EVENT RECONSTRUCTION

in TESLA CALORIMETER

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The copy of this talk one can find at the http://www.desy.de/˜morgunov

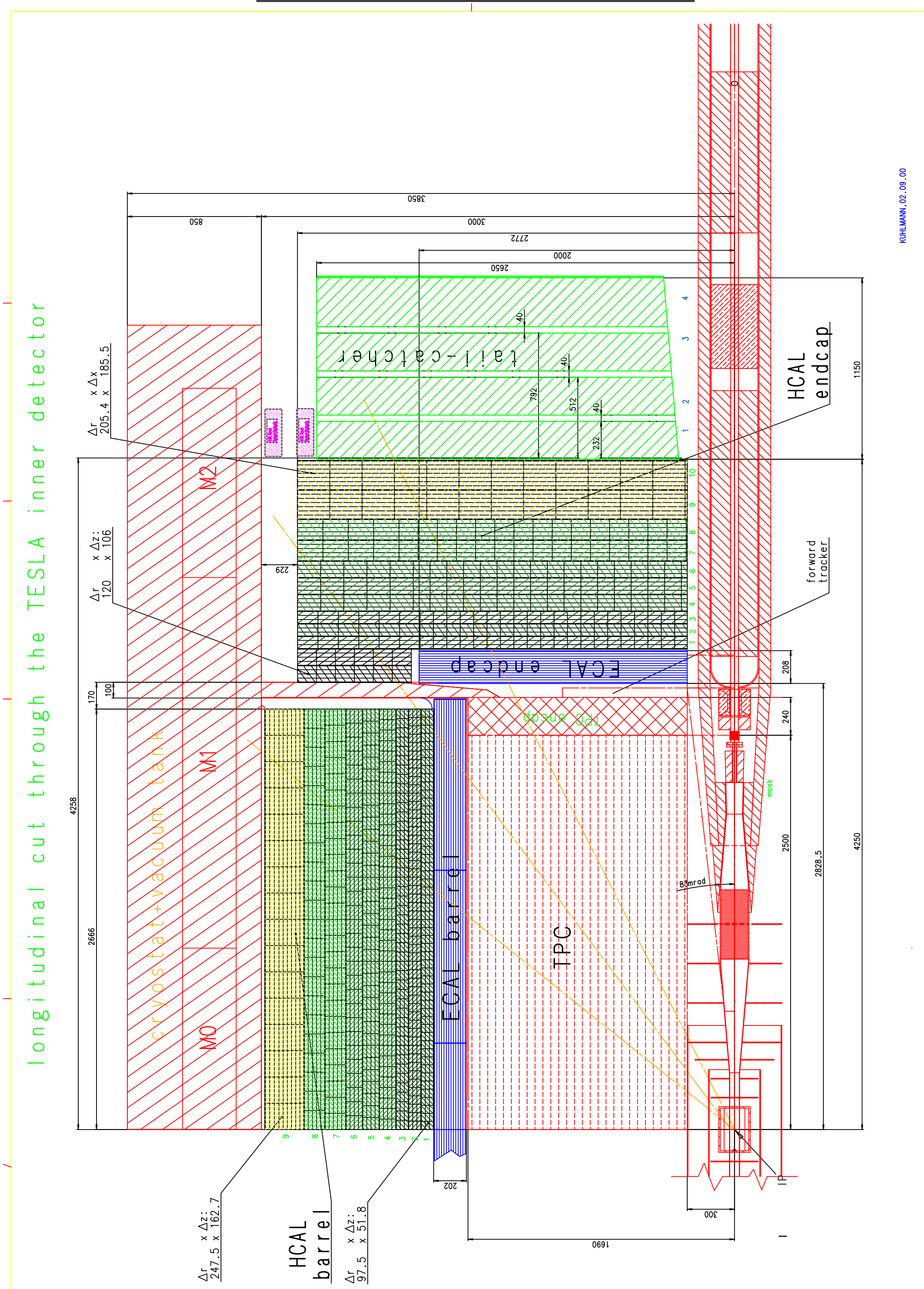
NEW CALORIMETRY

Preface

A new era in calorimetry will be started with the fine sampling
and high spatial segmentation calorimeter;
such a calorimeter *can* measure all properties of particles
energy, direction, momentum and particle type
with reasonable accuracy.

Technique required is close to a real pattern recognition $\rightarrow$ find not only clusters, but also try to measure as many parameters as possible with the calorimeter (energy, momentum, particle type ...)

TESLA Detector



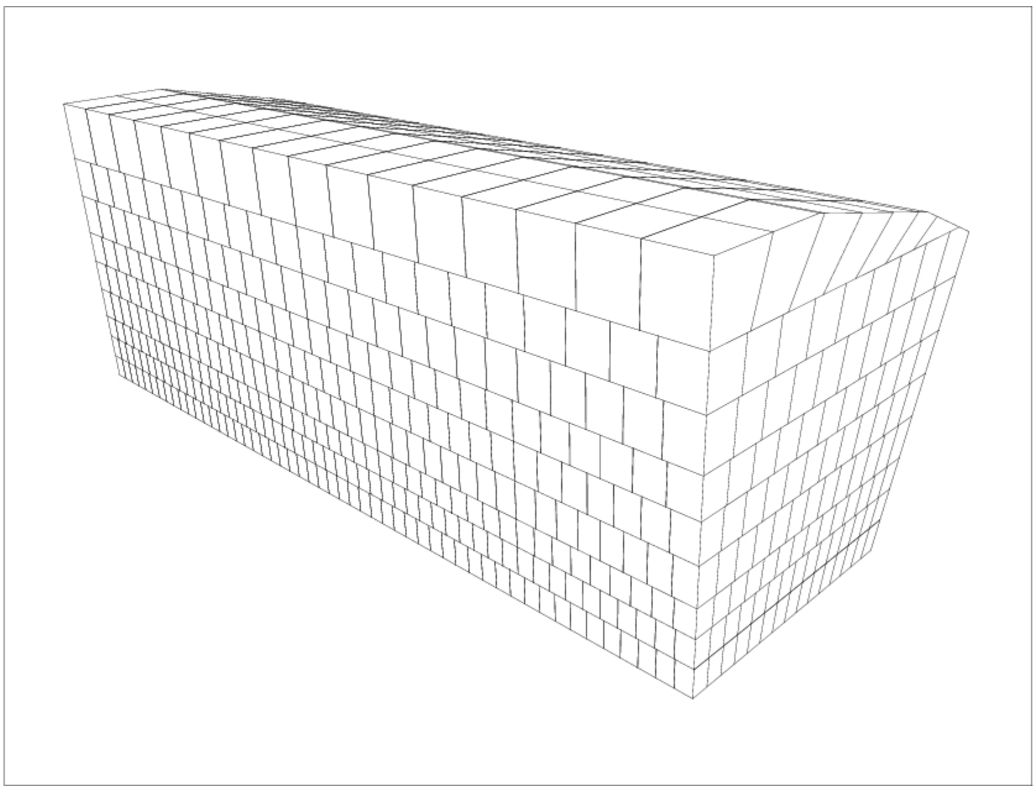
TESLA Calorimeter structure

Sampling structure

ECAL 1	W – 0.14	G10 – 0.1	Si – 0.05	G10 – 0.1	cm
ECAL 2	W – 0.42	G10 – 0.1	Si – 0.05	G10 – 0.1	cm
HCAL	Fe – 2.0	Sc – 0.5	Gap – 0.15		cm

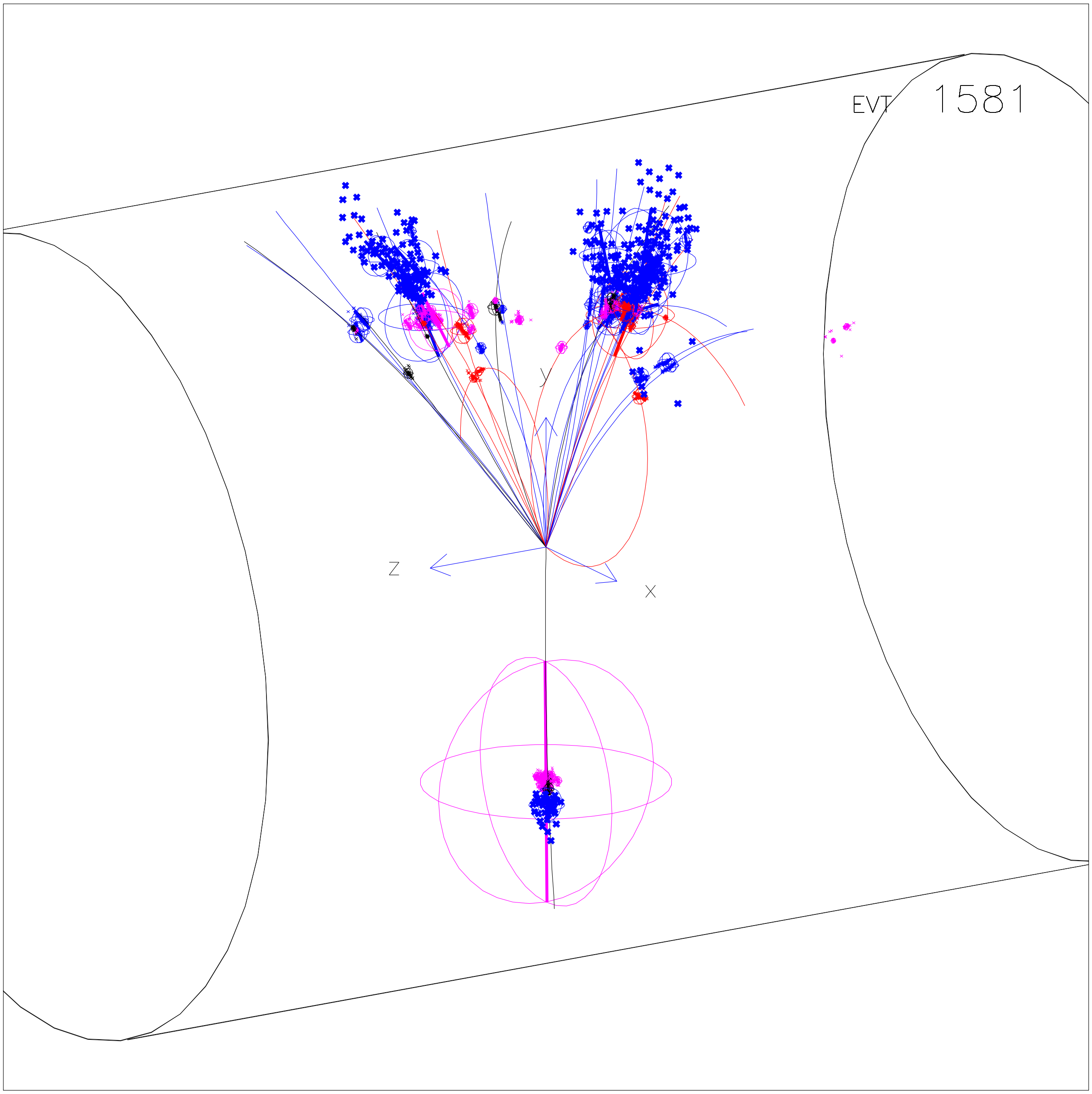
ECAL electronic cell structure – pad size $1 \times 1\ cm^2$

HCAL module



HCAL electronic cell structure – pad sizes from 5×5 up to $20 \times 20\ cm^2$

Event

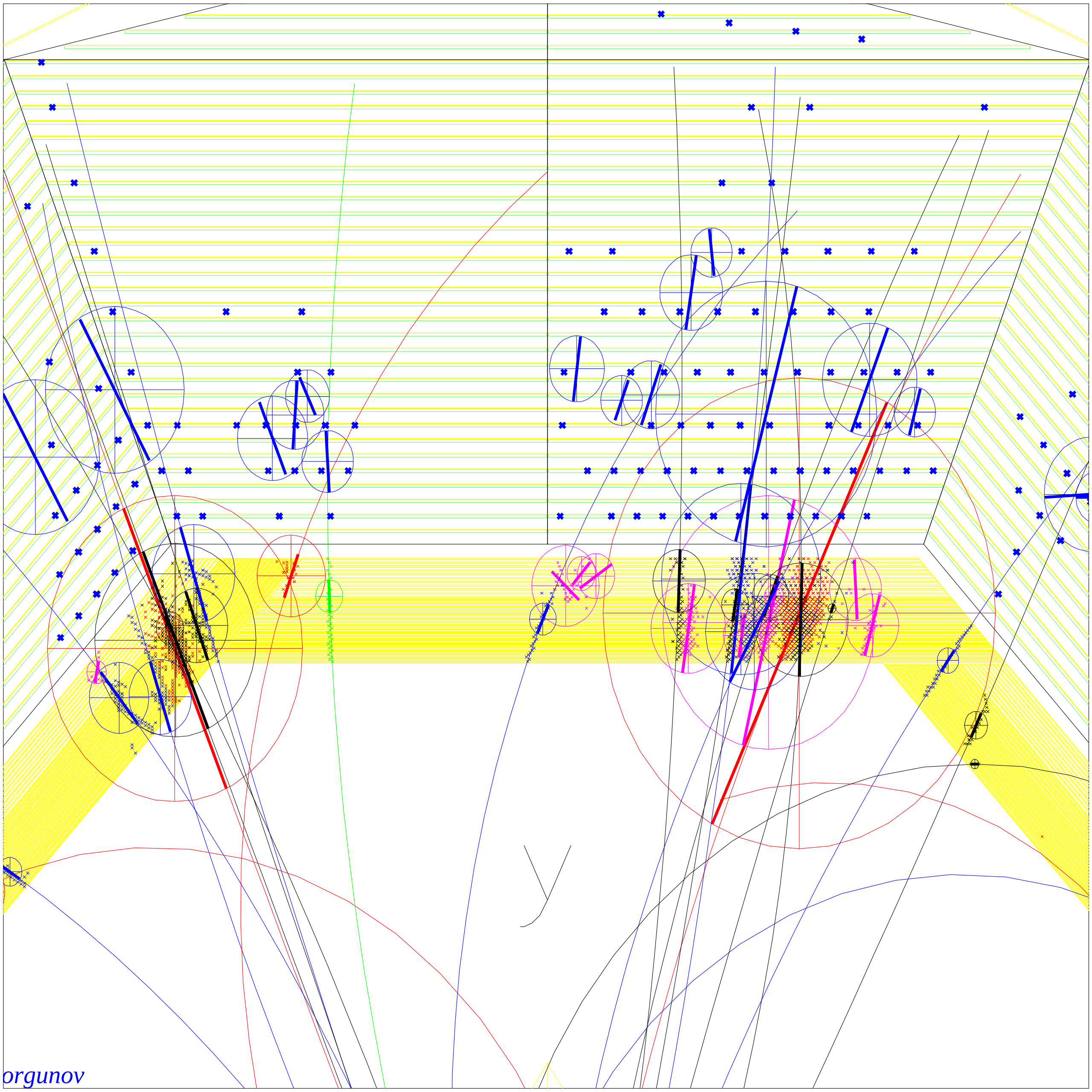


$$e^+e^- \to \gamma Z^0 \to \gamma\ q\ \bar{q}$$

– boosted hits

– many close–by particles

Event sample – close–up view



Two Z^0 jets from the reaction: $e^+e^- \rightarrow \gamma Z^0 \rightarrow \gamma\ q\ \bar{q}$

– area of circles proportional to particle energy

– lines are results of helix constrained to vertex

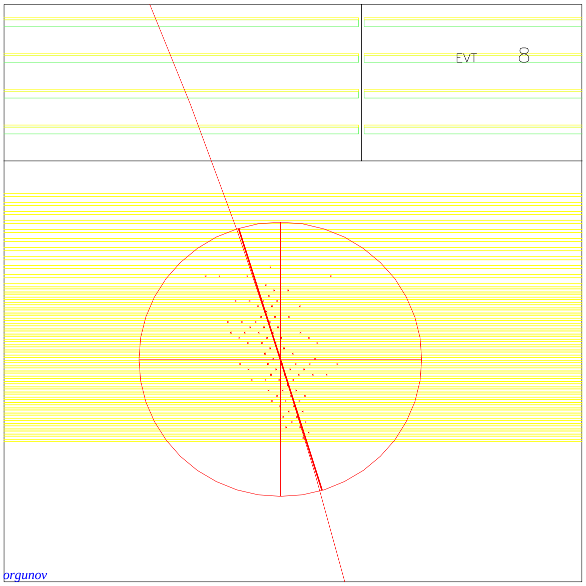
– color indicates particle hypothesis

Logic of the Reconstruction

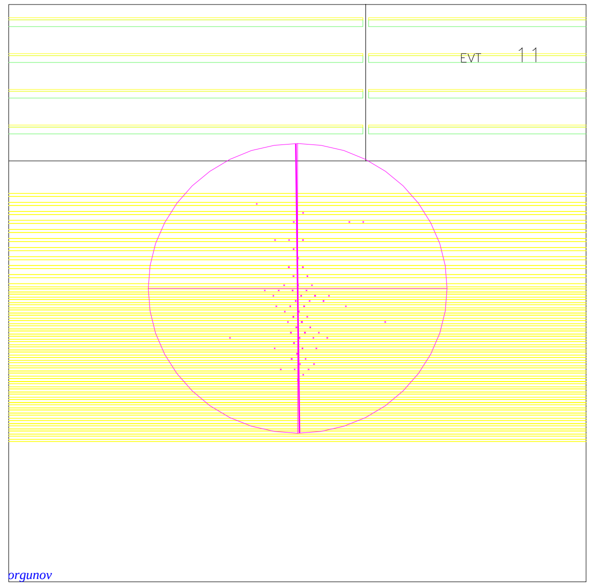
- Find super–clusters in $\Theta - \Phi$ coordinate space by combining all calorimeter hits which are within a certain distance Δ_1 in $\Theta - \Phi$ space.
- If two super clusters overlap, the energy inside the overlap region is assigned to both super–clusters weighted by the total energy of the respective cluster.
- Calculate properties of the super-cluster: energy, center position, main axes of the super–cluster.
- Find clusters inside the super–cluster by combining hits assigned to the super-cluster which are within a certain distance $\Delta_2 < \Delta_1$.
- Repeat the procedure for overlaps
- Calculate cluster properties:
  - ▷ energy
  - ▷ hit density, number of hits
  - ▷ center position of the cluster (both transverse and radial)
  - ▷ main axes of the cluster
  - ▷ Attempt a helix fit using the direction of the cluster and the primary vertex point as input.
  - ▷ Calculate a particle hypothesis based on cluster shape for electron, muon, hadron
- Clean up by picking up hits which are yet un-assigned and assign them to the closest cluster.
- Merge clusters whose main axes are overlapping within a certain window
- Recalculate all cluster properties.
- Do this for both ECAL and HCAL separately.
- Attempt to join HCAL clusters to ECAL clusters.
- Attempt to join CAL clusters to tracks from the central tracker.

Cluster shapes

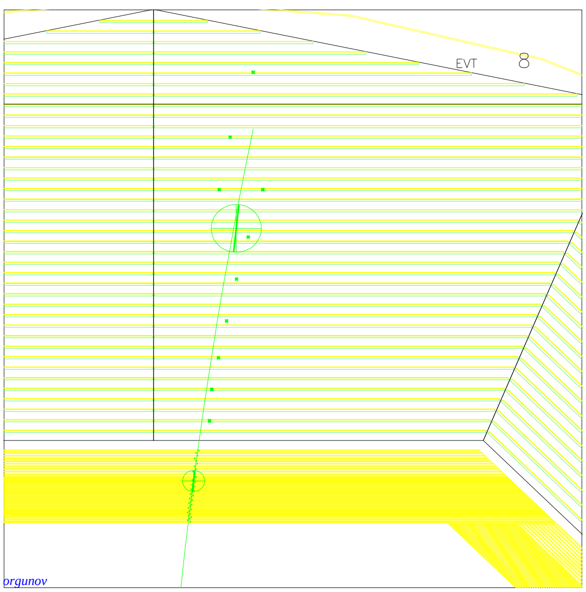
Electron



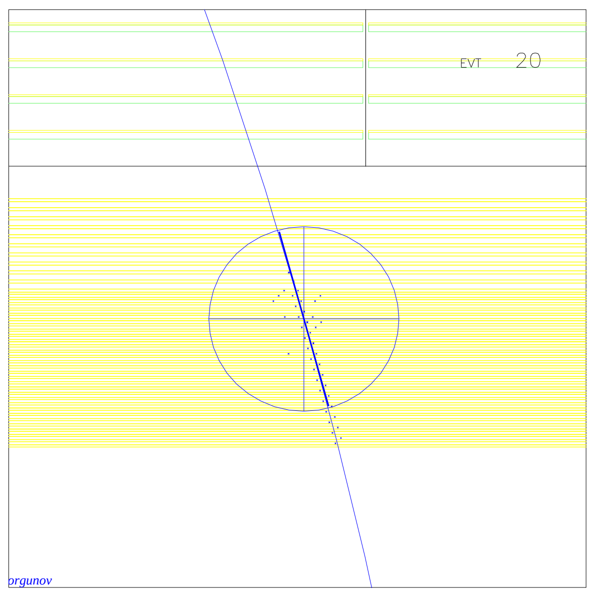
Gamma



Muon

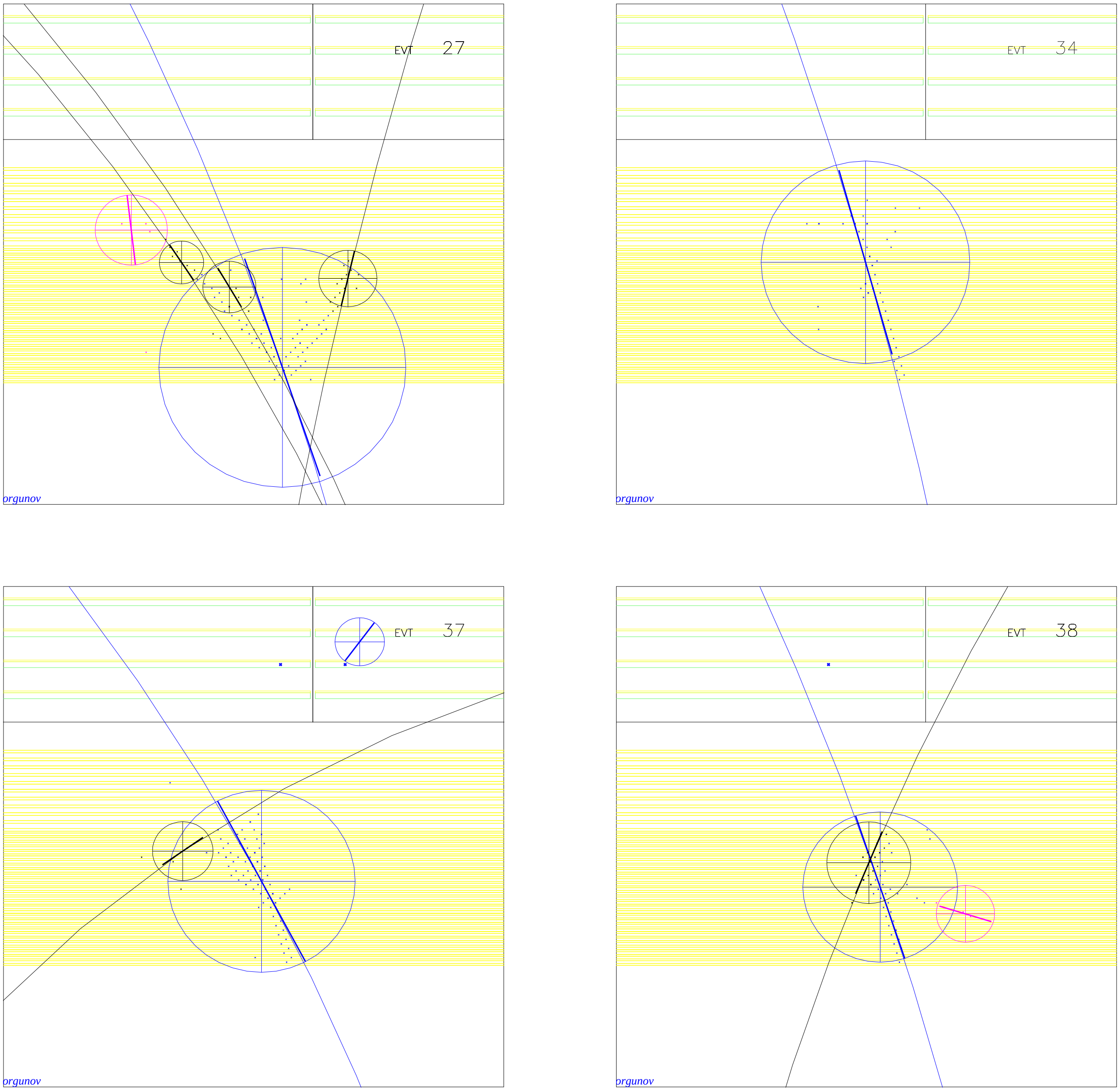


π meson



Cluster shapes

π mesons



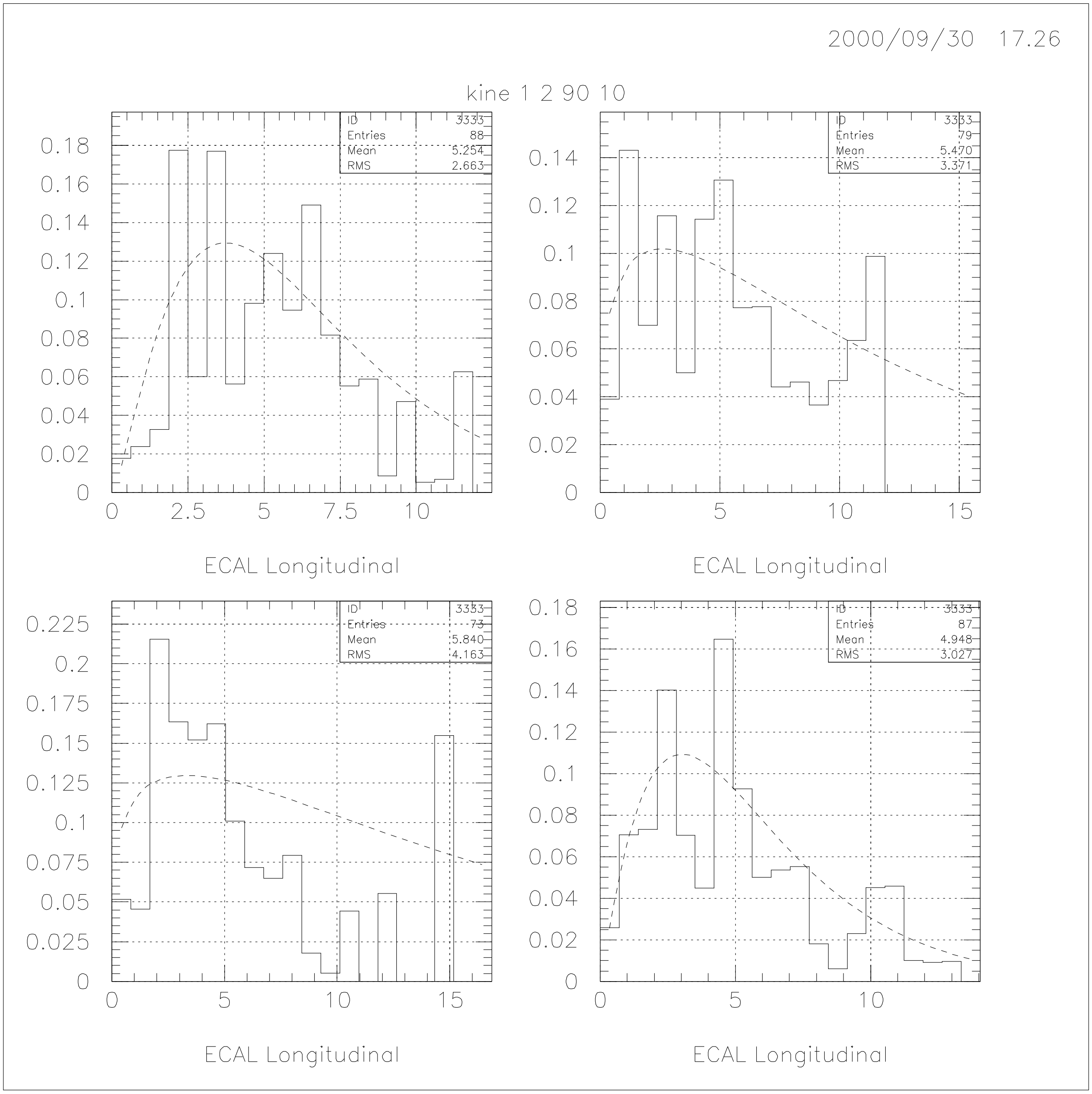
Cluster properties

One can calculate this set of cluster properties and parameters:

- Cluster energy and hit density;
- Cluster center position $\vec{r_s} = \sum_i \vec{r_{h_i}} w_i \,/\, \sum_i w_i$.
- Direction cosines of the main cluster axes are defining from maximum sum of projections of hit vectors to this axes. (that is close to usual event THRUST definition) $\chi^2_{max} = \sum_i \frac{(\vec{r_{h_i}} - \vec{r_0})(\vec{r_s} - \vec{r_0})}{|\vec{r_s} - \vec{r_0}|^2} w_i$
- Helix parameters from cluster center to IP are defining from cluster center position and direction cosines of the main cluster axes
- Parameters of longitudinal energy distribution of EM–shower (see PDG) $dE/dt = E_0 \frac{(\beta\, t)^{(a-1)}\, e^{(-\beta\, t)}}{\Gamma(a)}$
- Cluster shape numerical description uses the density of first and second part of cluster, “theoretical” density for electromagnetic and hadronic cascades, number of empty layers in the cluster, cluster radius, prediction from helix parameters .....

Longitudinal shower profile

$2\ GeV$ photon at 90 degree to the calorimeter face



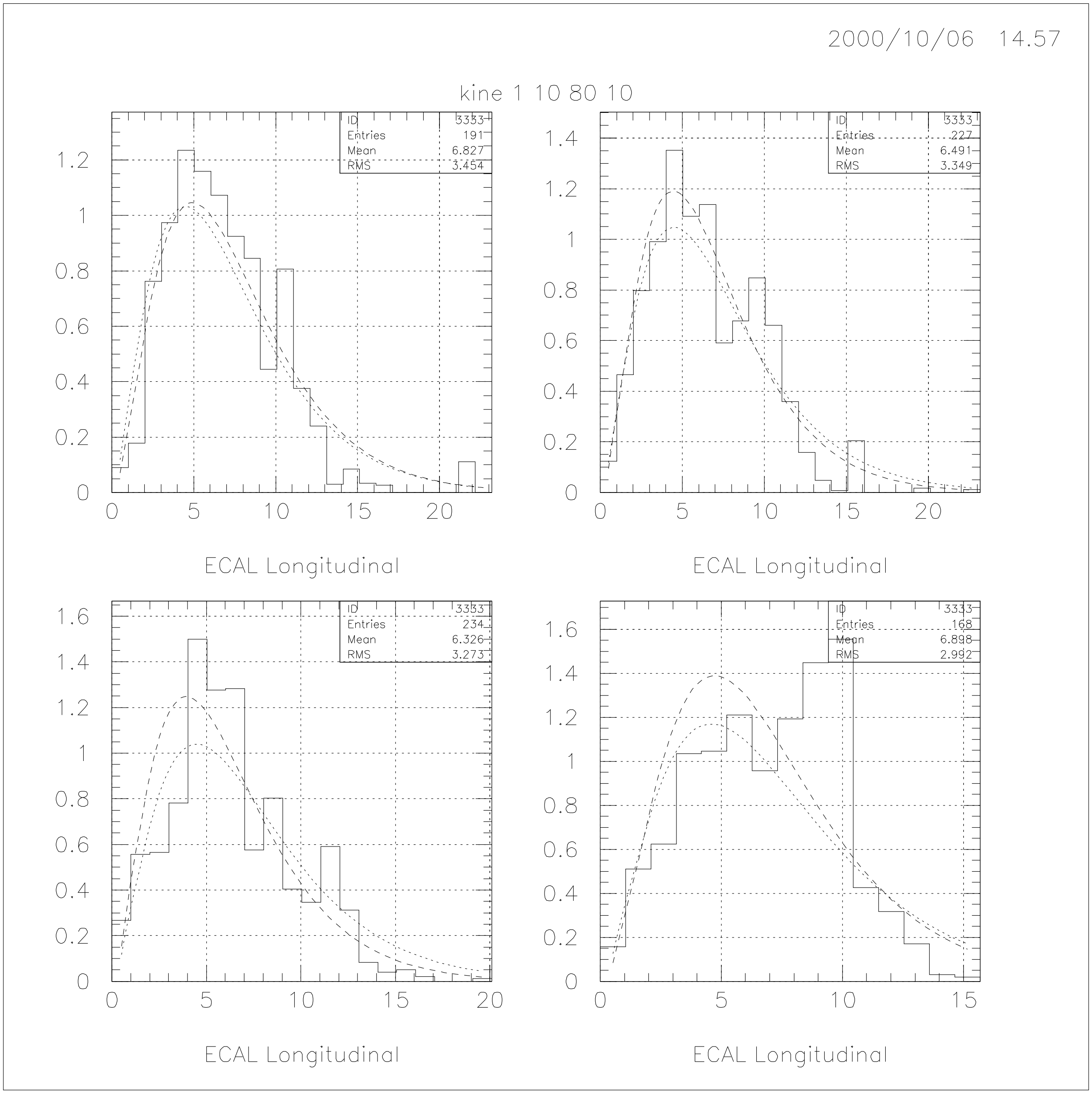
One can see a big deviation of every shower with the same energy.

Photon electromagnetic showers were shifted to its beginning.

Axes: Y – an arbitrary units, X – X_0 units.

Longitudinal shower profile

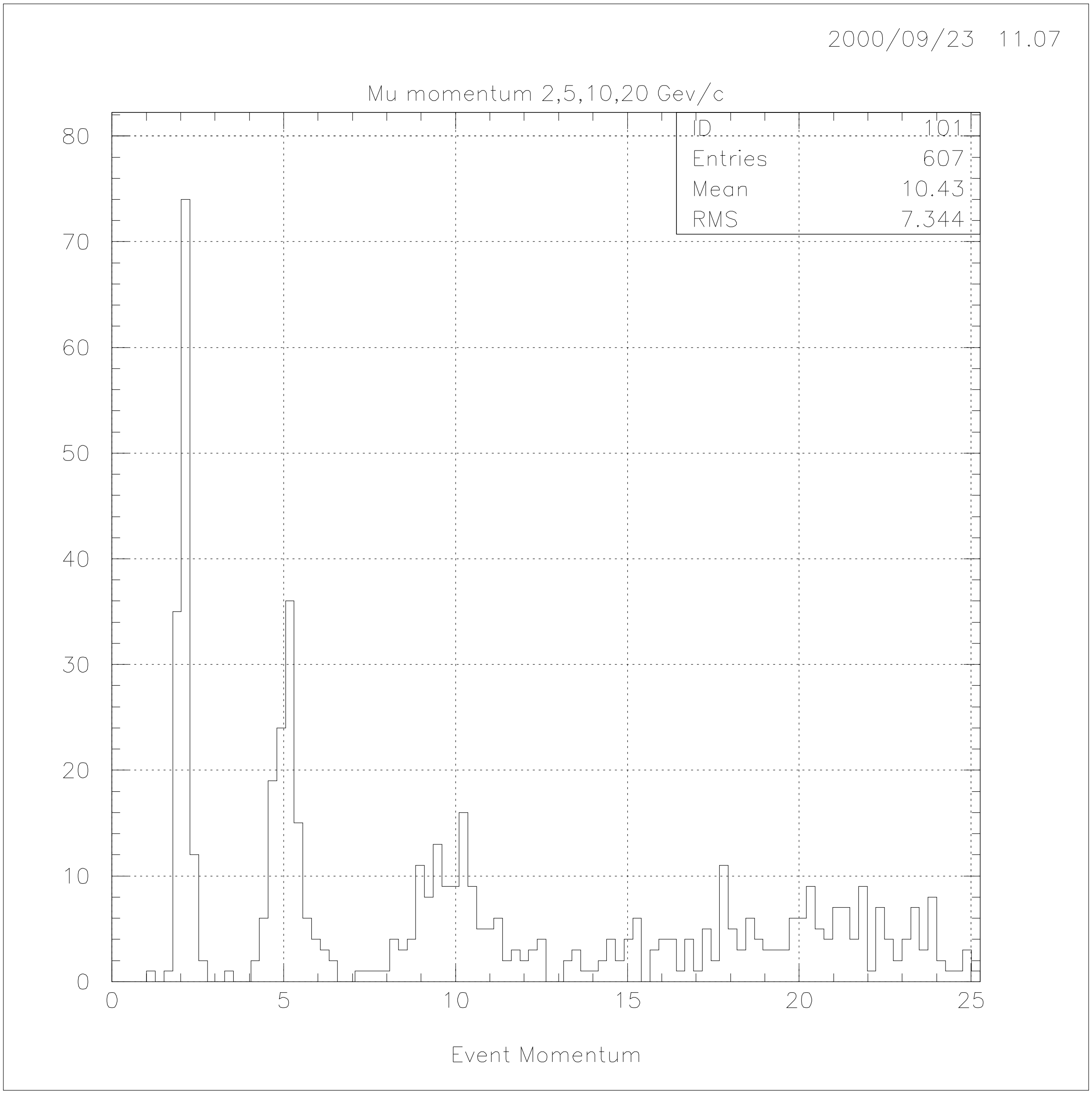
$10\ GeV$ photon at 80 degree to the calorimeter face



Fit (dashed line) and prediction (doted line)

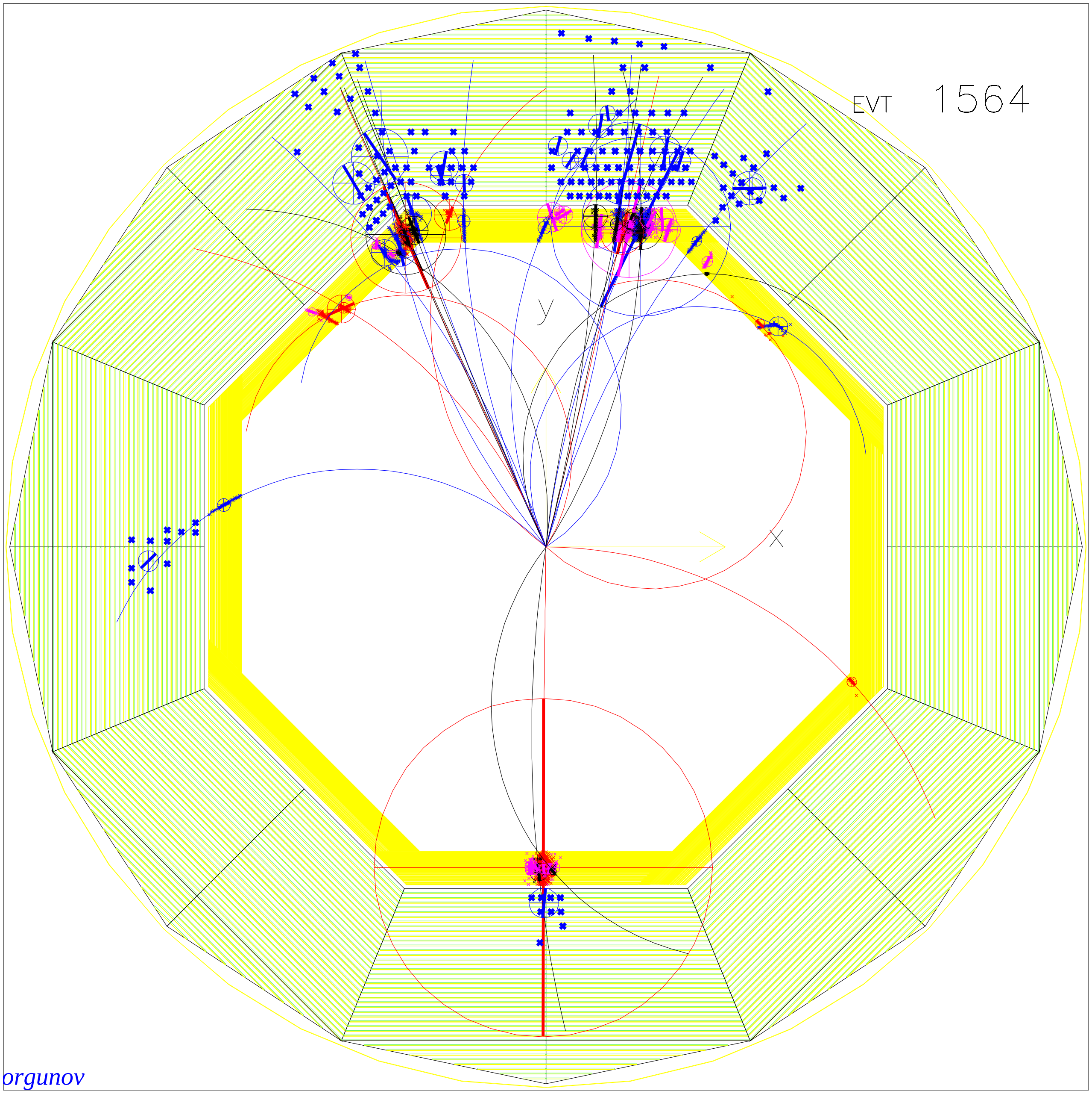
The predictions were made by the statistical definition of the electromagnetic shower parameters in separate runs with fixed photon energy.

Reconstructed momentum



Electromagnetic calorimeter can reconstruct the momentum by helix–fit to IP. The same histogram can be shown for electrons or even for hadrons but with worse resolution.

Event sample



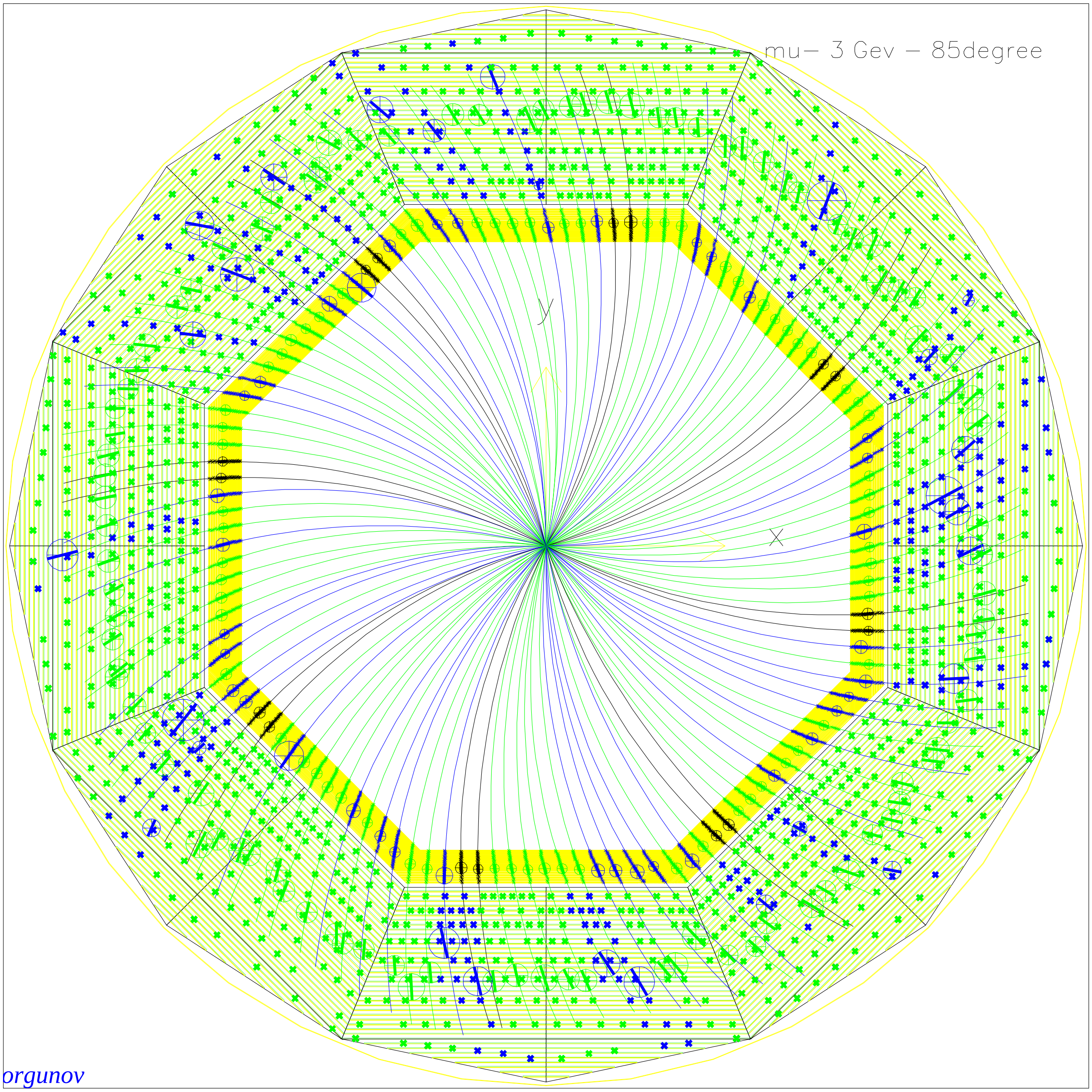
Sometimes helix fit to IP allows to find hadron cluster that is at the unusual position, as it is shown at the left side of picture.

Particle hypothesis

Hypothesis assignment for muon with 3 GeV momentum.

Green color means μ–hypothesis,

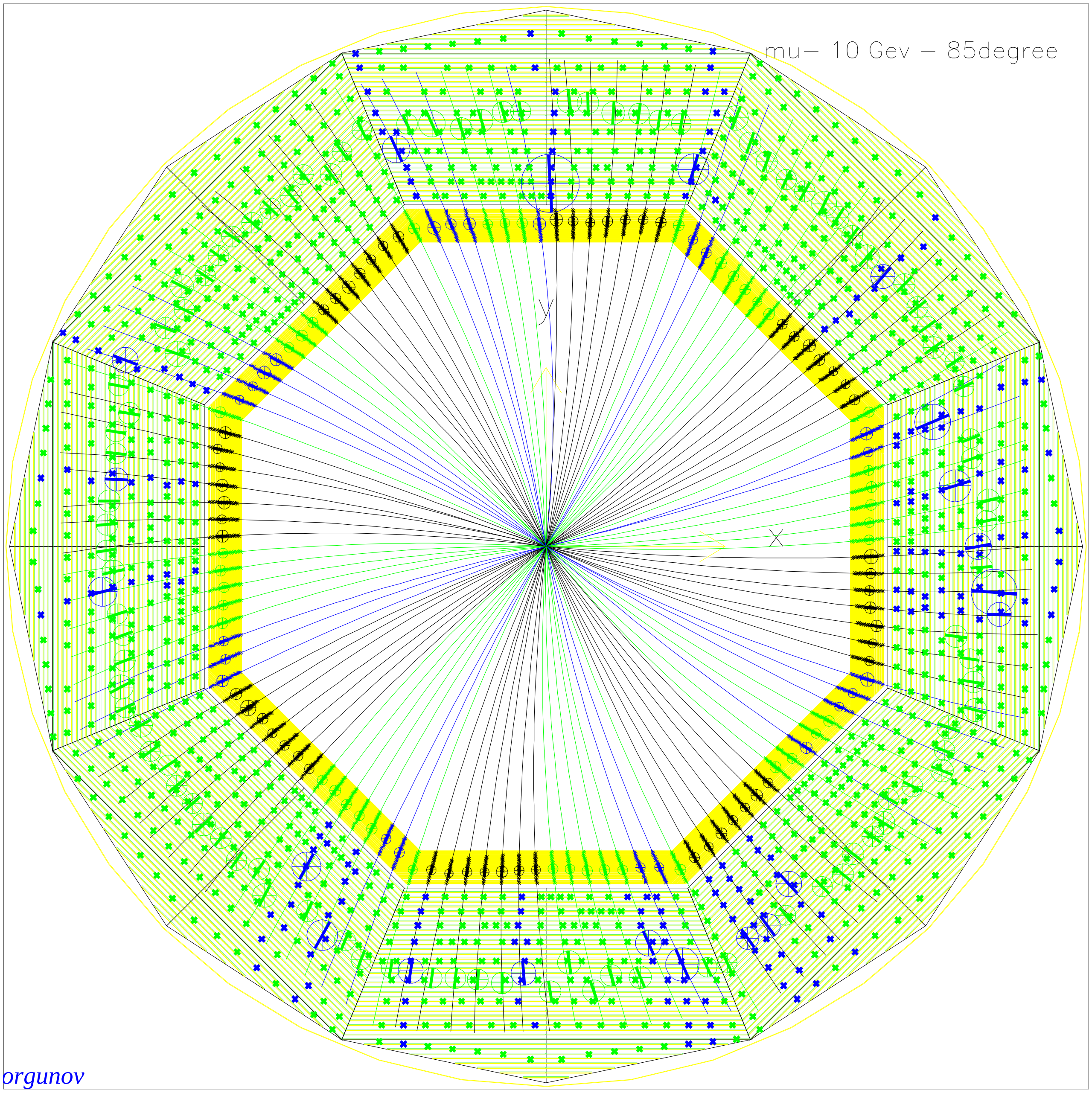
blue and black are hadrons.



Curves are helix fit hypothesis constrained to primary vertex.

Particle hypothesis

The same for muon with 10 GeV momentum.

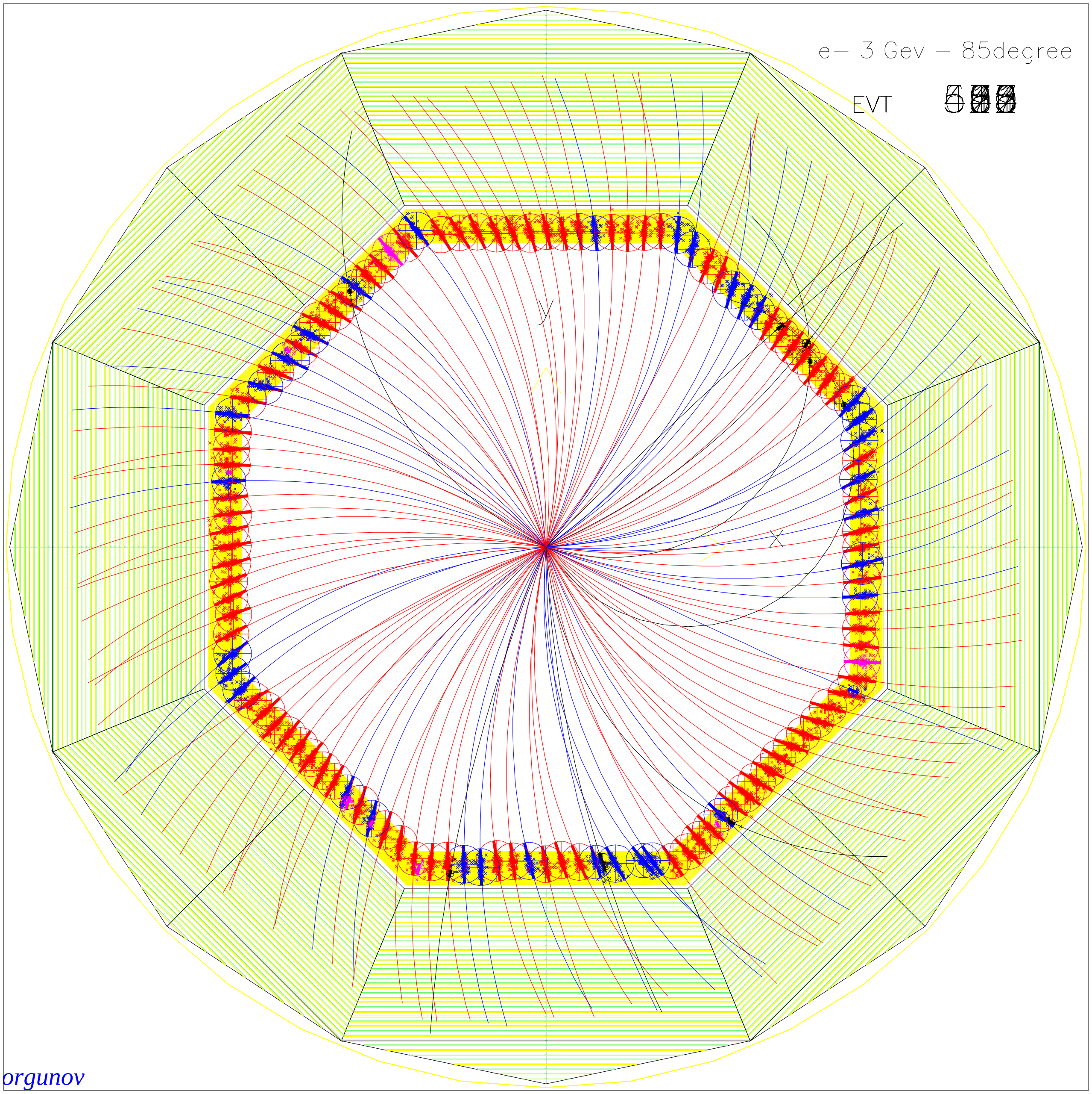


The artifact – black regular structure is coming from the bug in the GEANT geometry of calorimeter that still exist (no first hit in ECAL for charged track).

Particle hypothesis

Hypothesis assignment for electron with 3 GeV momentum.

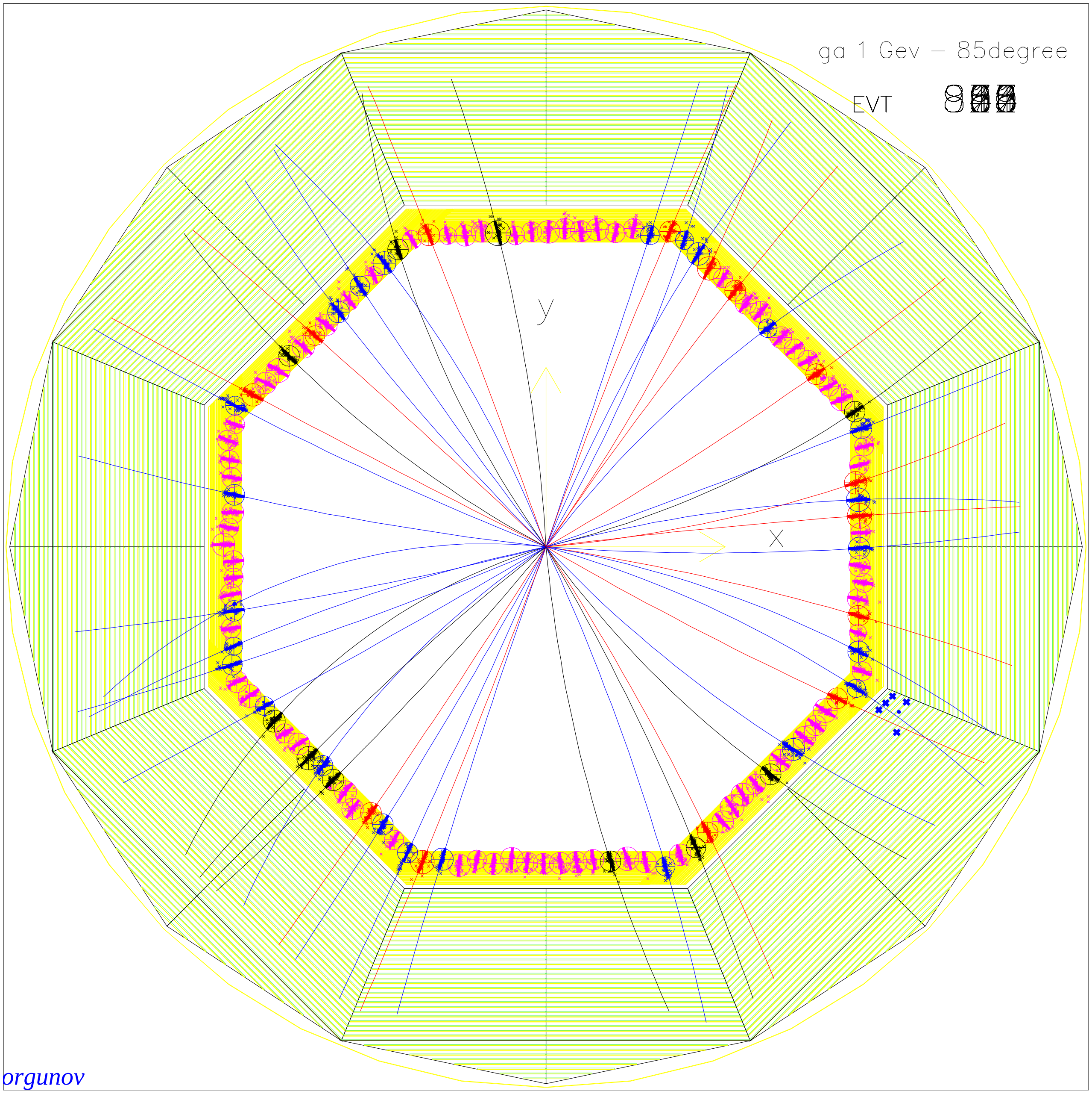
Red color means electron–hypothesis,



Curves are helix fit hypothesis constrained to primary vertex.

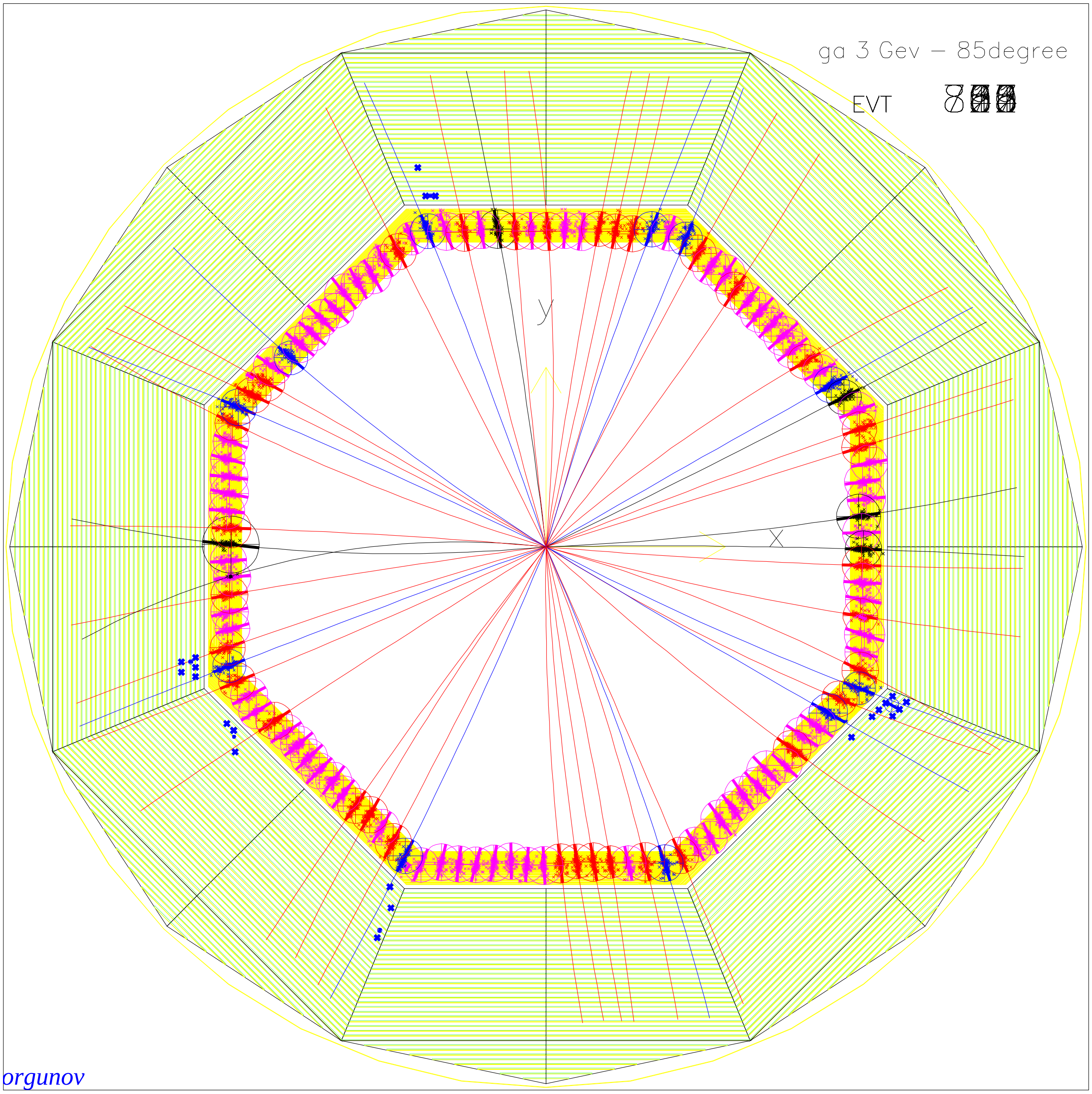
Particle hypothesis

Hypothesis assignment for photon with 1 GeV momentum.



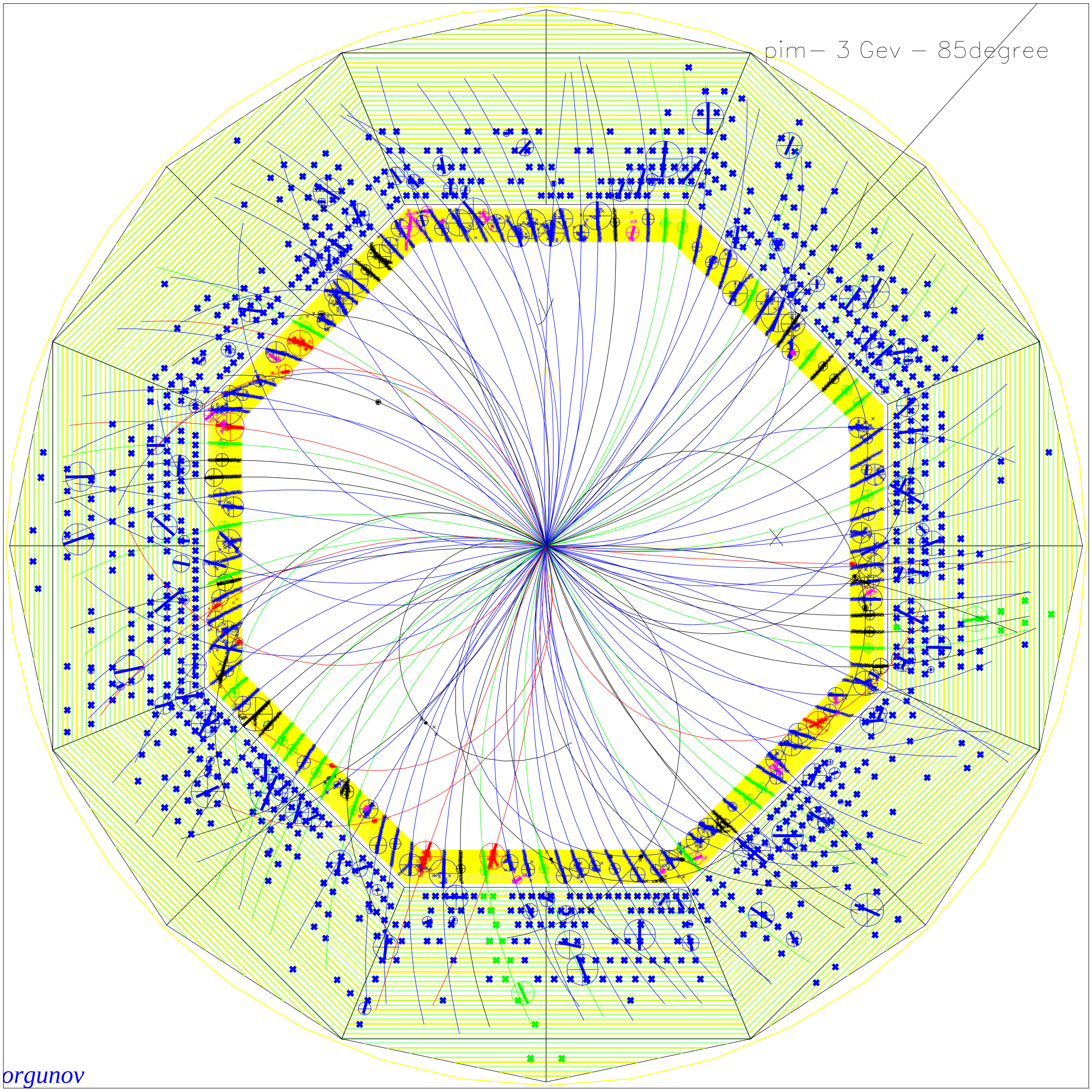
Particle hypothesis

Hypothesis assignment for photon with 3 GeV momentum.



Particle hypothesis

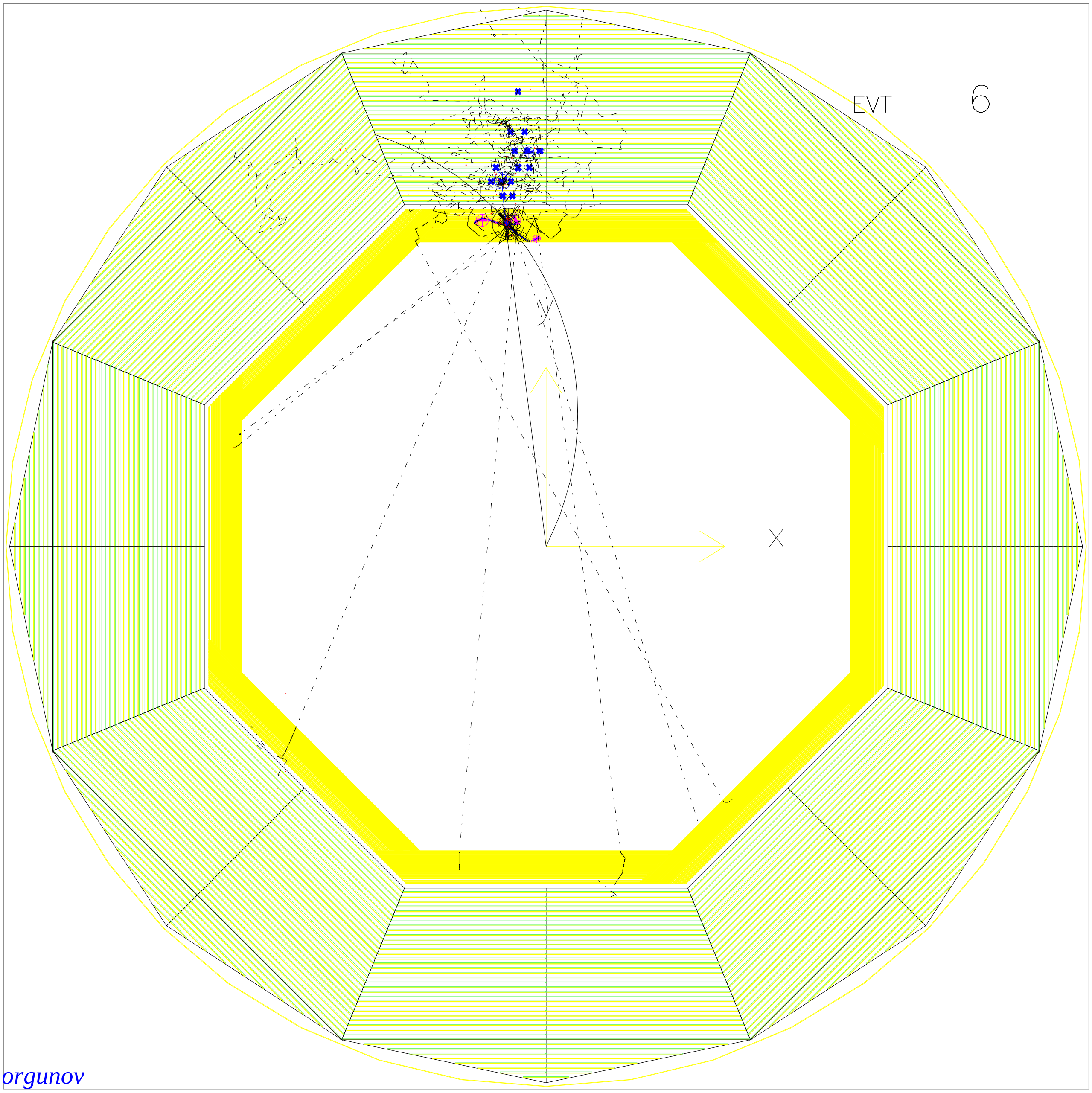
Hypothesis assignment for π^{-}–meson with 3 GeV momentum.



It will be too surprising to see the same quality of the helix–fit for hadrons as for muons.

One hadron sample

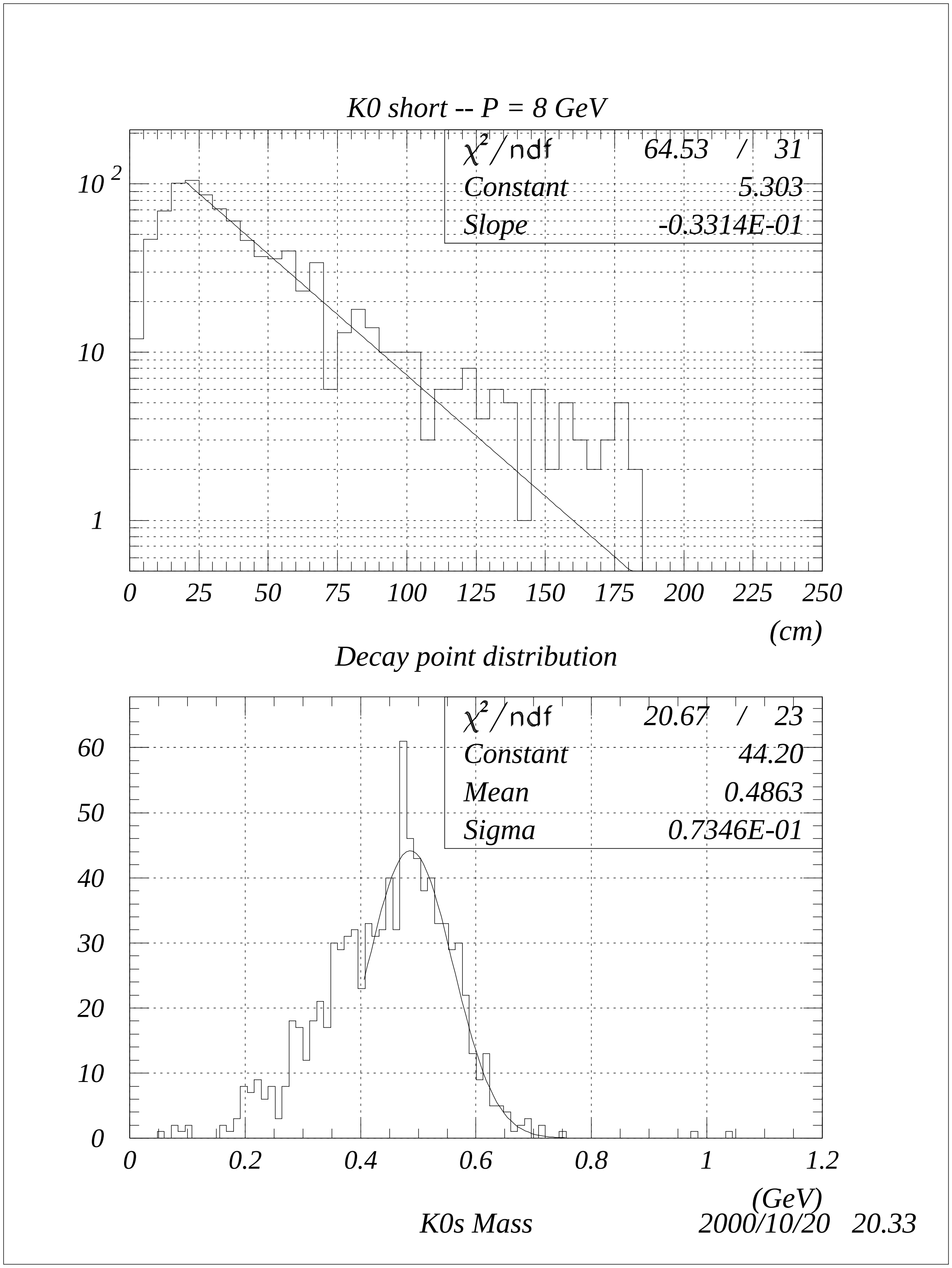
π–meson $10\ GeV$ with neutron tracks from hadron shower.



Programs

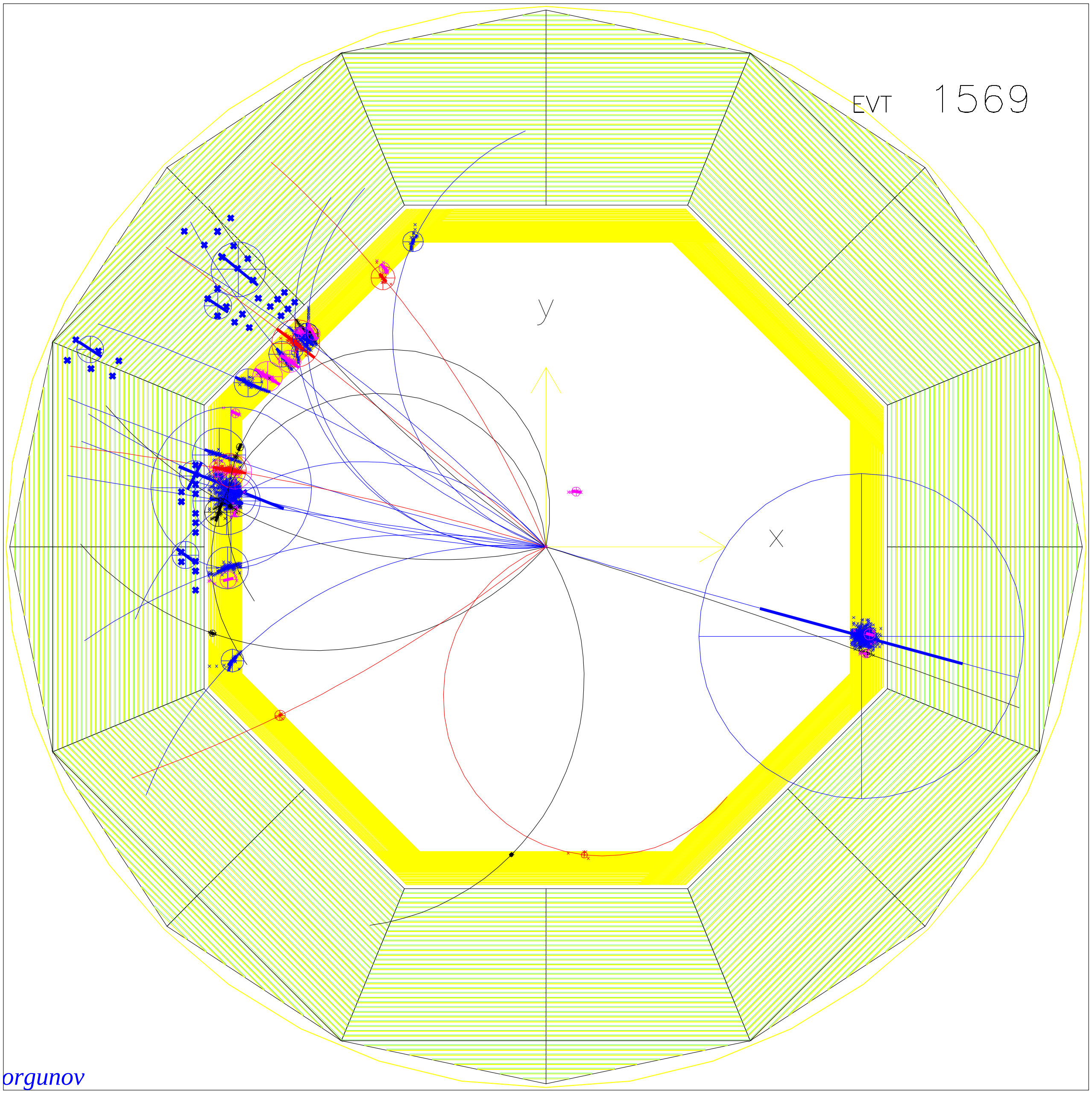
- HCAL barrel geometry with electronic cells structure – done
- HCAL barrel hit packing for the output – done
- HCAL barrel hit unpacking (reconstruction) to XYZ – GEANT mother coordinate system (program works inside GEANT environment and it uses GEANT geometry routines !) – done
- Super–Cluster and Cluster of hits search in ECAL and HCAL barrel – done
- Sub–Cluster search in HCAL to make energy weighting for better HCAL energy resolution – can be written
- Shower analysis – done
- Track finder in ECAL and HCAL – done
- Merge ECAL and HCAL to one pseudo–particle – will be written
- Merge calorimeter information with TPC information to replace charged particles parameters to TPC measured parameters and to find the neutral hadrons – will be written
- Event reconstruction and selection – will be written
- Event analysis (the simplest one) – done
- Code consists of about 15 K FORTRAN cards for now.
- CPU time for reconstruction of one $500GeV$ event is about 1 second.

$K_s^0 \rightarrow \pi^0 \pi^0 \rightarrow \gamma\gamma\gamma\gamma$

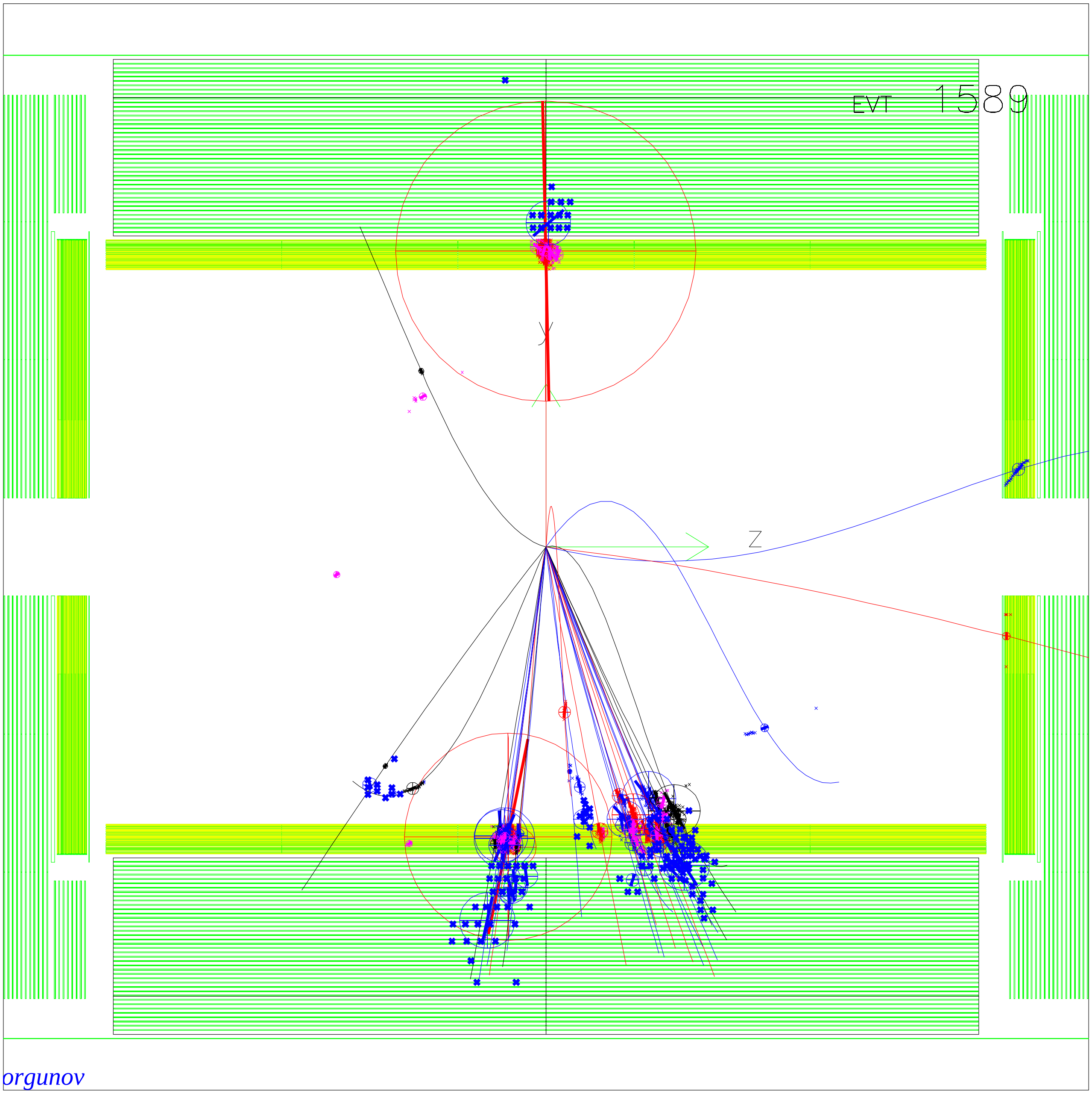


– no kinematic constraint was used at this stage

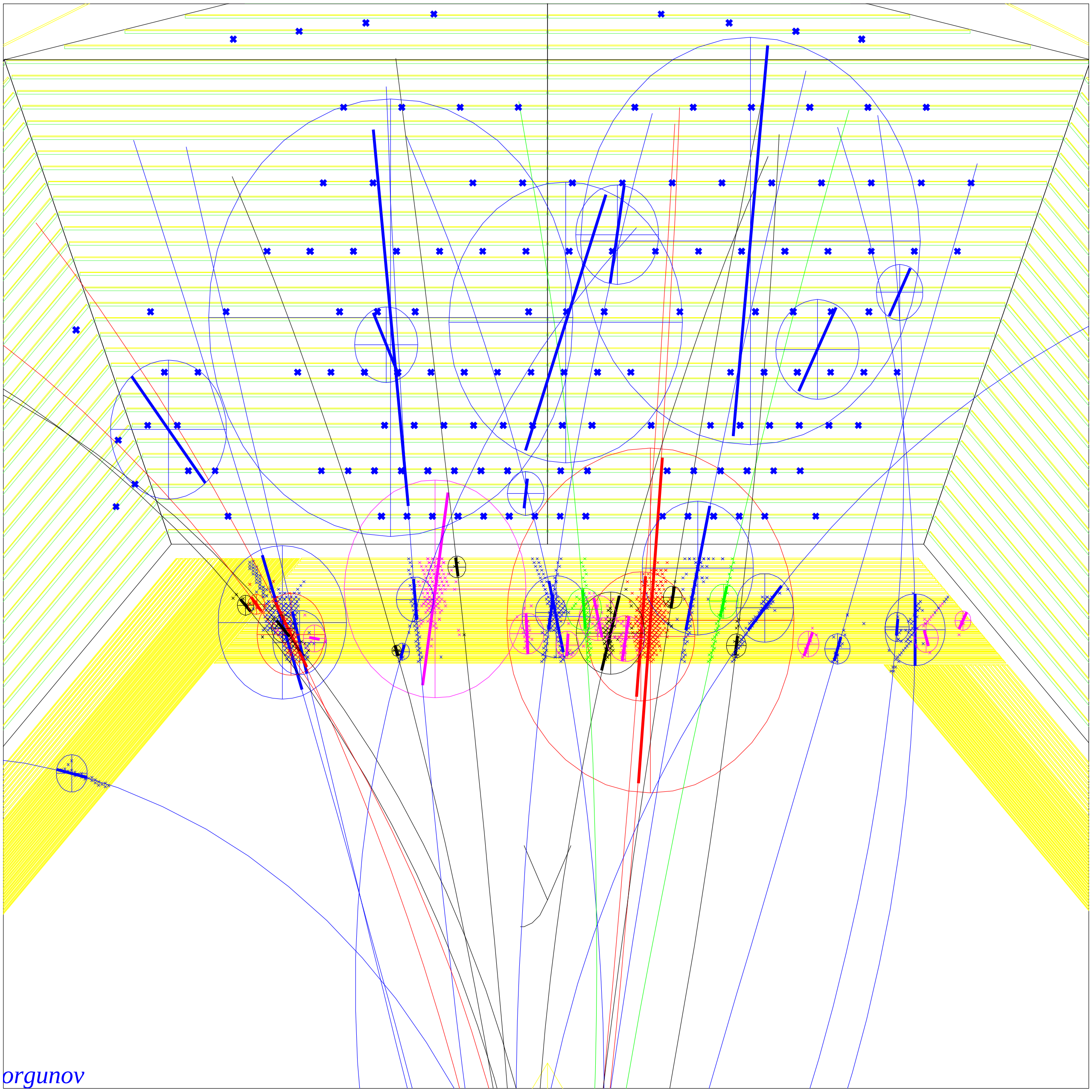
Event sample



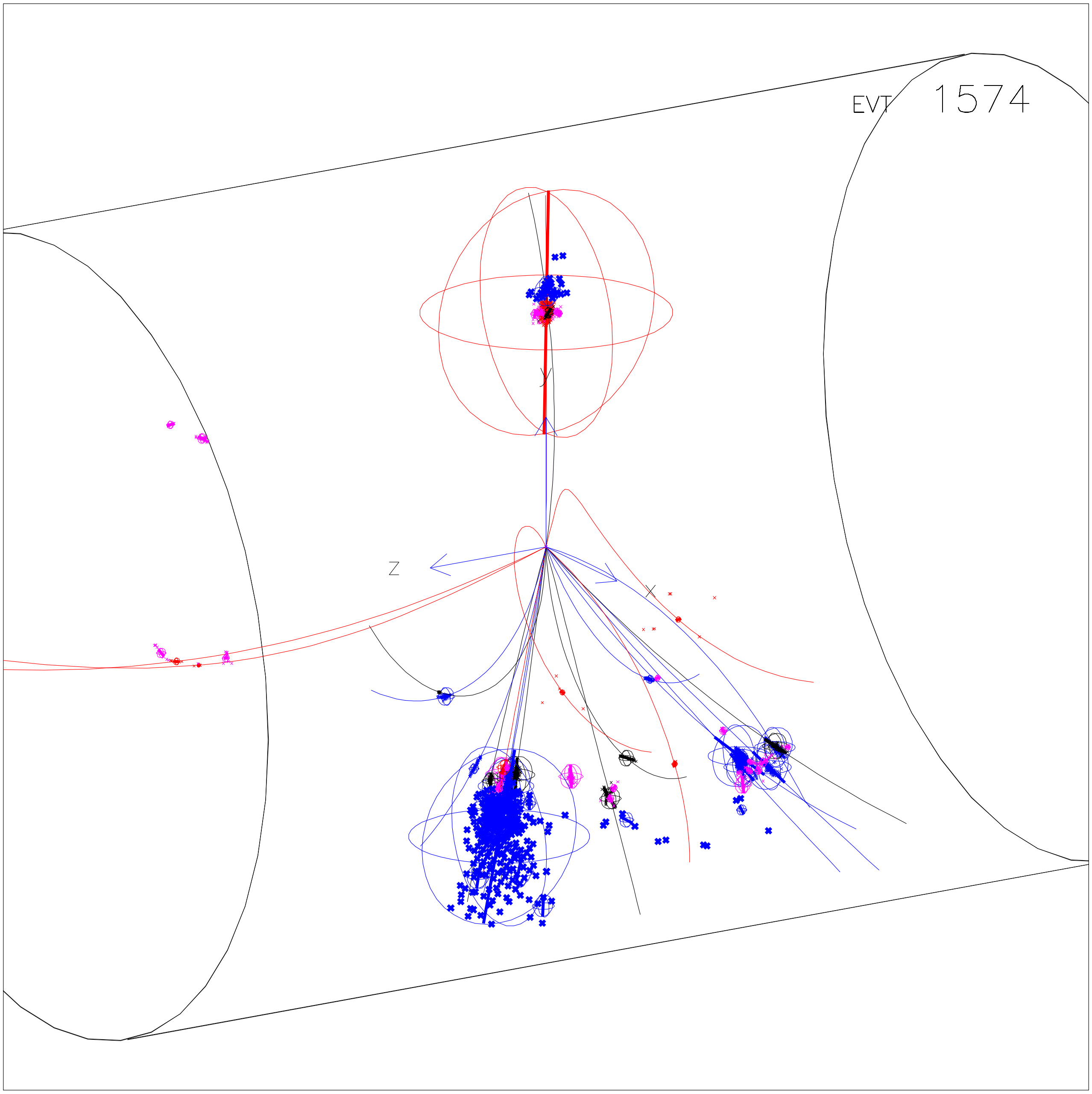
Event sample



Event sample



Event sample



Event sample