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Determining the photon yield for the LHCb RICH Upgrade photo-detection system

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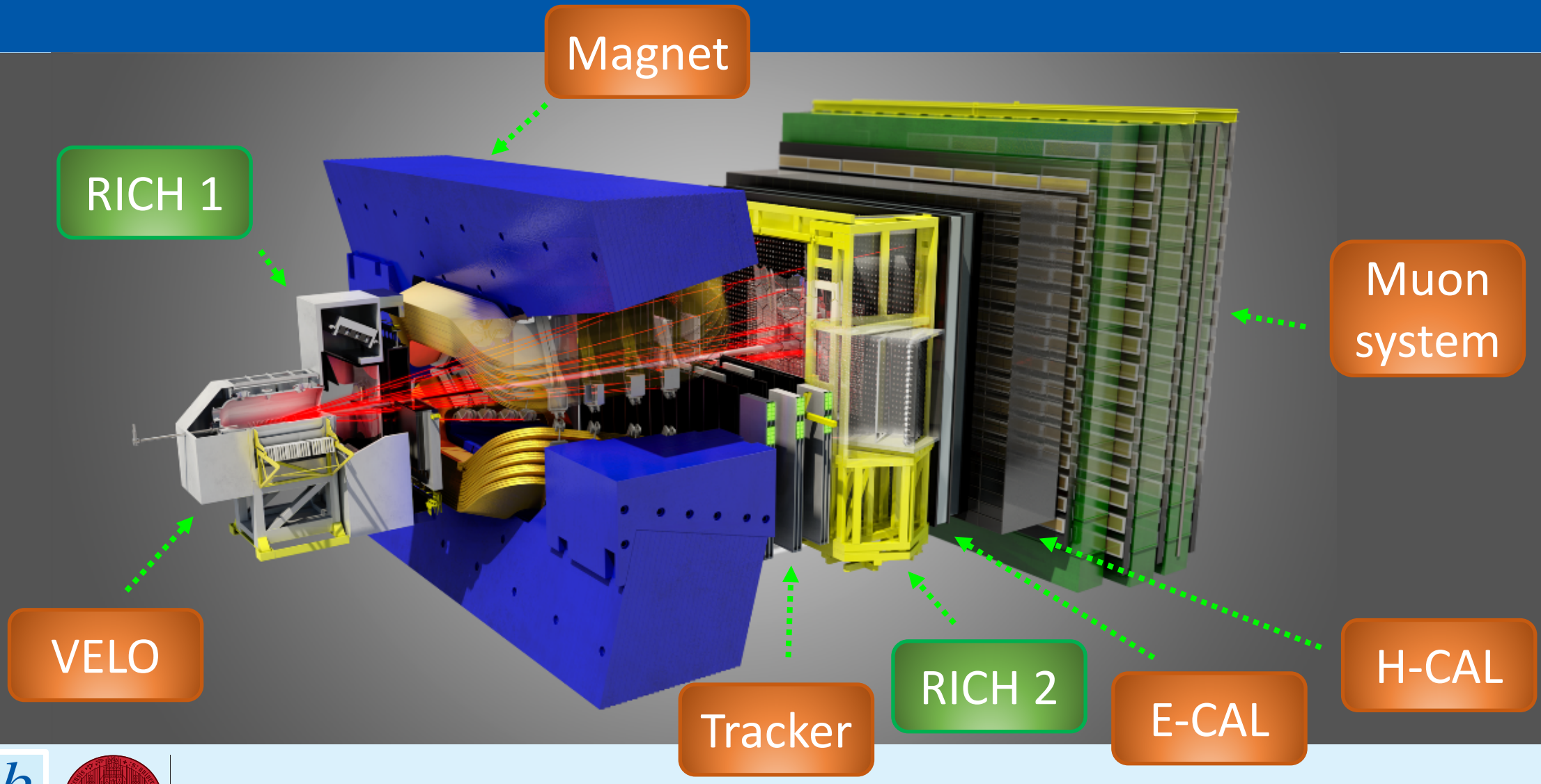
The LHCb detector



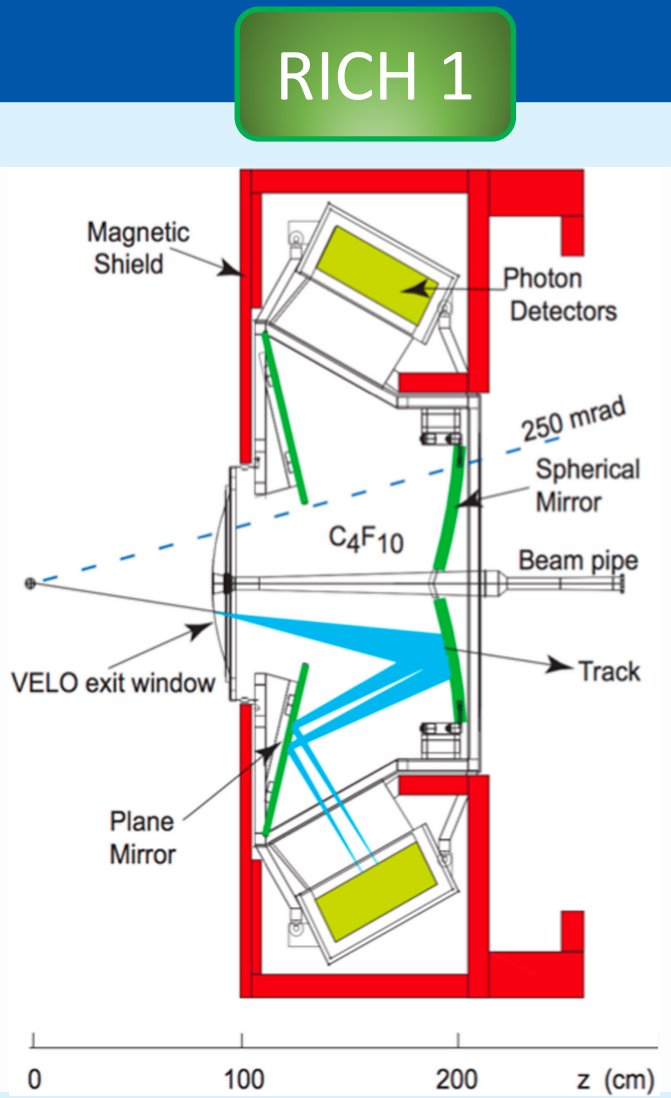
The LHCb RICH detectors

RICH: **R**ing **I**maging **Ch**erenkov Detector.

Particle Identification by determining Cherenkov angle.

C_4F_{10} (RICH 1) and CF_4 (RICH 2) gas as **Cherenkov radiators**.

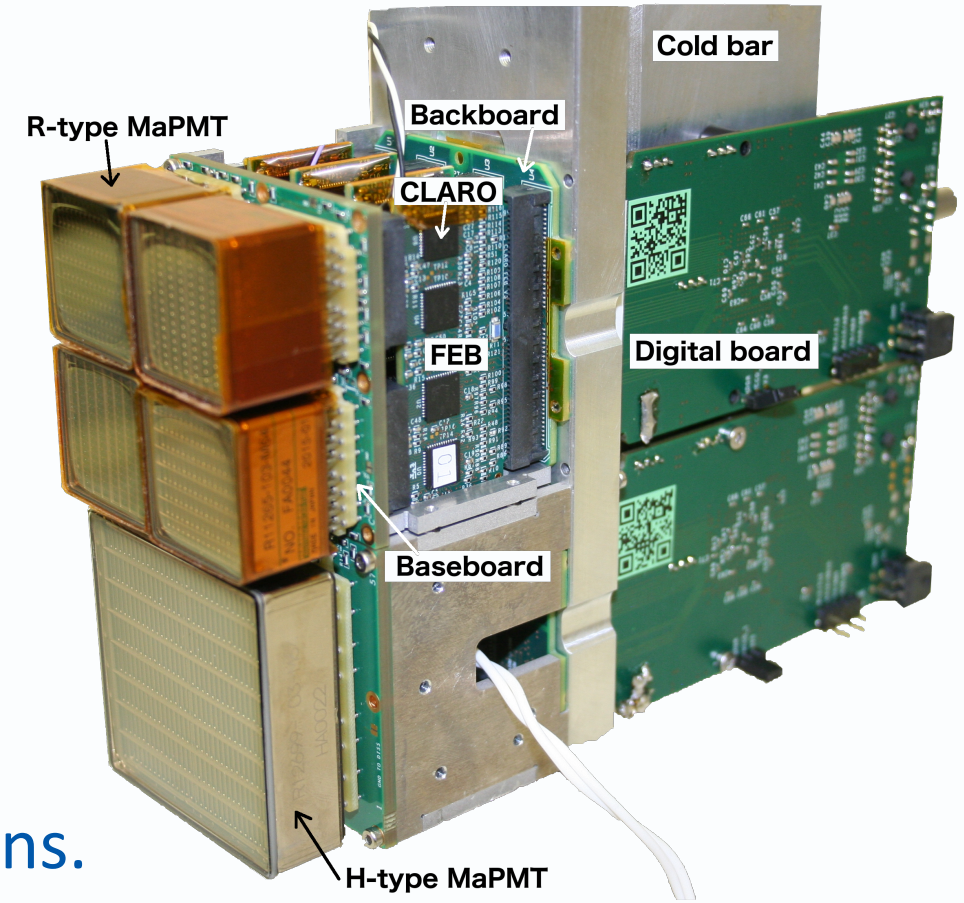
Photon detection using **Hybrid Photon Detectors** (HPDs): solid state detectors with readout electronics integrated inside vacuum tube.



The LHCb RICH detector upgrade

Replace L0-hardware trigger (1 MHz) by **software trigger (40 MHz)** for LHC Run III.

New readout rate requires **upgrade of readout electronics**.



New photo detection system:

R-MaPMTs (1 x 1 in^2) in high-occupancy regions

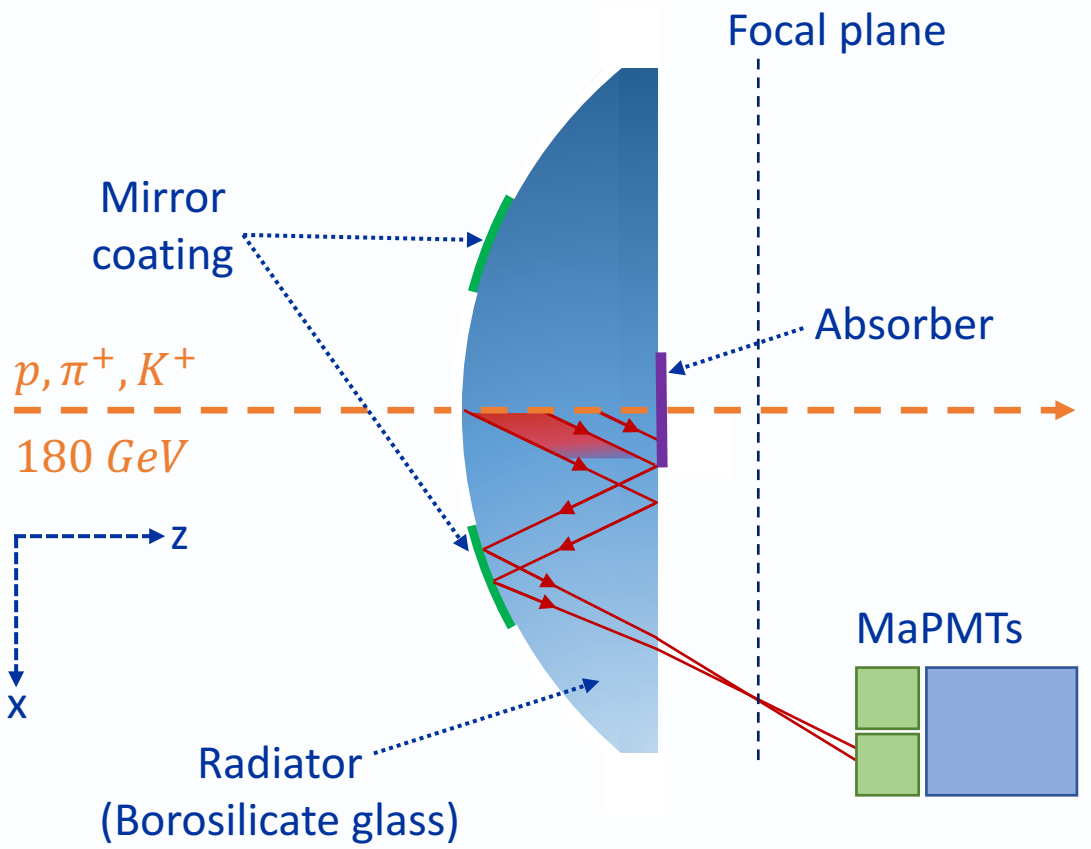
and H-MaPMTs (2 x 2 in^2) in low-occupancy regions.

The LHCb RICH Upgrade test beam

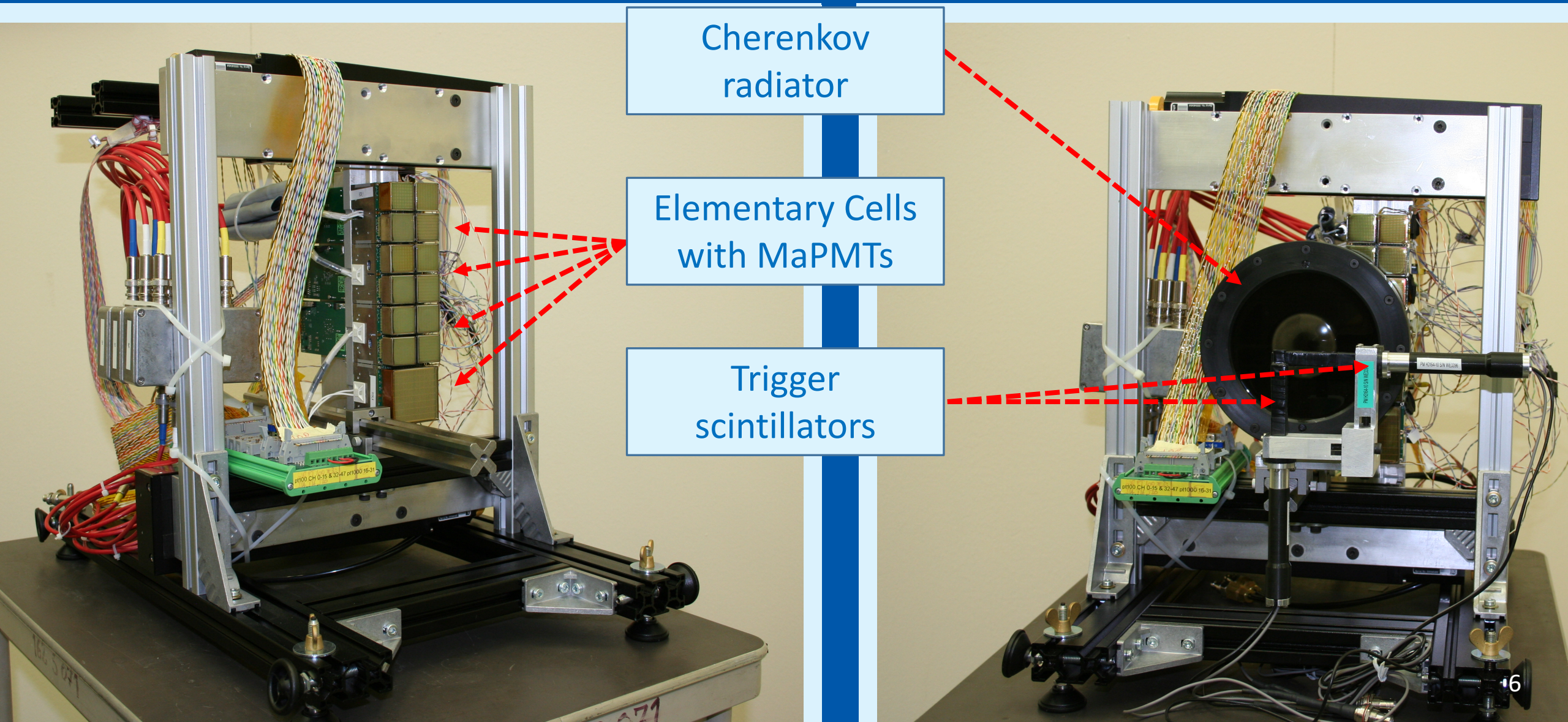
Goal of the study:

Create realistic **simulation** of RICH Upgrade photon-detection system using Geant4 toolkit.

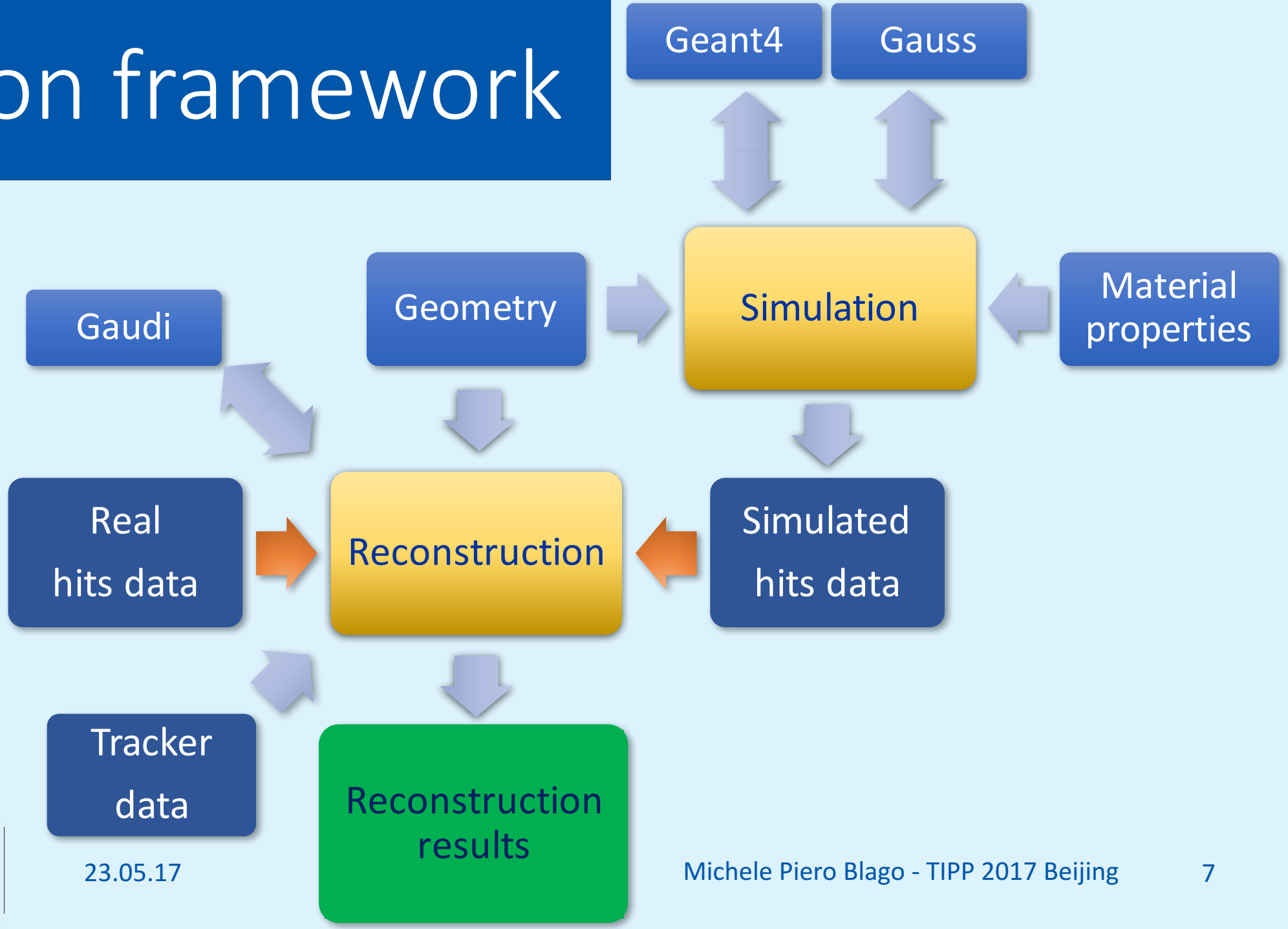
Photon yield as parameter to compare simulation with data.



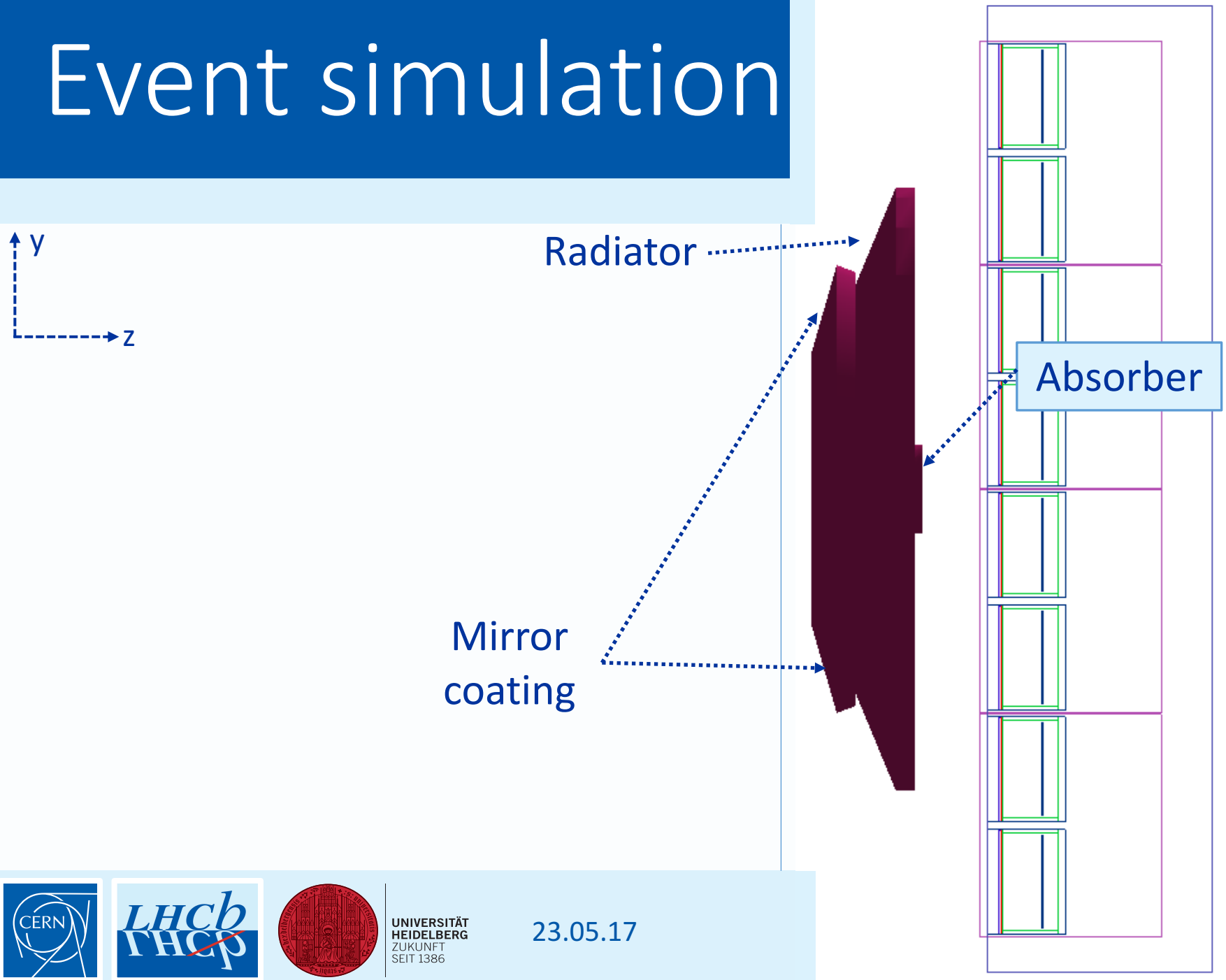
Experimental Setup



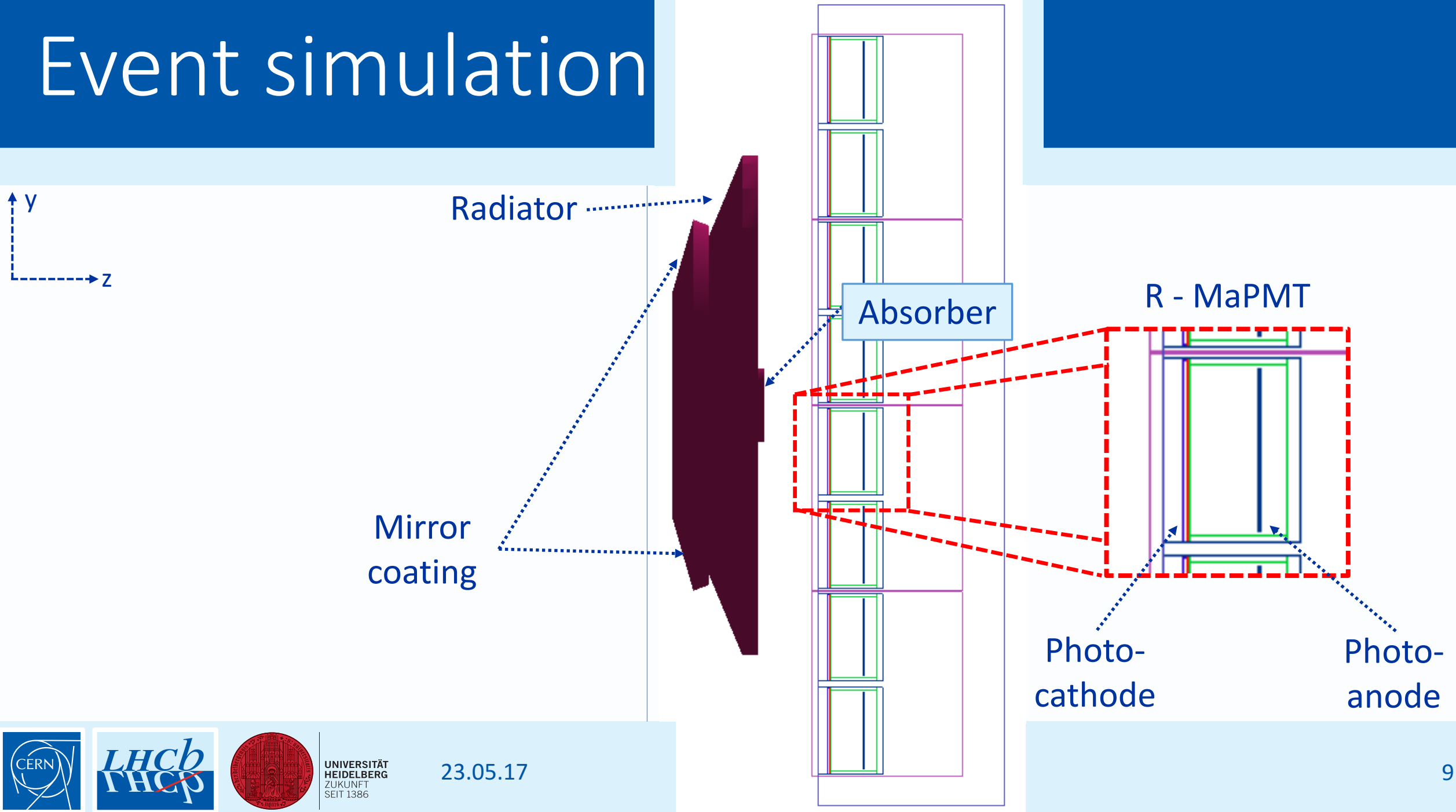
Simulation framework



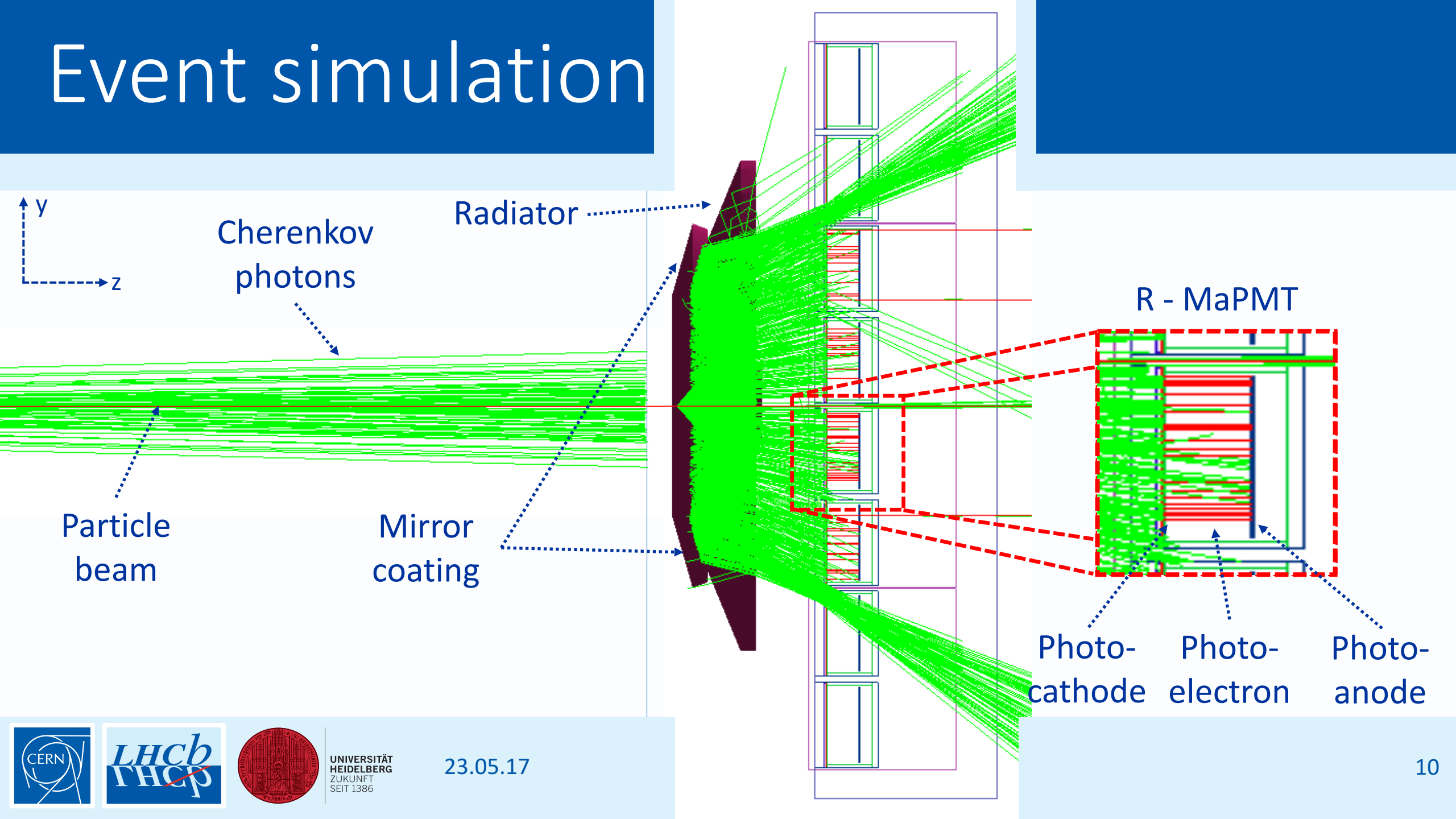
Event simulation

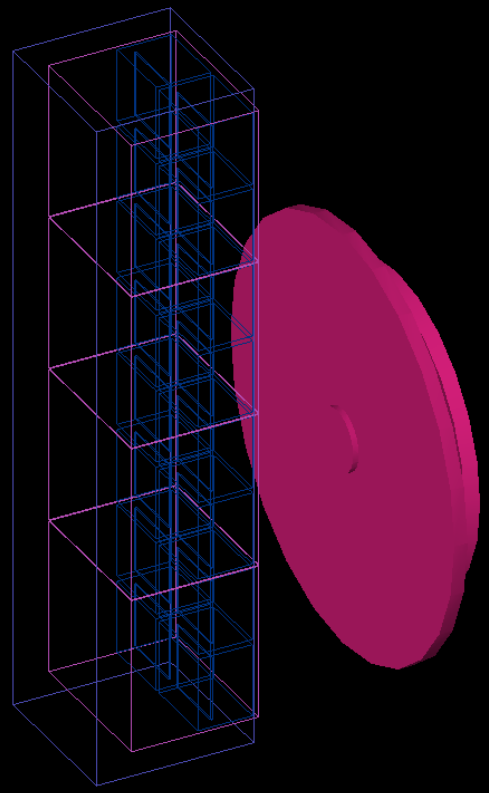


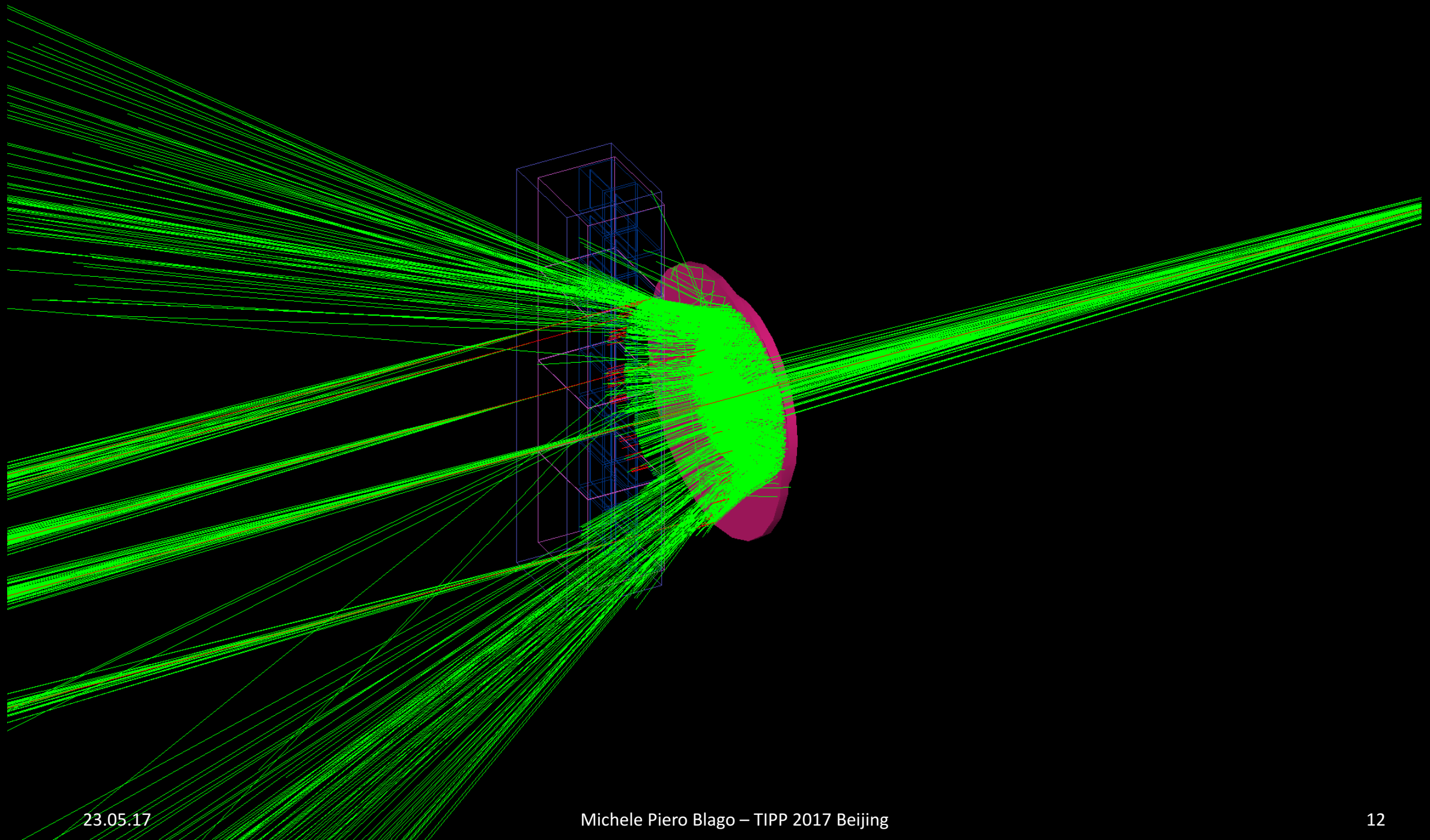
Event simulation



Event simulation

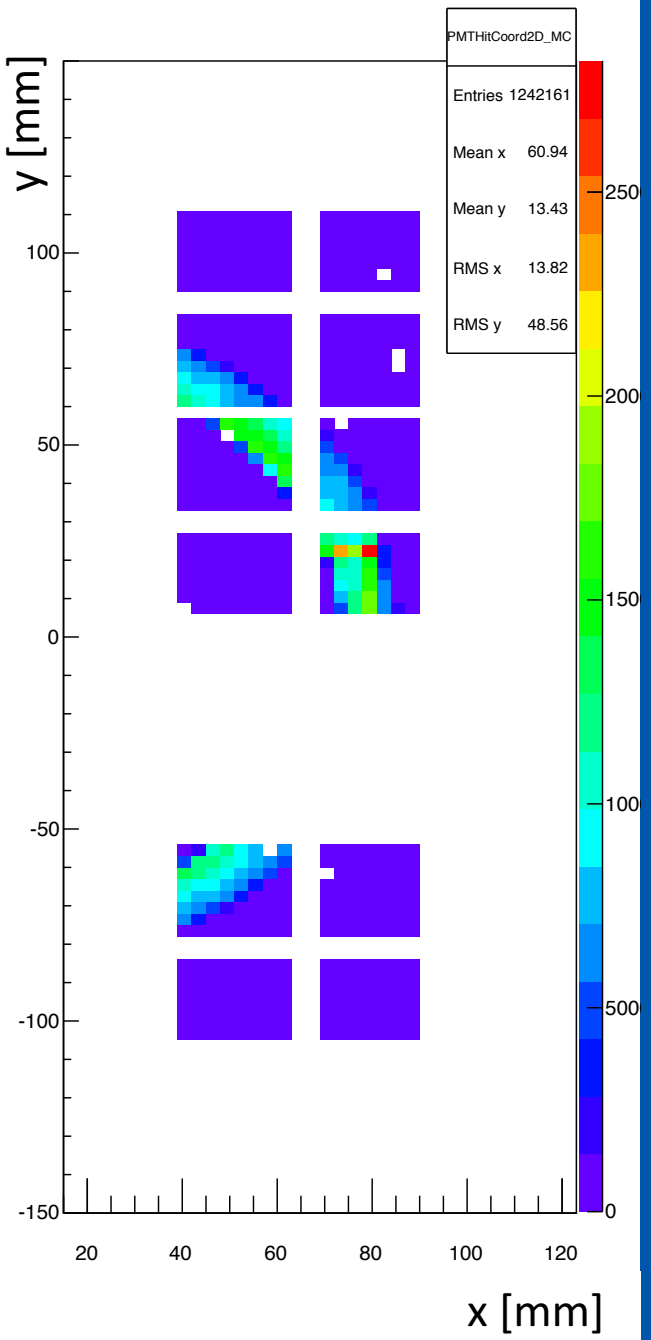




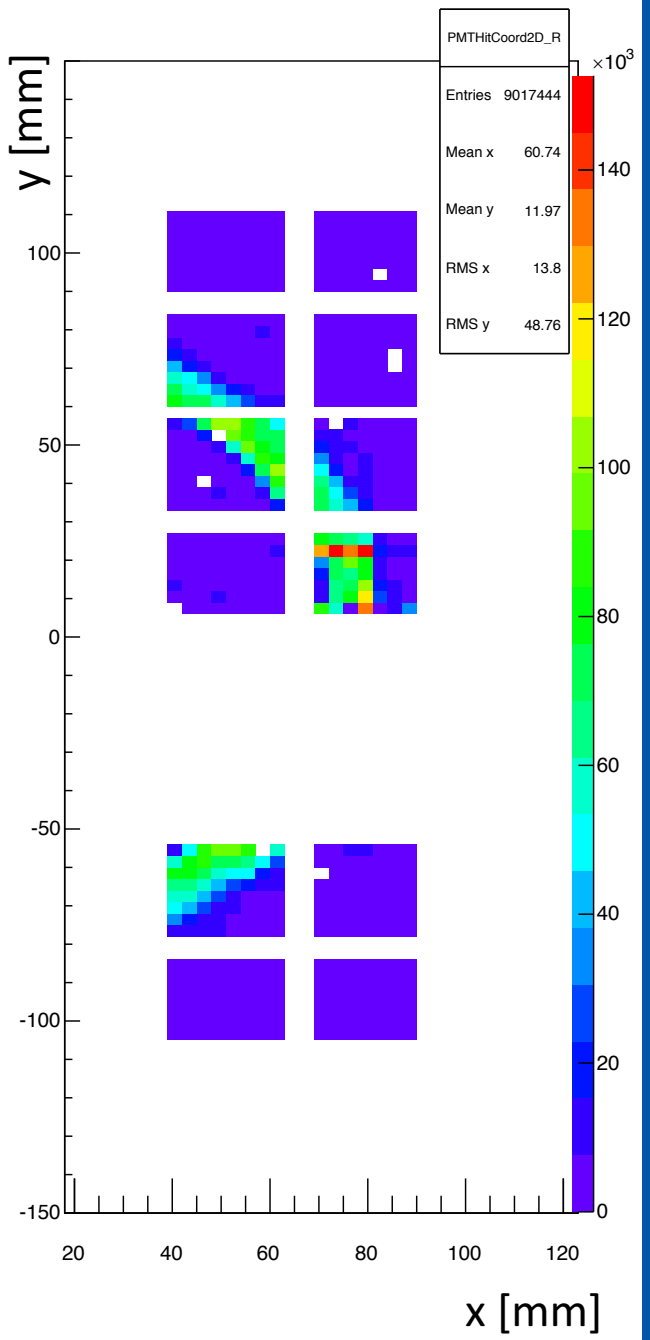


Simulation

MC data pixel hit coordinate



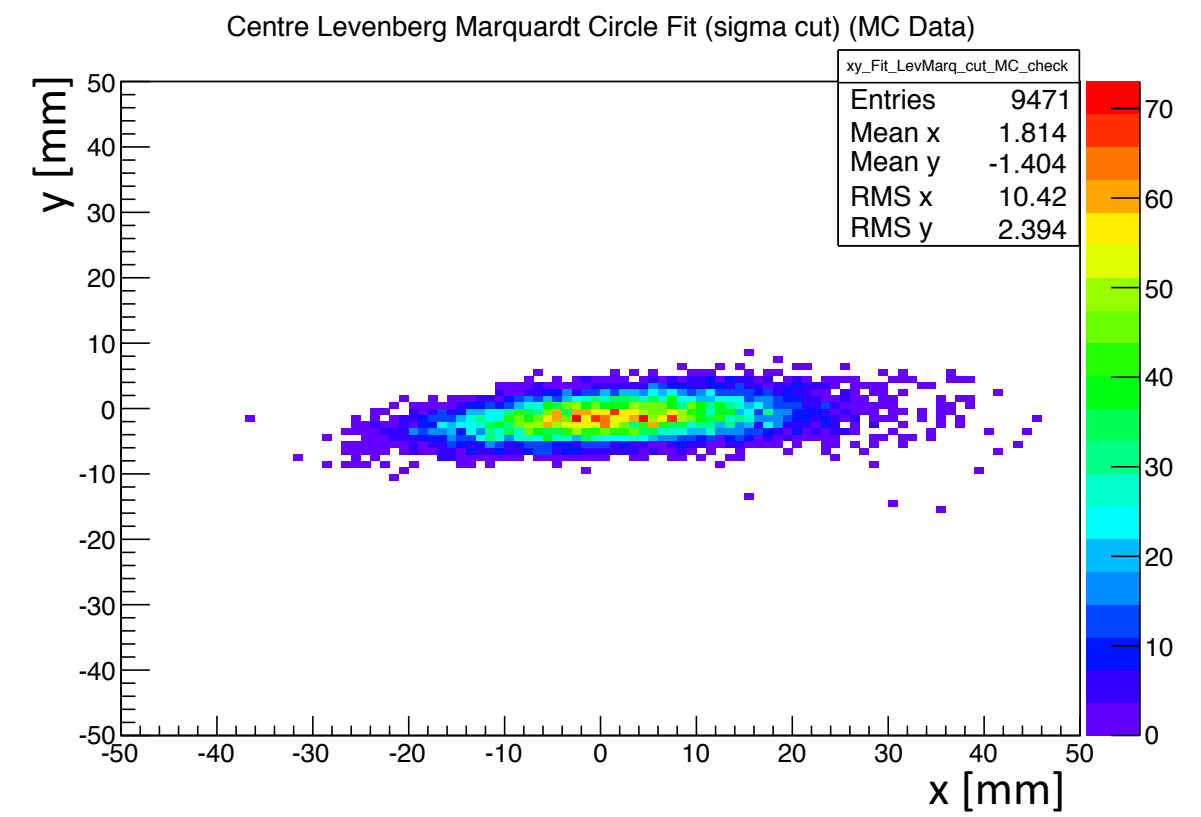
Real data pixel hit coordinate



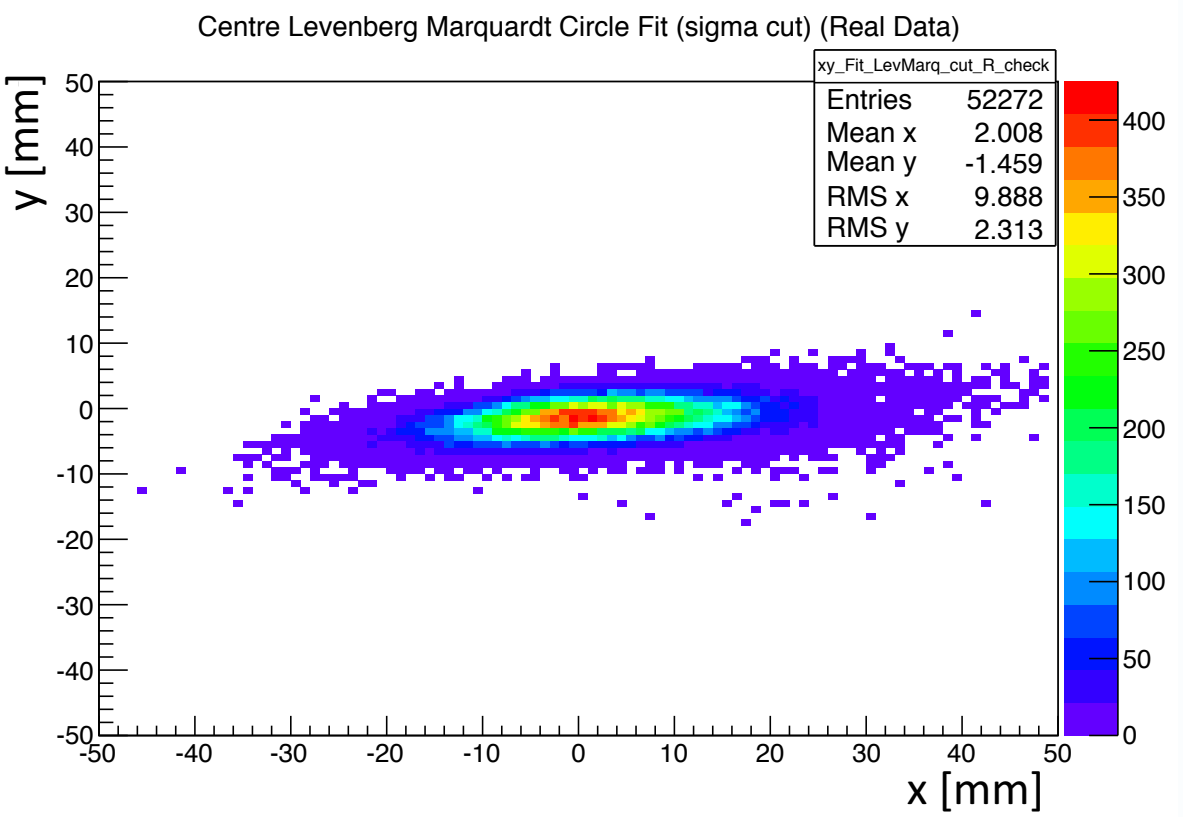
Data

Circle centre – Geometric fit

Simulation



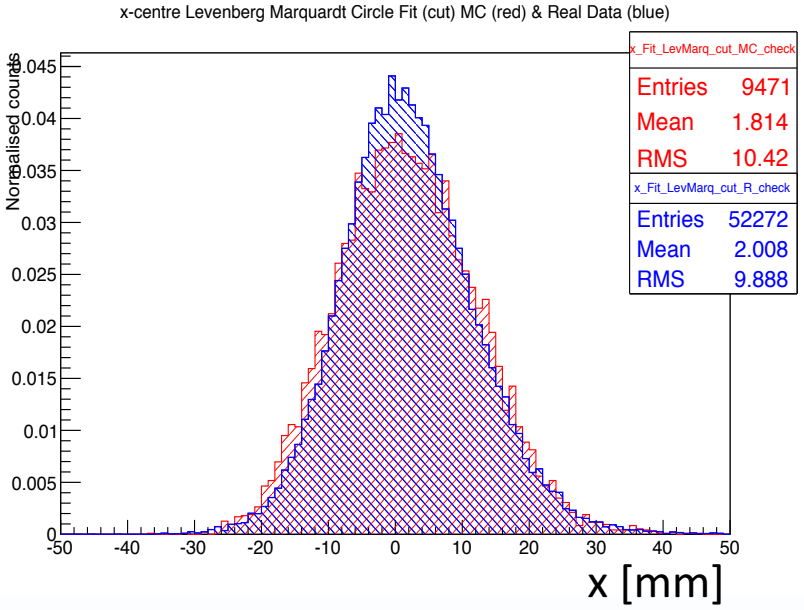
Data



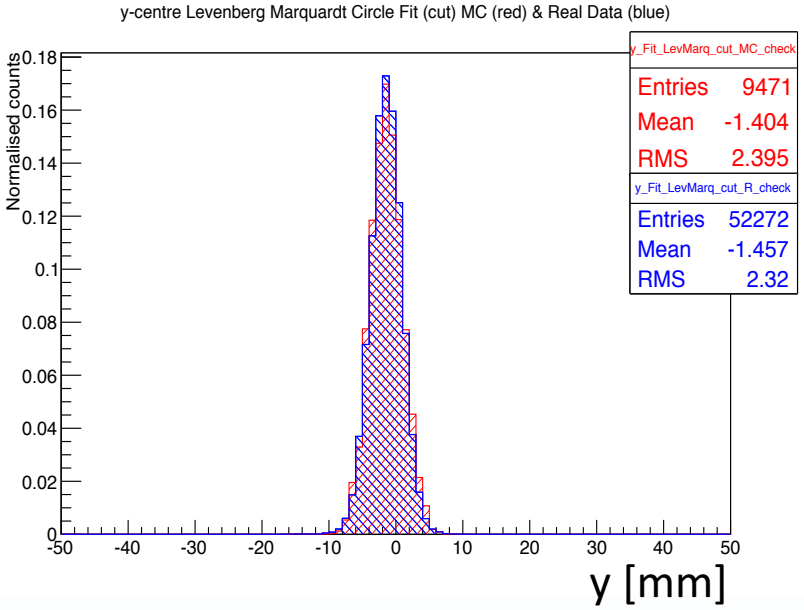
Fitted circle

RED: Simulation
BLUE: Data

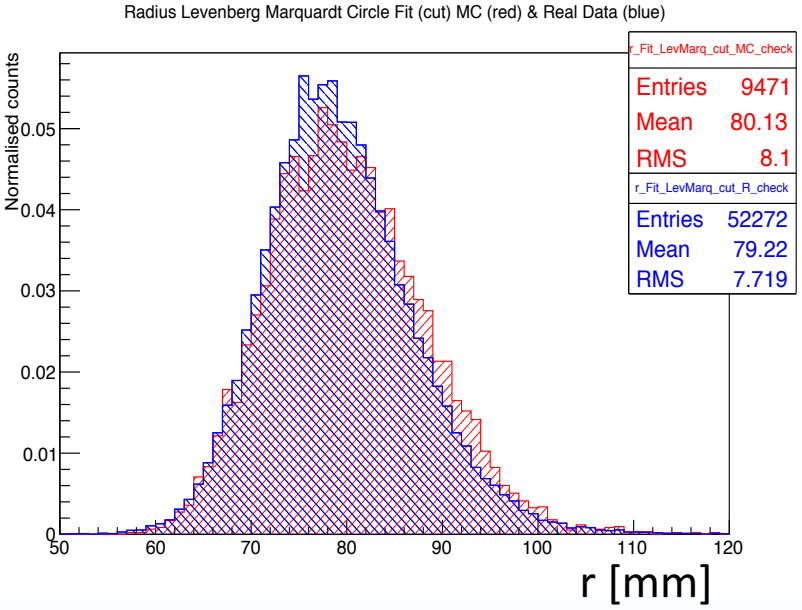
x-position



y-position



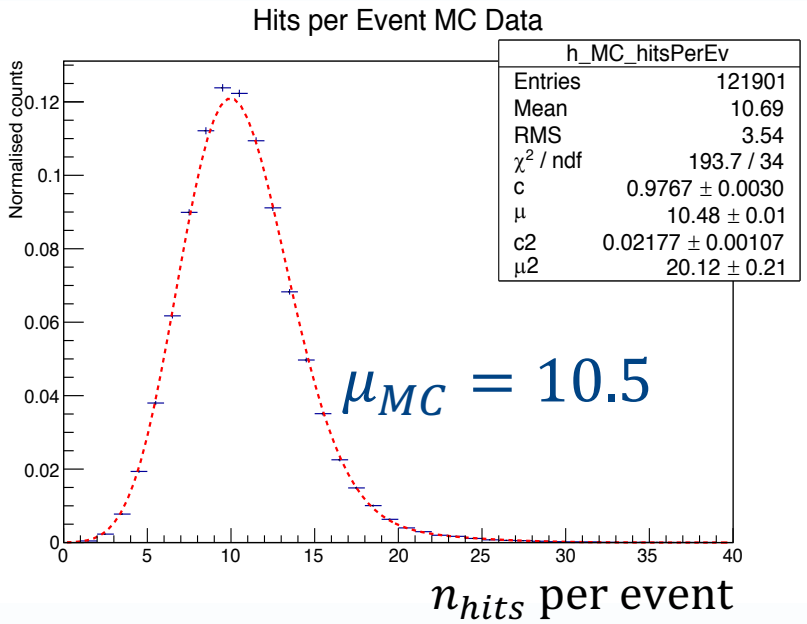
radius



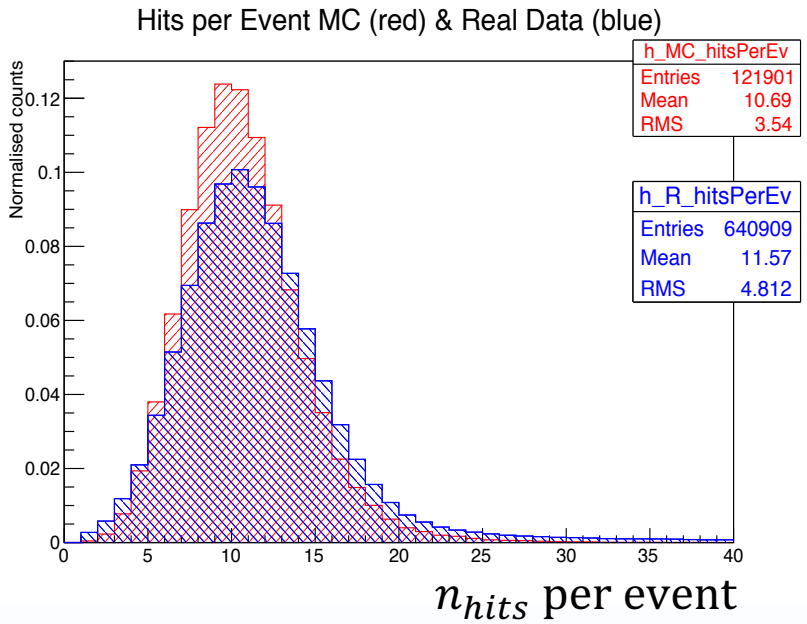
Number of hits per event

RED: Simulation
BLUE: Data

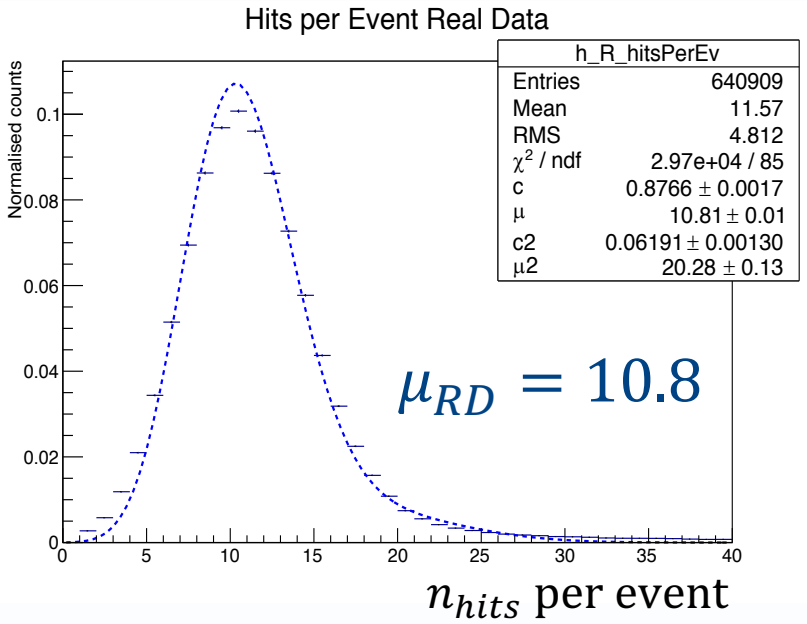
Simulation



Comparison



Data



Fit: $c_1 \cdot Poisson(x, \mu) + c_2 \cdot Poisson(x, \mu_2)$

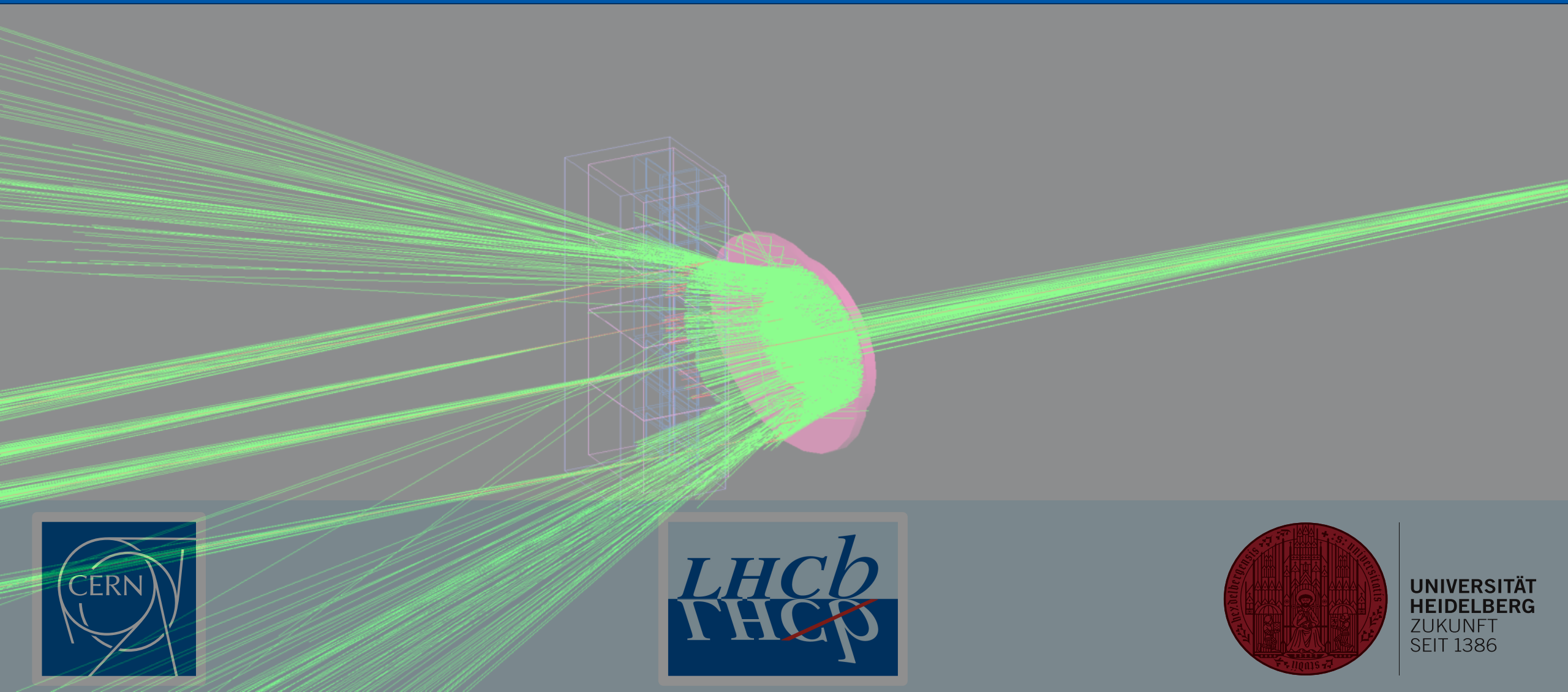
Conclusion

Parameters as circle centre, radius and radius spread **are matching** well within uncertainties.

Photon yield in simulation and data is matching. Small discrepancies can be explained by secondary particles in radiator lens that are not equally often generated in the simulation.

The simulation is able to reproduce the photon-detection system and readout which is foreseen for the LHCb RICH Detector Upgrade.

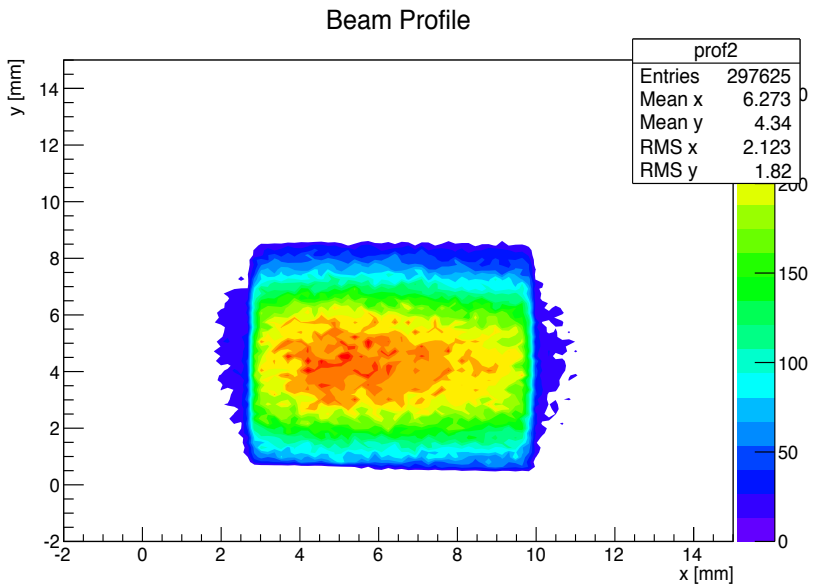
Thank you.



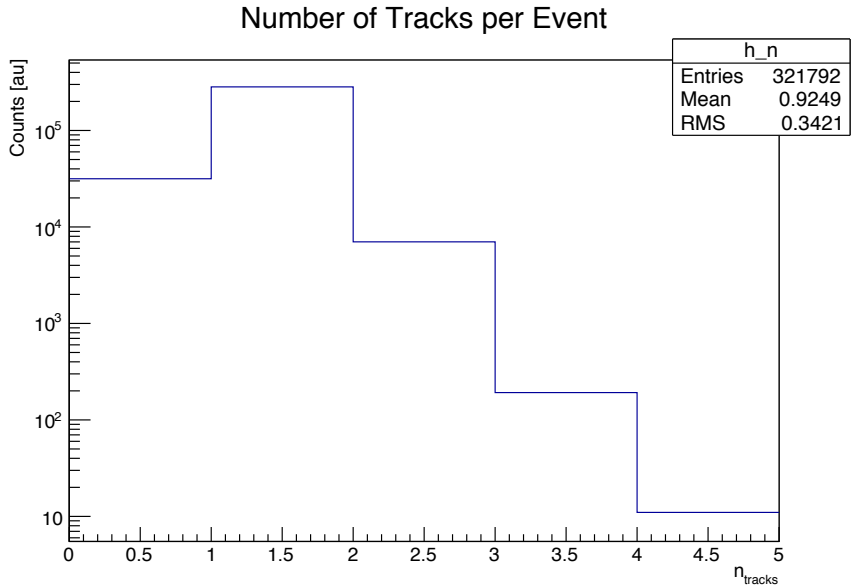
Backup

Particle beam (Telescope tracker data)

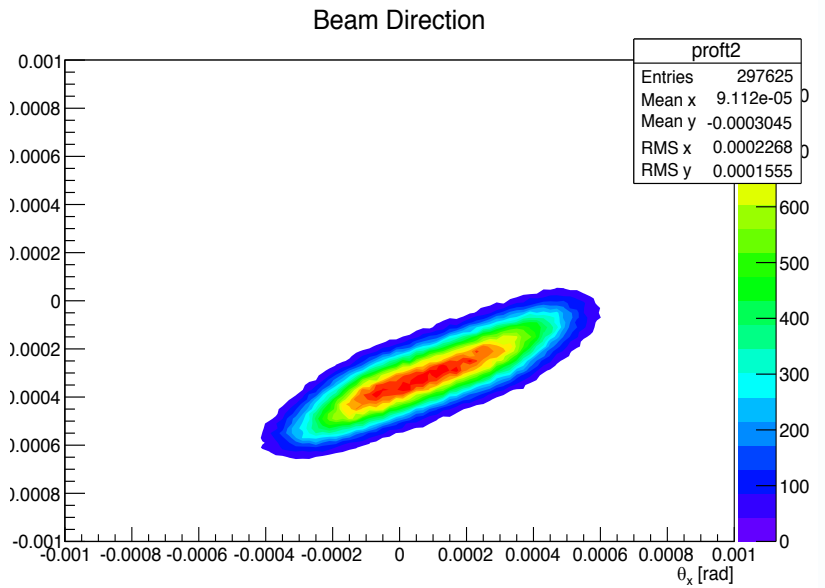
Profile



N_{Tracks}



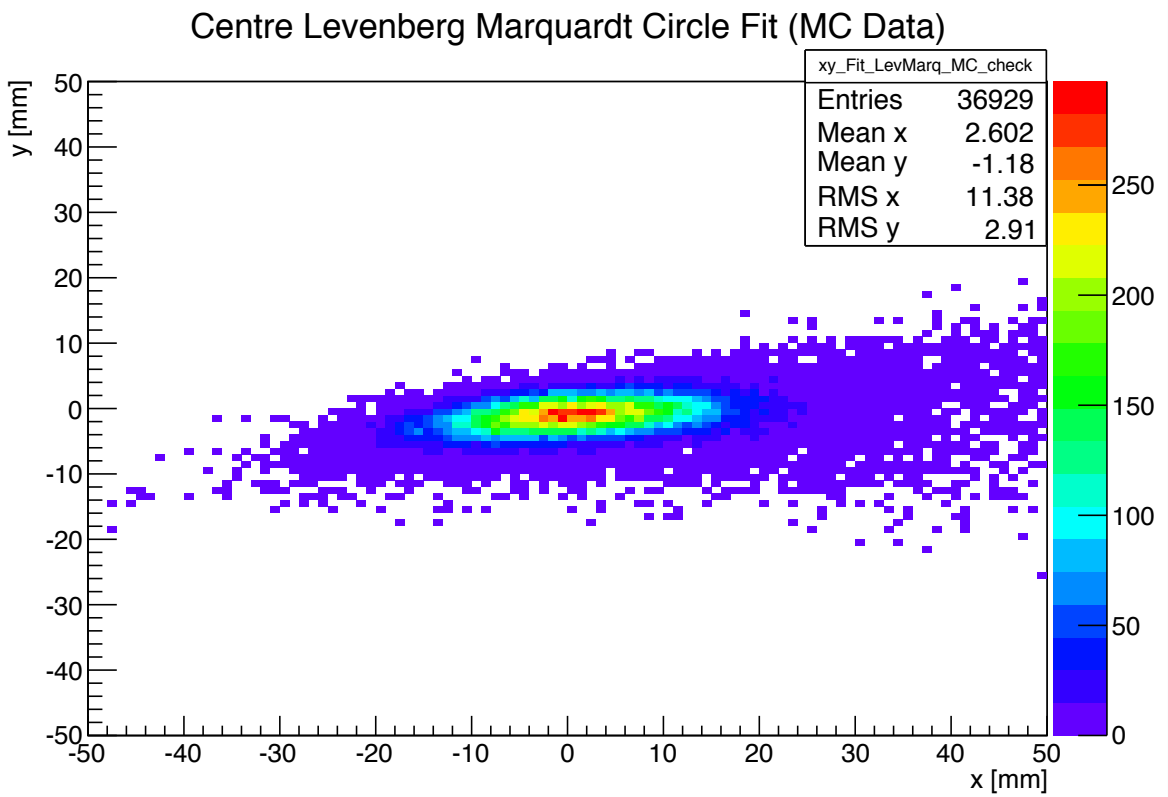
Direction



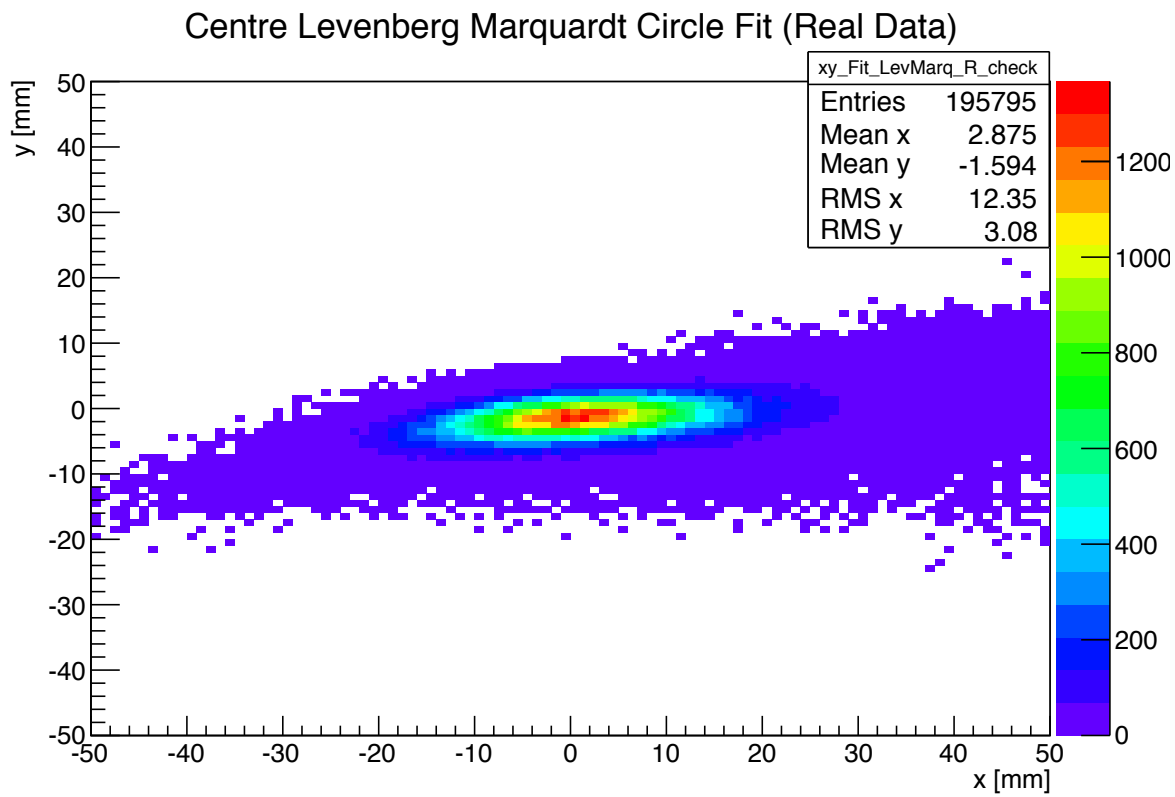
180 GeV: protons (67 %) + π^+ (30 %) + K^+(3 %)

Circle centre – Geometric fit (no cut)

MC



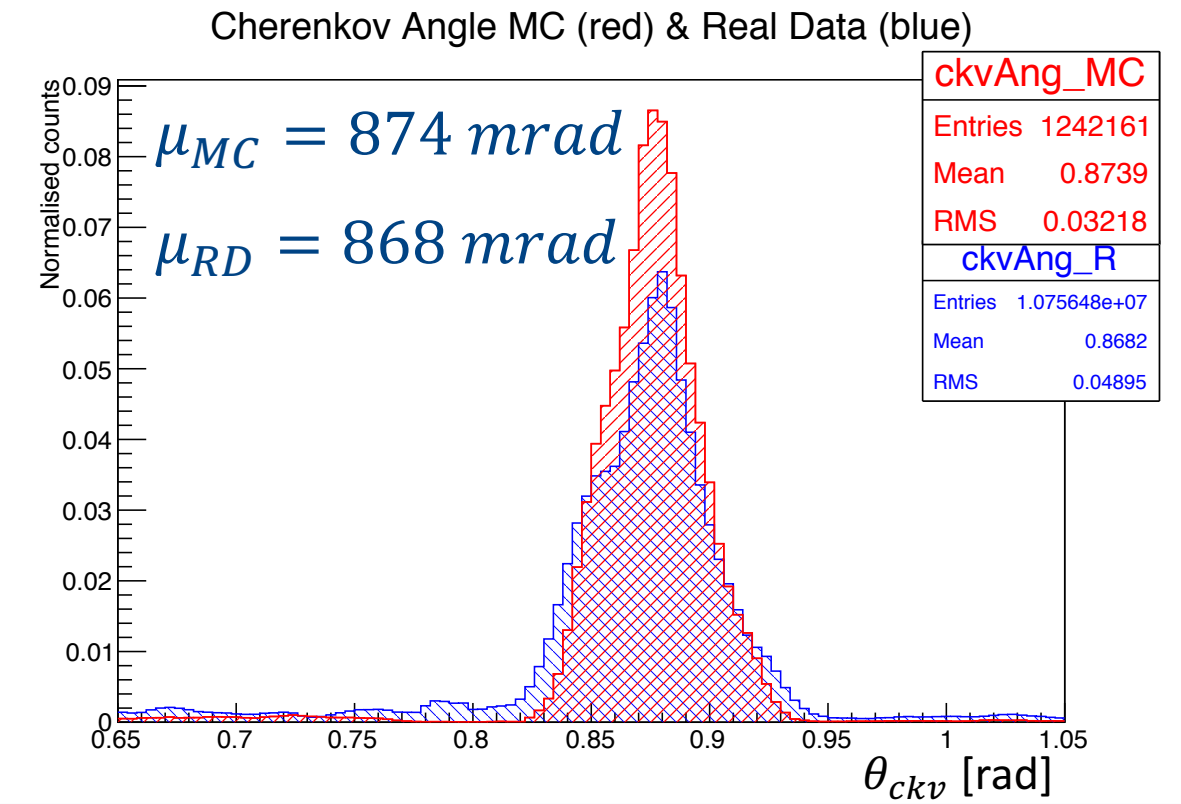
Real data



Cherenkov angle

RED: Simulation
BLUE: Data

Cherenkov angle reconstructed for every hit:



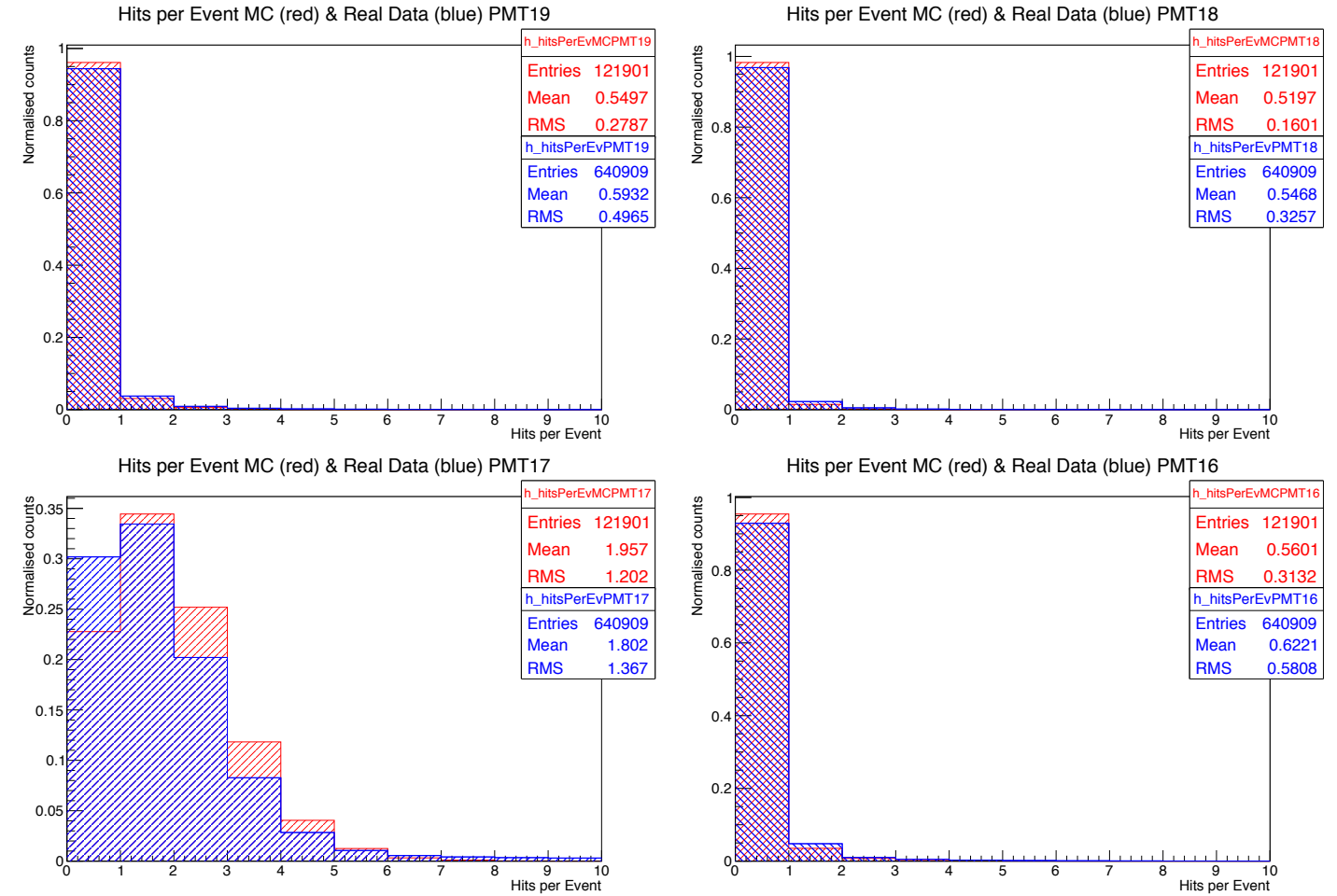
Cherenkov angle calculated:

$$cos\theta_{ckv,calc} = \frac{1}{\beta \cdot n_{rad}(\lambda)}$$

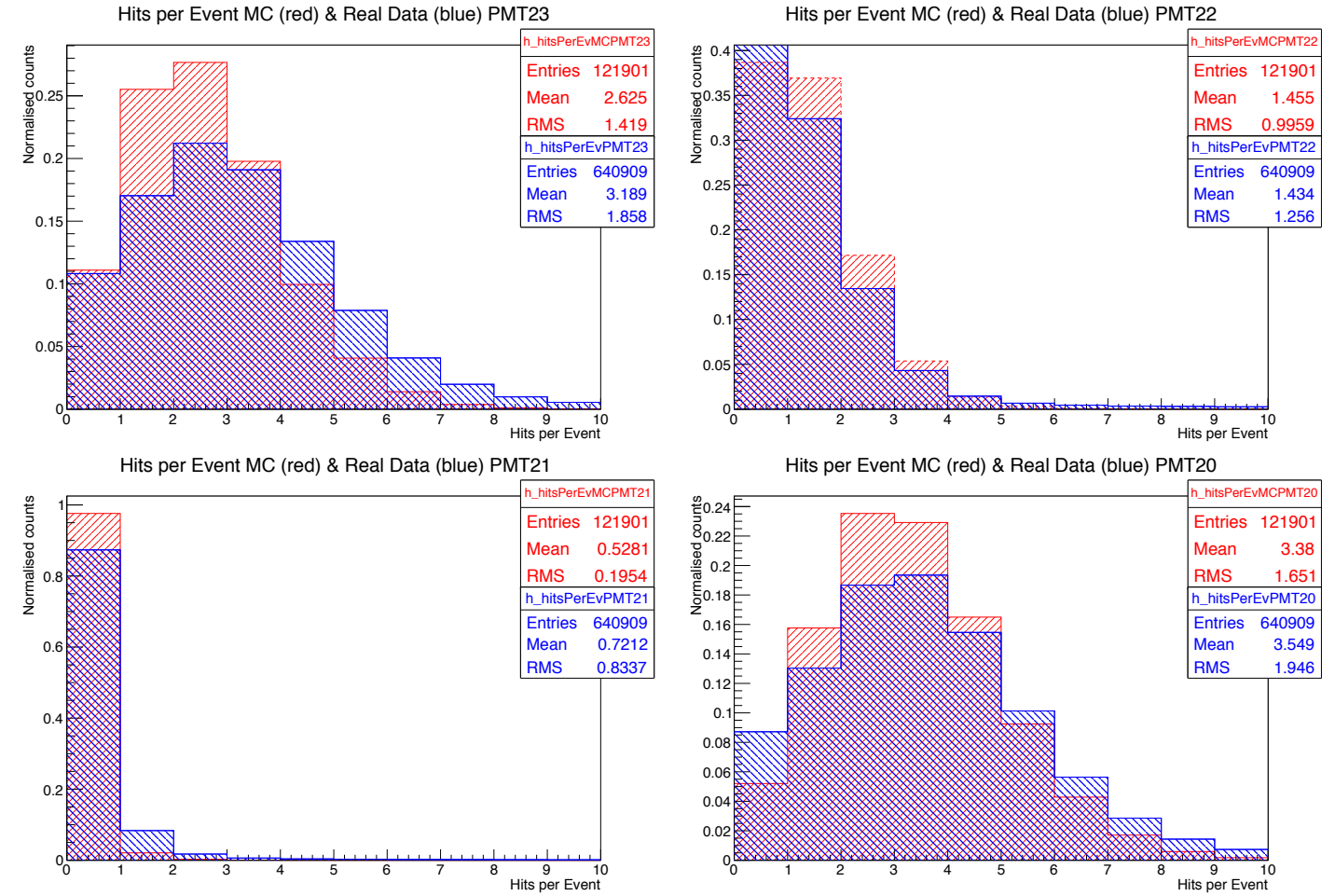
$$\theta_{ckv,calc}(n_{max} = 1.56) = 875\,mrad$$

$$\theta_{ckv,calc}(n_{min} = 1.55) = 870\,mrad$$

Hits per MaPMT – EC-T



Hits per MaPMT – EC-MT



Hits per MaPMT – EC-B