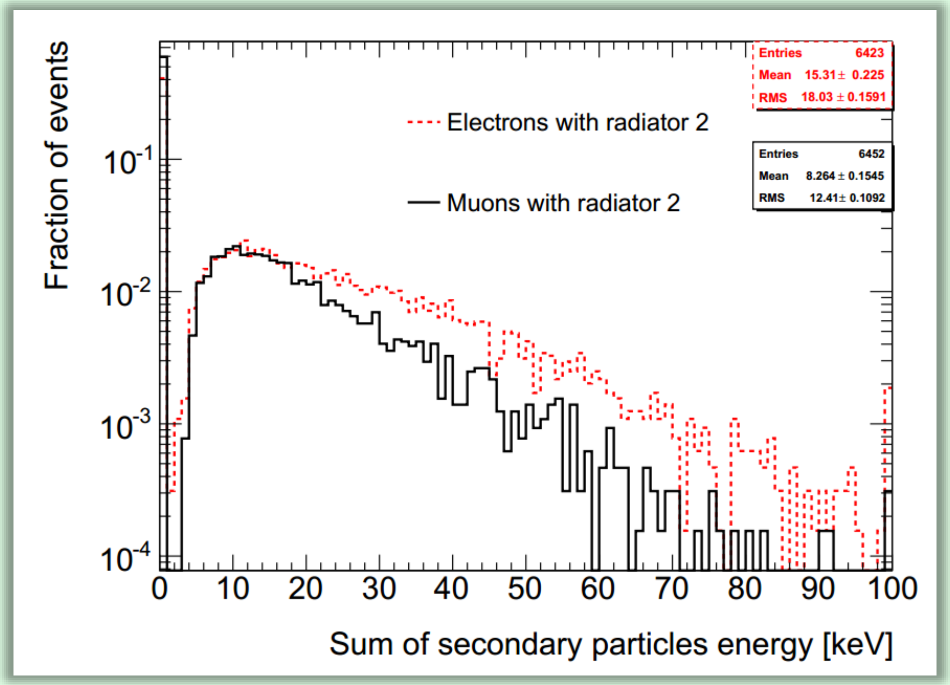
- Distributions of the overall number of clusters in event for the case without (left) and with radiator (right);
- Only events with an identified primary cluster are shown;
- A case with radiator: average N detected TR photons from electrons = 1.0, average N detected TR photons from muons = 0.5.

Secondary particles energy

Energy of every single TR photon



Sum of TR photons energies per event

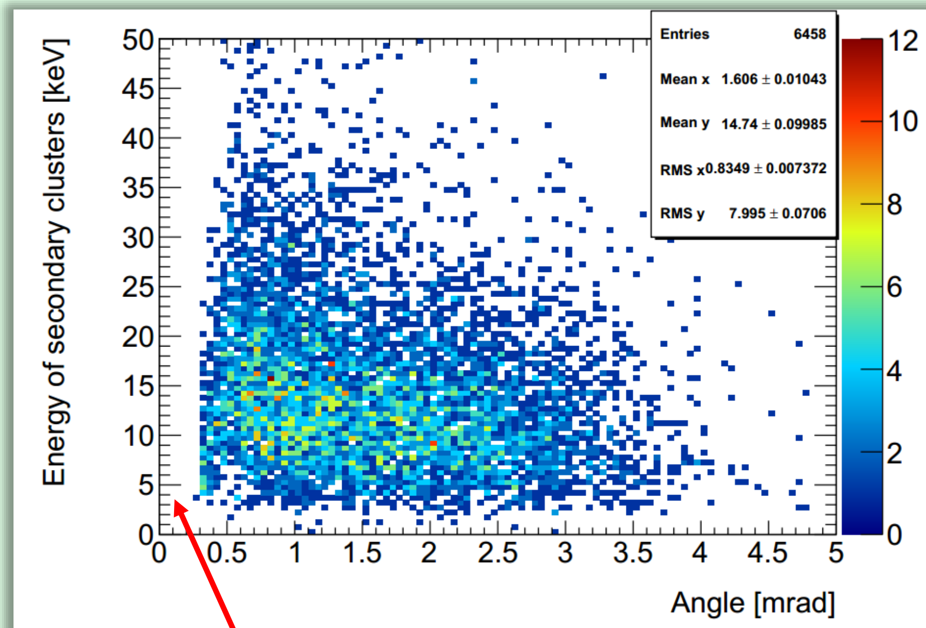


Distributions are very similar

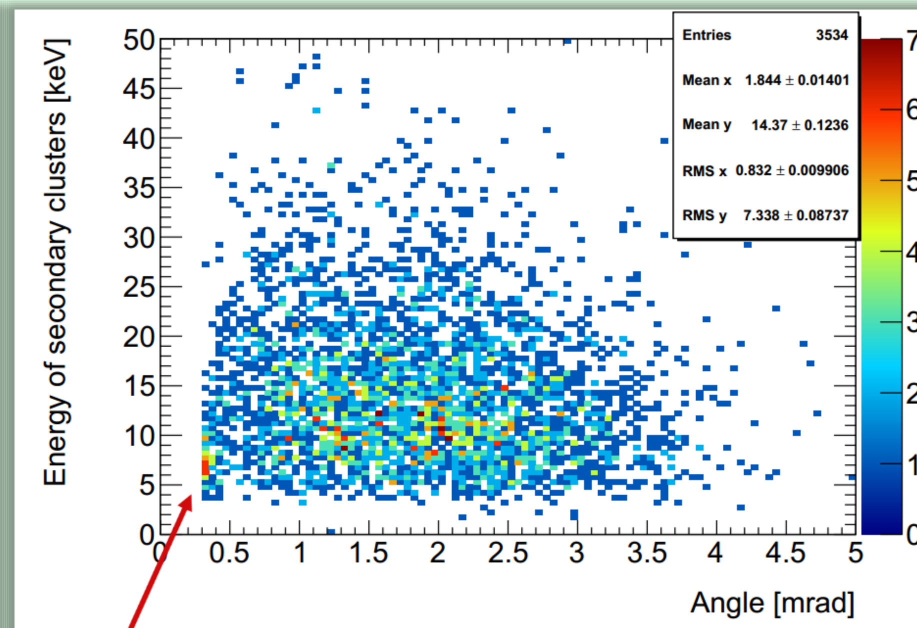
The difference is due to the fact that electrons yield more than 1 secondary cluster more often

TR photons energy vs. angle

Electrons



Muons

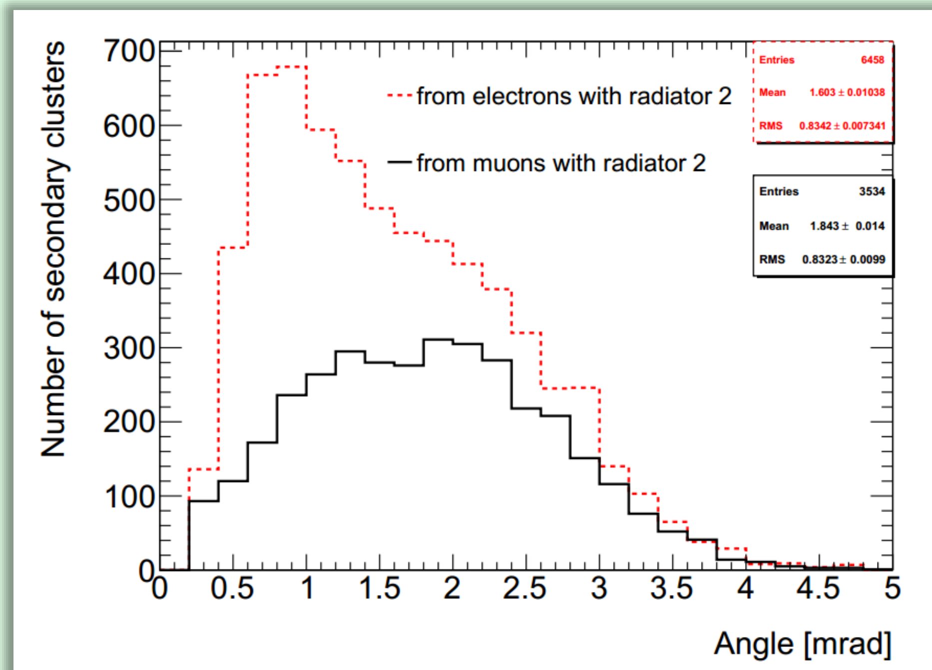


These empty areas are due to the fact that two clusters can not be reconstructed if too close to each other

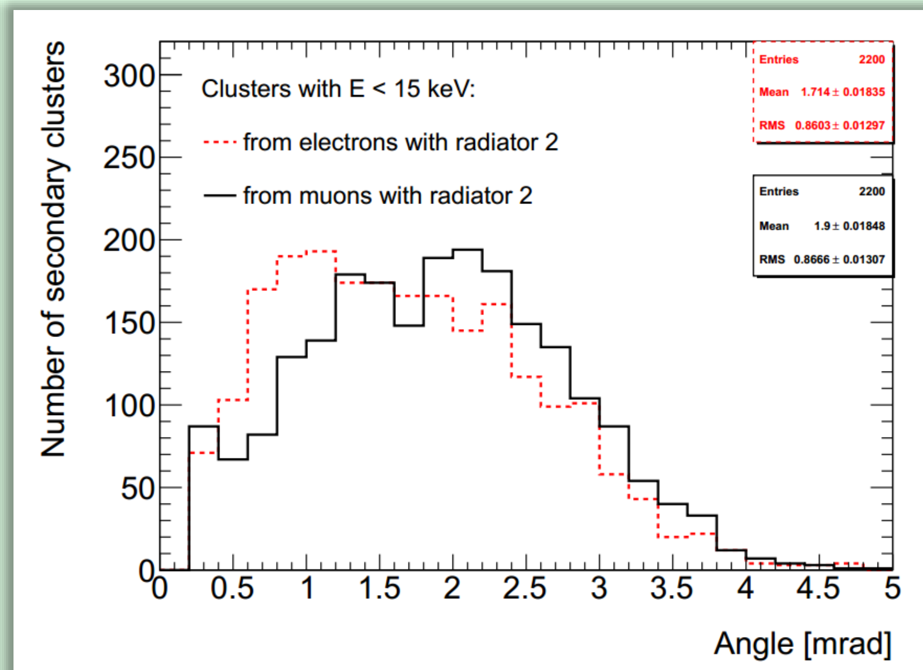
- TR is generally concentrated at angles below 4 mrad.

TR photons angle

All TR photons



Low-energy TR photons

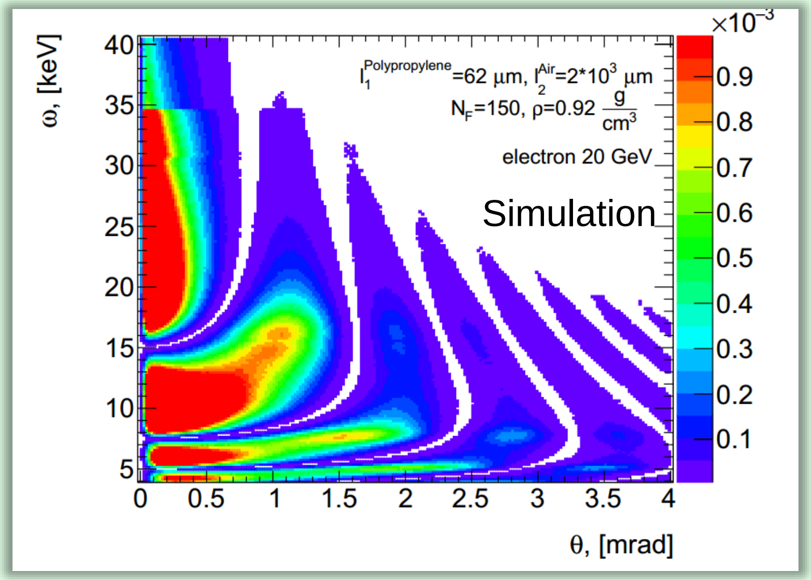


- TR photons originating from electrons tend to concentrate at smaller angles compared to those from muons ($\theta \sim {}^{1}/_{\gamma}$);

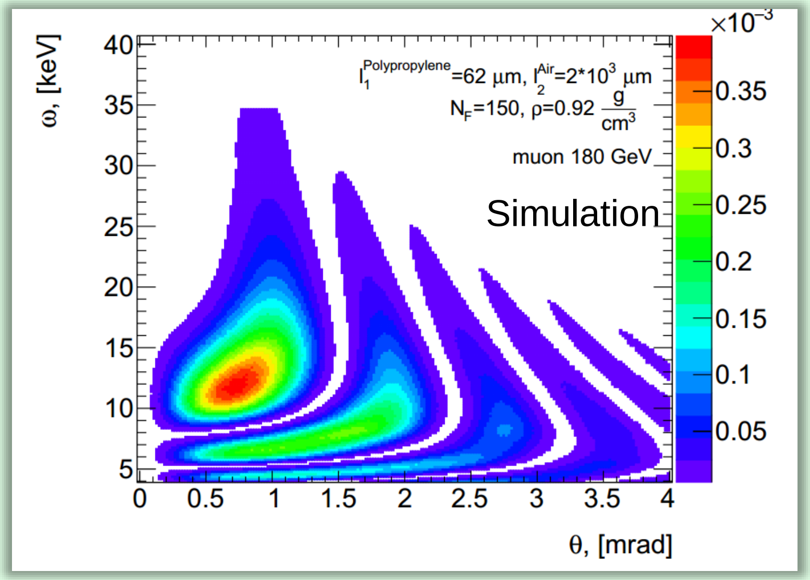
- Double-peak structures for muons?

TR photons angle vs. energy: simulation

Electrons



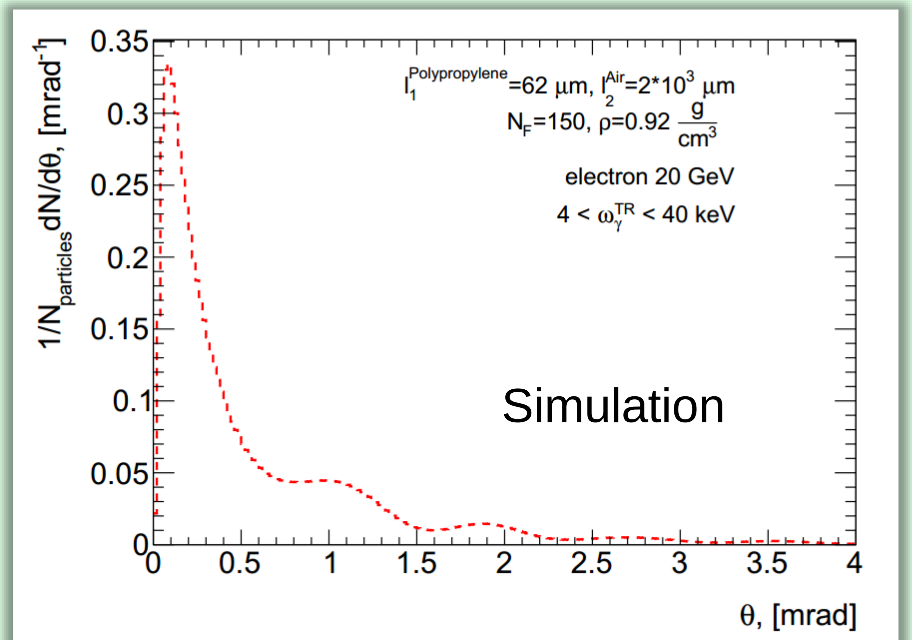
Muons



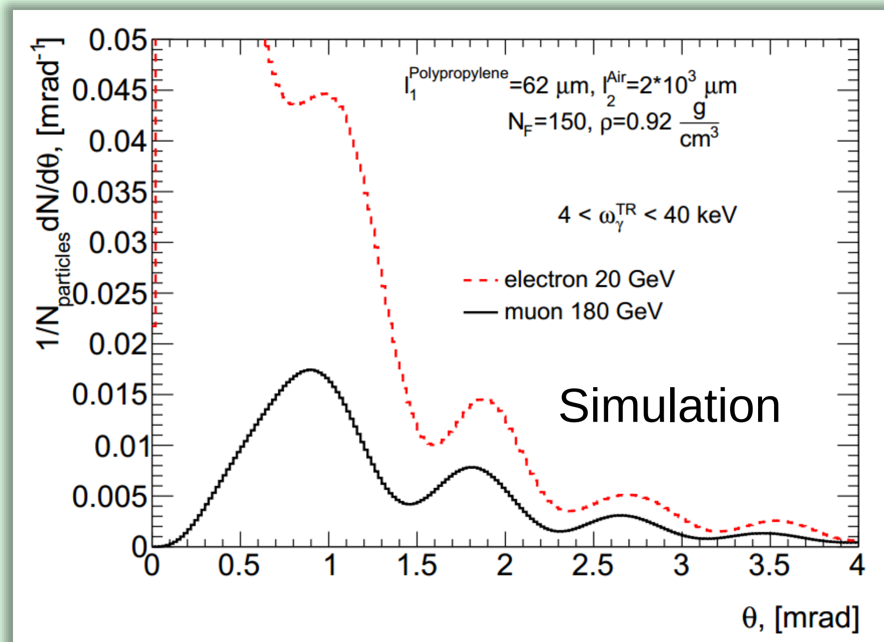
- For TR photons coming from electrons (as opposed to muons), a significant part is concentrated at angles < 0.5 mrad;
- Multiple-peak structure both energy- and angle-wise;
- Why no significant difference between corresponding energy spectra in experimental data?
- Minimal angle constraint → the most energetic TR photons from electrons do not get reconstructed; algorithm internal limitations (e.g., upper bound on a cluster radius) to reconstruct such photons also deform energy spectra.

TR photons angle: simulation

Electrons only



Electrons and muons



- Different distribution shapes for electrons and muons, multiple-peak structures;
- Reconstruction cut at 0.3 mrad would reject half of TR photons coming from electrons;
- At larger angles, the shapes get more alike (especially given that muons yield ~ 2 times less TR photons than electrons do);
- Two peaks (at ~ 1 and ~ 2 mrad) are pronounced more significantly in simulation than in data.

Conclusion

- Simultaneous measurements of angular and energy distributions of TR photons were performed for the first time with the help of GridPix detector;
- Multiplicities of TR photons originating from 20 GeV electrons and 180 GeV muons are different by a factor of 2 ← expected;
- Angular distributions of TR photons from electrons and muons are also different, the angle is inversely proportional to the Lorentz factor ← expected;
- However, theoretical calculations predict a different shape of angular distributions at small angles than the one observed in data ← partially explained by the internal limitations of the cluster searching algorithm;
- The same may explain the likeness of energy distributions, which contradicts the simulation results;
- Double-peak structure in the angular distributions was predicted, but it was pronounced less significantly in the experimental data;
- The sources of all these discrepancies are a subject of future studies.

Thanks!