Simulation and feasibility studies for the upgraded BM@N set-up

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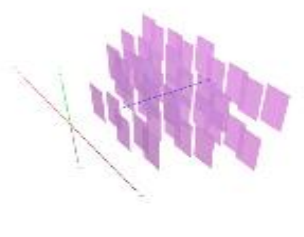
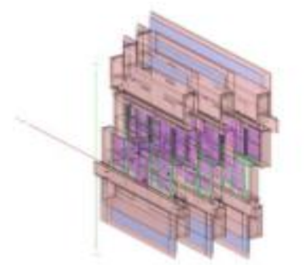
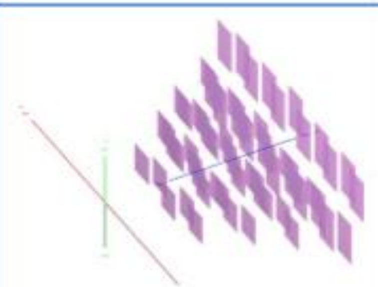
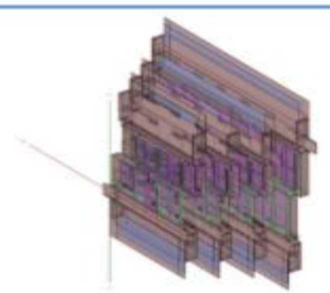
Outline

1. **Detector configurations in run 8**
2. **Feasibility studies**
3. **Track reconstruction based on the Vector Finder approach**

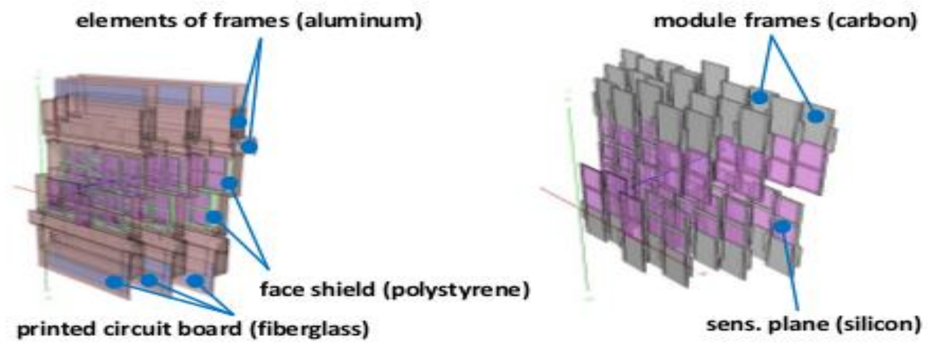
Forward Silicon detector: ROOT geometry

There are two versions of ROOT geometry for each configuration of the Forward Silicon detector: **simplified** and **detailed**.

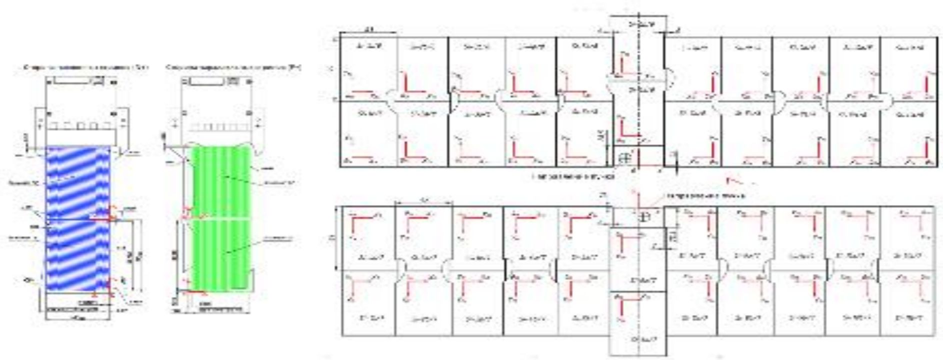
- **Basic ROOT geometry** consists of only sensor elements without any passive materials.
- **Detailed ROOT geometry** completely describes the detector including passive elements such as electronics, housing and supporting components.

Configuration	Basic ROOT geometry	Detailed ROOT geometry
1st configuration	 *42 Si-modules*	 *3 stations (or 6 half-planes)*
2nd configuration	 *64 Si-modules*	 *4 stations (or 8 half-planes)*

Adding passive elements to the geometry allows us to take into account detector materials which affect the passage of particles trough matter. This, in turn, improves the accuracy of the Monte-Carlo simulation.



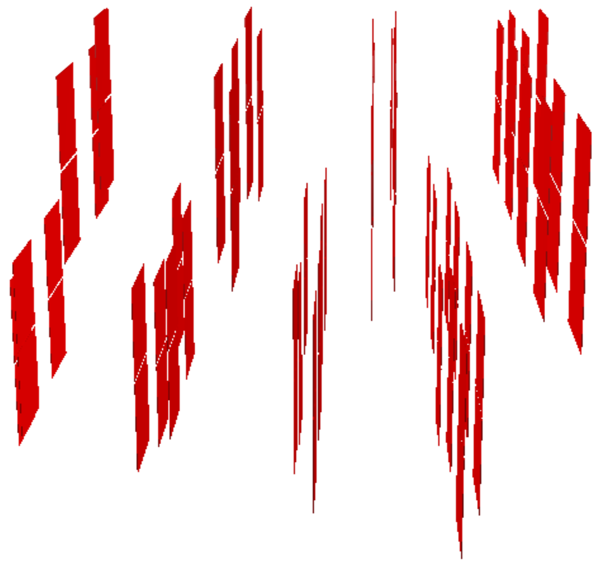
Materials of some elements of the Forward Silicon detector

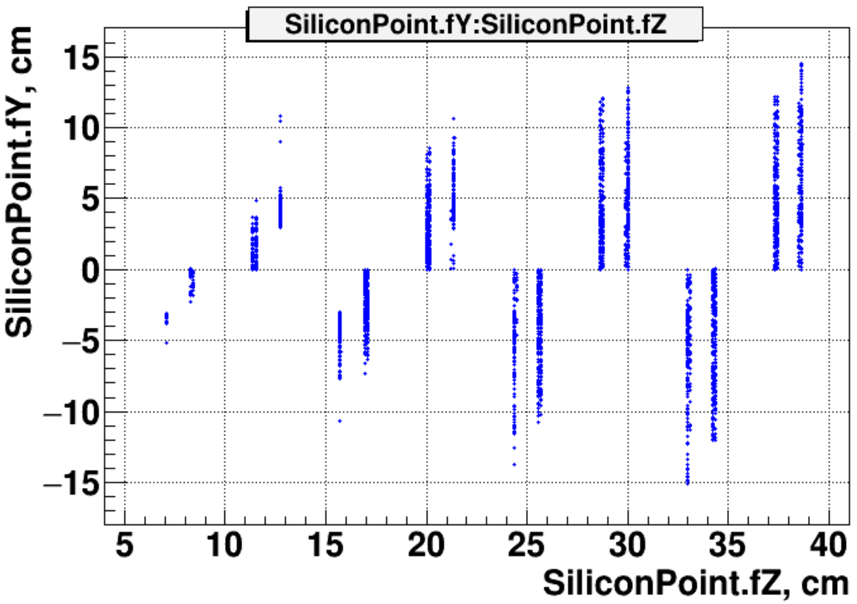


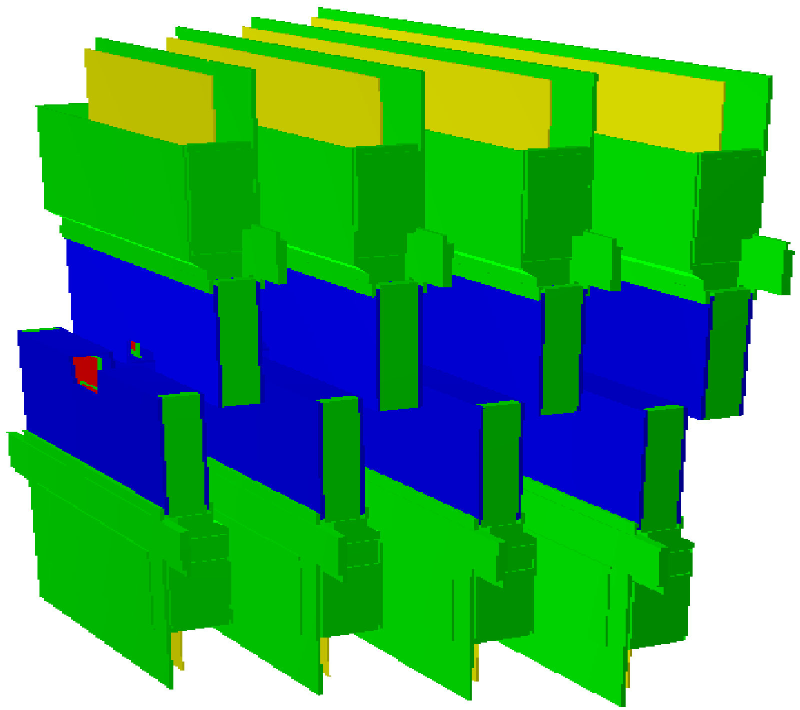
The present geometry was prepared in according to the drawings and schemes provided by E. Zubarev and other members of the detector group

D.Baranov, 8th Coll. Meeting

Detector geometry: Forward Silicon (possible option)







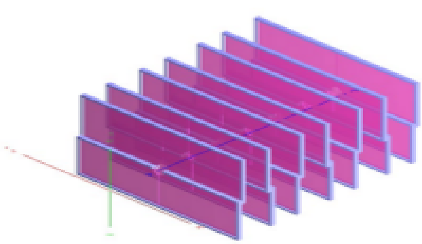
6 – 10 – 14 – 18 modules

Detector geometry: GEM

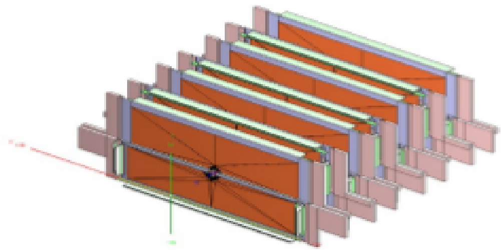
GEM detector: ROOT geometry

Two versions of ROOT geometry of the GEM detector have been prepared for the next RUN-8 configuration:

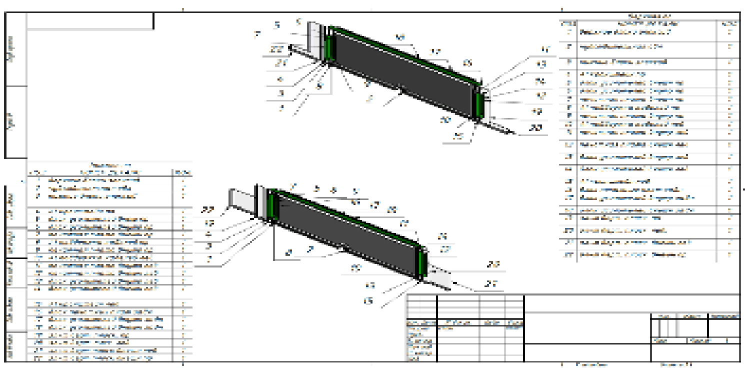
- **Basic ROOT geometry** comprises 14 sensitive volumes with simplified frames around each one.
- **Detailed ROOT geometry** completely describes the detector including passive elements such as electronics, housing and supporting components.



Basic ROOT geometry of the GEM detector



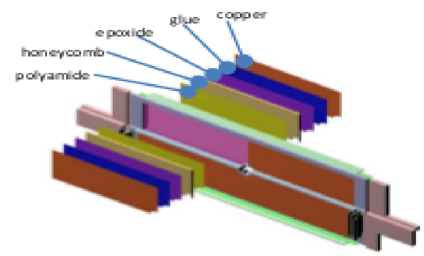
Detailed ROOT geometry of the GEM detector



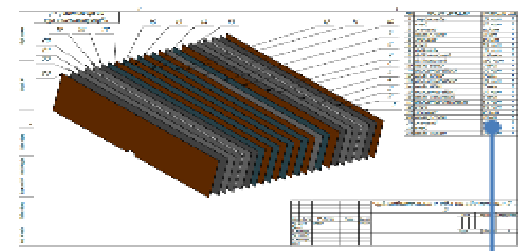
Geometry of the GEM detector was created in accordance with detailed drawings prepared by the GEM group

Sensitive area of a GEM chamber:

Each active zone in a GEM chamber has a multi-layer structure. A layer has the following properties: thickness, material type and other characteristics which are taken into account in the Monte-Carlo simulation process.



Multi-layer structure of a GEM chamber (ROOT-geometry)



Scheme of layers in a half-plane (prepared by the GEM group)

copper: 35μm + 35μm + 7μm + 7μm + 7μm + 5μm + 35μm = **131μm**
glue: 50μm + 50μm +50μm + 50μm = **200μm**
epoxide: 0.5mm + 0.5mm + 100μm + 0.5mm + 0.5mm = **2.1mm**
honeycomb: 15mm + 15mm = **30mm**
polyamide: 110μm + 30μm + 30μm + 30μm + 50μm = **250μm**

layer	material	density [g/cm-3]	thickness (X) [cm]	X0 [cm]	X/X0 [%]
gas	ArC_4H_{10} (80/20)	0.002	0.9	12343	0.0073
copper	copper	8.96	0.0131	1.435	0.9129
glue	acrylic glue	1.25	0.02	32.1603	0.0622
epoxide	polyurethane	1.8	0.21	22.5351	0.9319
honeycomb	nomex aramid honeycomb	0.048	2.86	755.397	0.3786
polyamide	polyamide	1.14	0.025	36.4052	0.0687

Properties of layers

Detector geometry: material budget

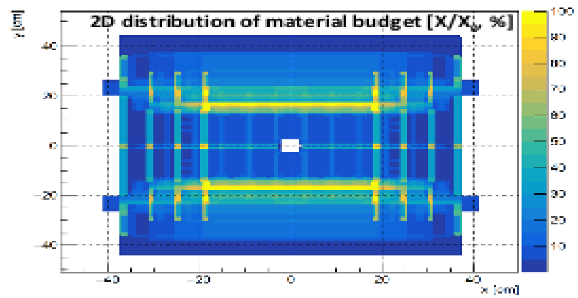
Tracking detectors: material budget

Based on the detailed geometry of the detectors, described in the previous slides, we have calculated **material budget** for the RUN-8 configuration.

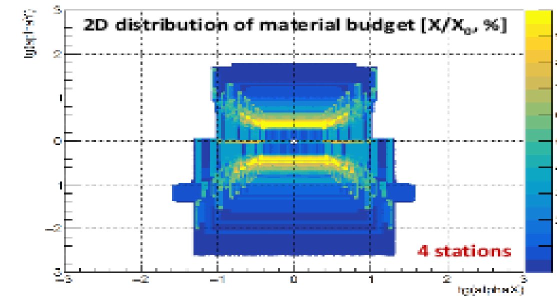
$$\textit{Material budget} = \frac{X}{X_0} \cdot 100\%$$

The material budget is a ratio of a total thickness (X) of some compound material to its radiation length (X_0), that is expressed in percentage terms (X/X_0, %).

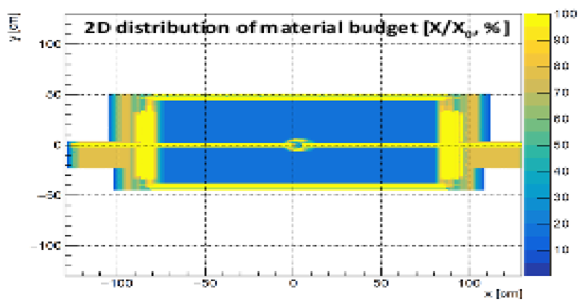
The **radiation length** (X_0) is the mean path which an electron passes in a certain material to reduce its energy by the factor 1/e.



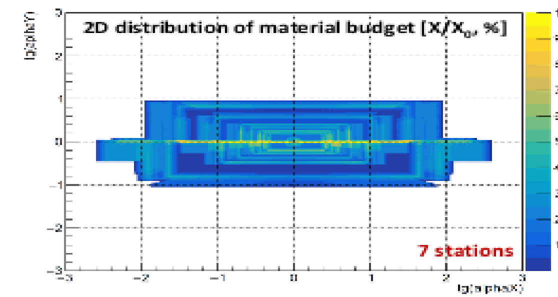
*Material budget for the **Forward Silicon** detector. XY distribution plot*



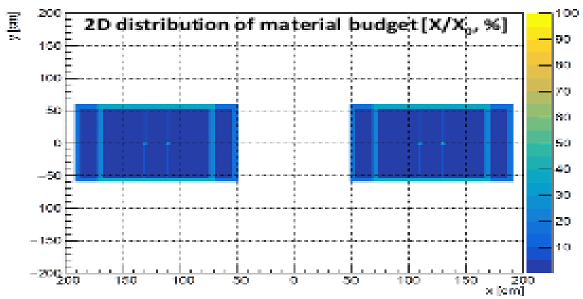
*Material budget for the **Forward Silicon** Detector. Angular distribution ($tg(\alpha_x)/tg(\alpha_y)$)*



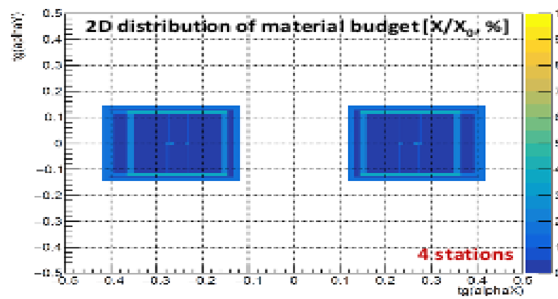
*Material budget for the **GEM** detector. XY distribution plot*



*Material budget for the **GEM** detector. Angular distribution ($tg(\alpha_x)/tg(\alpha_y)$)*

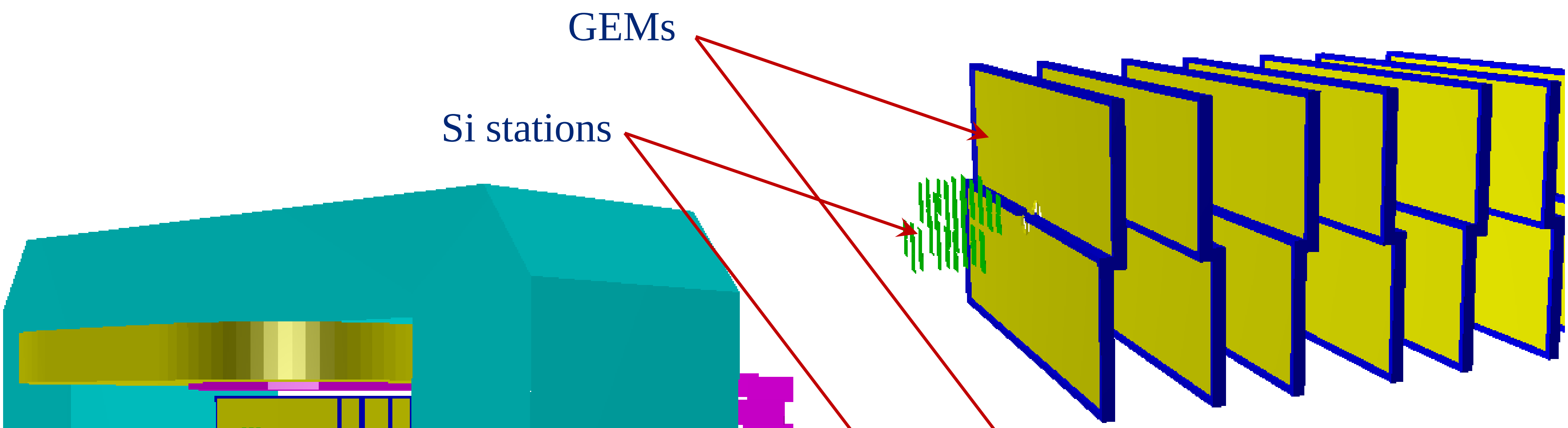


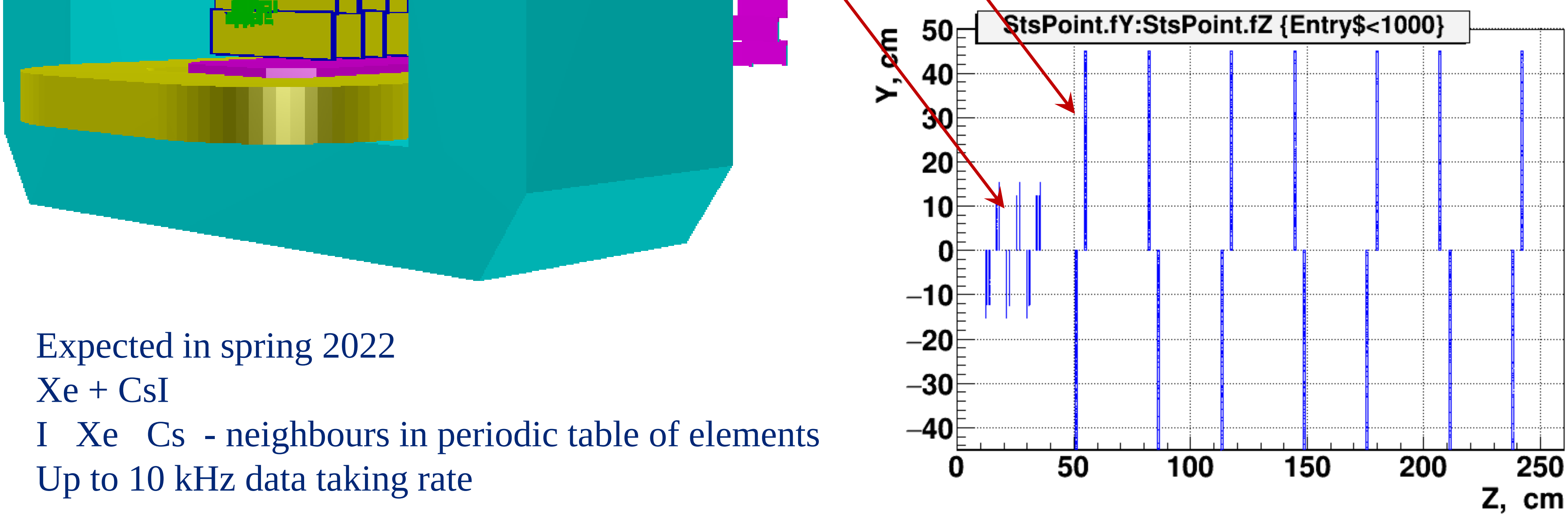
*Material budget for the **CSC** detector. XY distribution plot*



*Material budget for the **CSC** detector. Angular distribution ($tg(\alpha_x)/tg(\alpha_y)$)*

Detector geometry in Run 8





Expected in spring 2022

Xe + CsI

I Xe Cs - neighbours in periodic table of elements

Up to 10 kHz data taking rate

Data set in Run 8

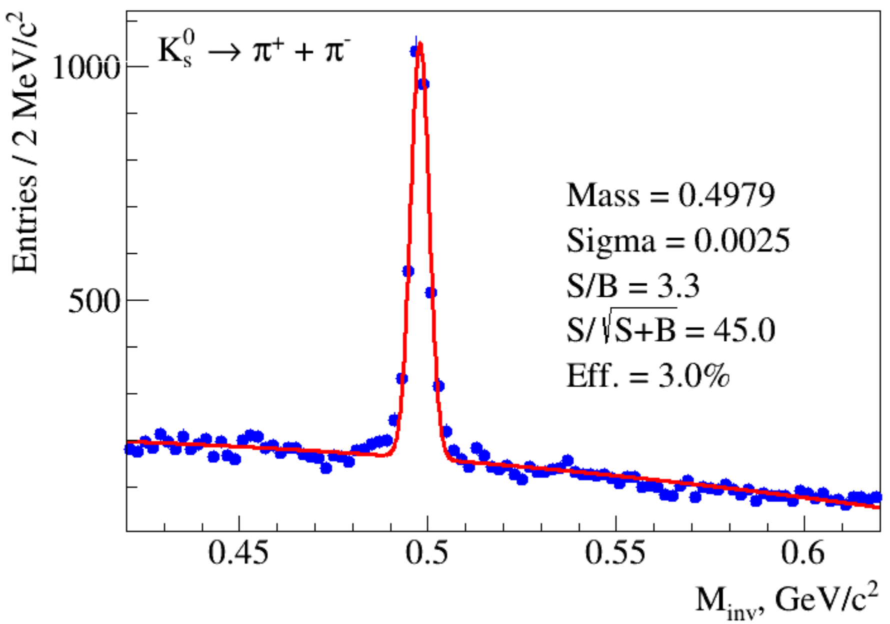
Detectors: Si (3 stations) + GEMs (7 stations)

Generator: DCM-SMM, Xe+Sn at T_0 = 3.9A GeV
($\sqrt{s_{NN}}$ = 3.296 GeV), 10k-5M min. Bias events

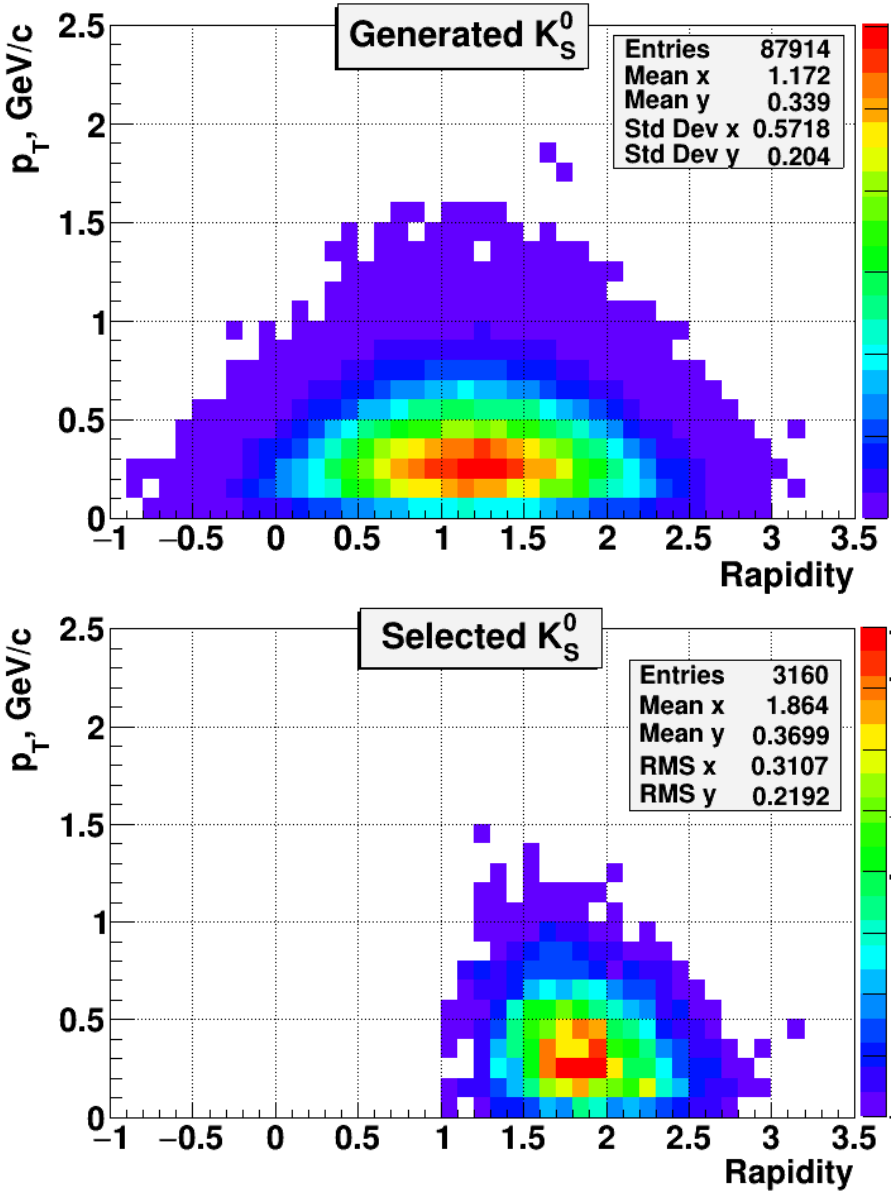
PID: TOF (if needed)

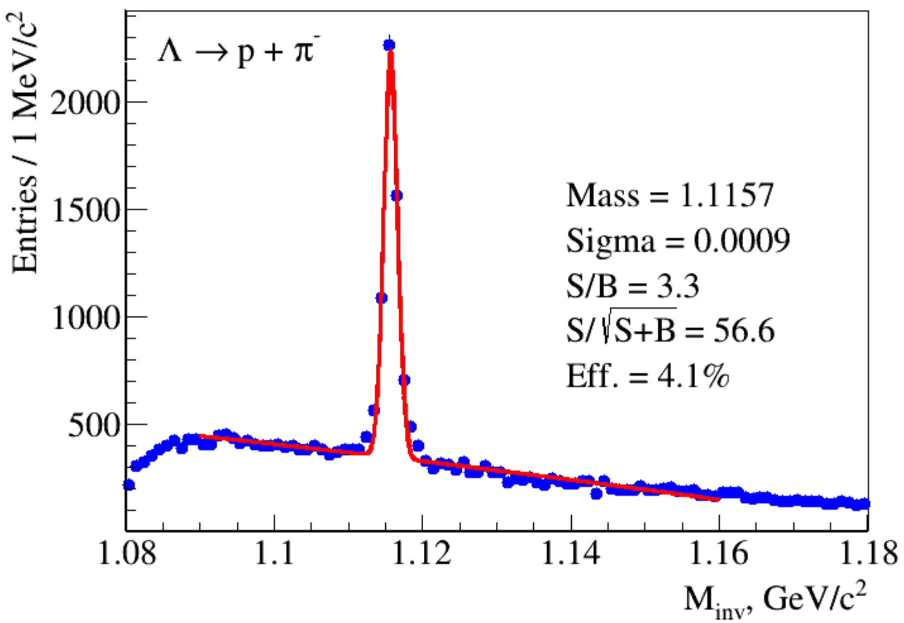
Statistics: K^0_s – 8818 within 50 cm of primary vertex (in 10k events)
Λ – 10225 within 50 cm of primary vertex (in 10k events)
Ξ^- – 111 in 10k (54175 in 5M)
Ω^- – 95 in 5M
${}_{\Lambda}H^3$ – 6309 in 5M → enriched ${}_{\Lambda}H^3$ sample (randomly add 1 ${}_{\Lambda}H^3$ per 30 events according to y-p_T distribution) → scale factor 27.4

K^0_s reconstruction in Run 8

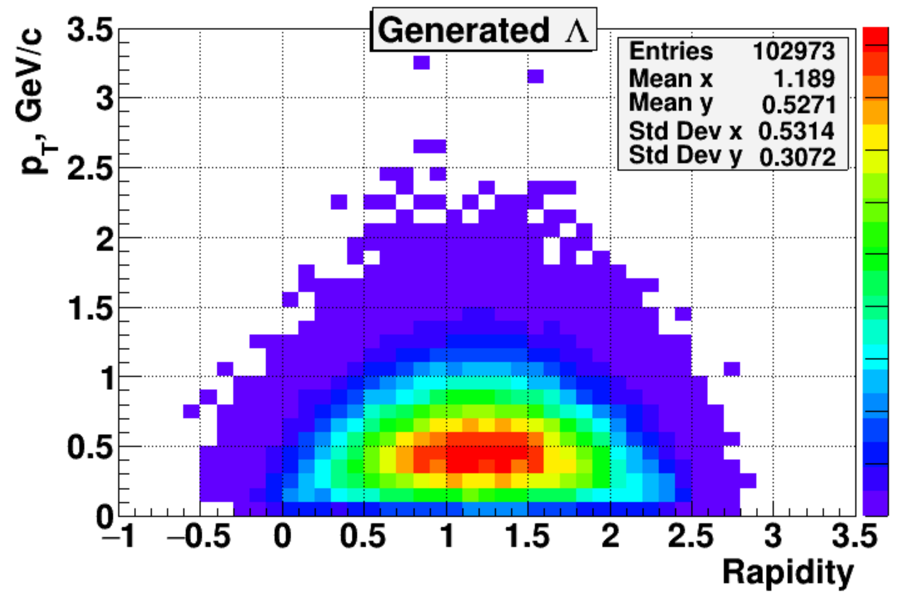


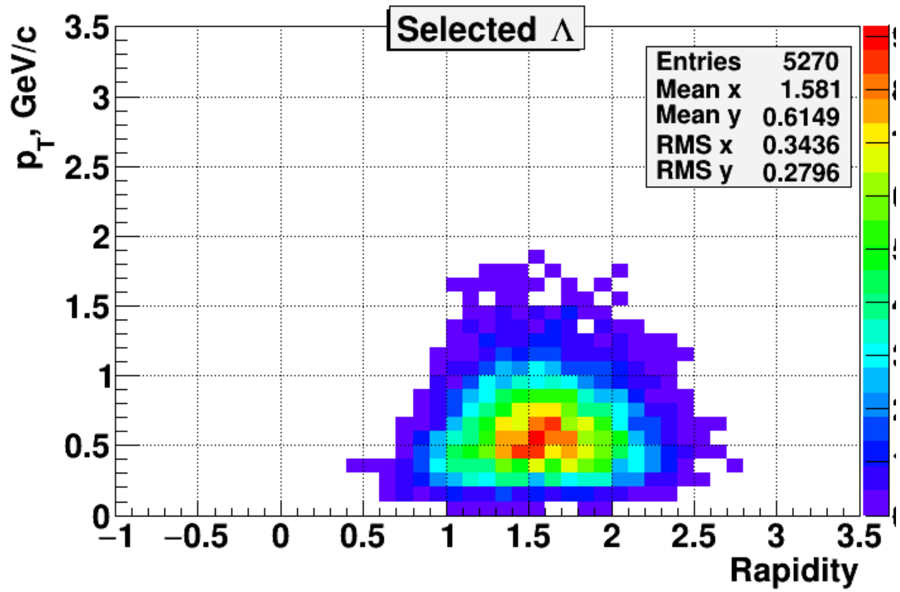
10k interactions



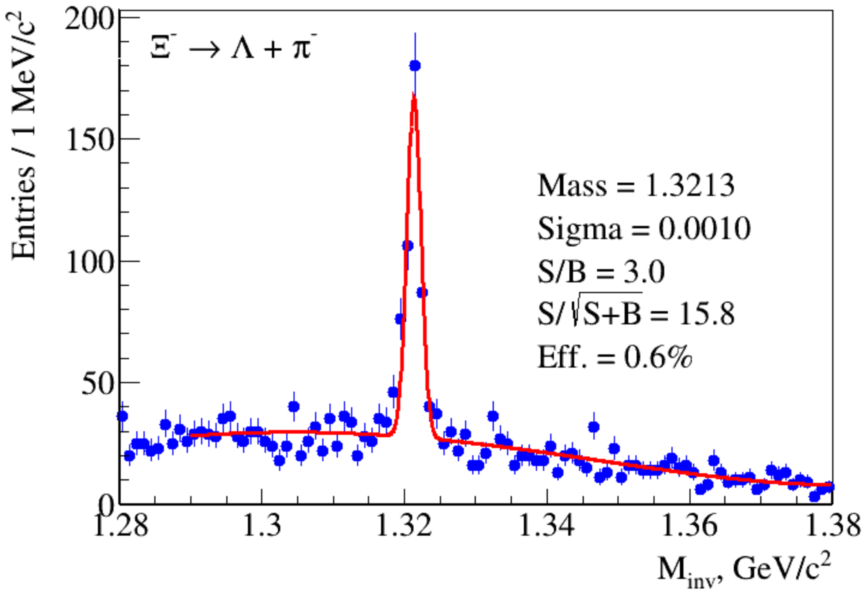


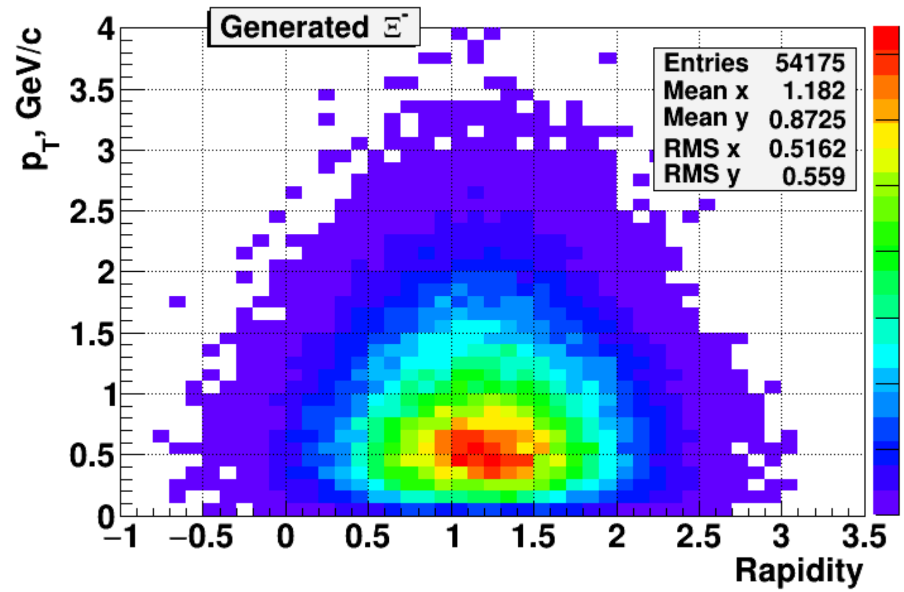
10k interactions

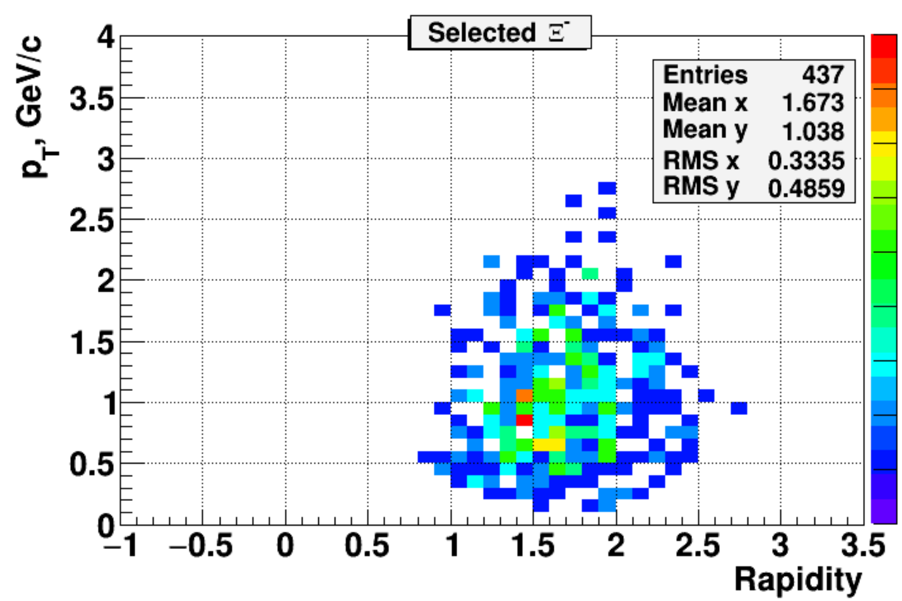




Ξ^- reconstruction in Run 8

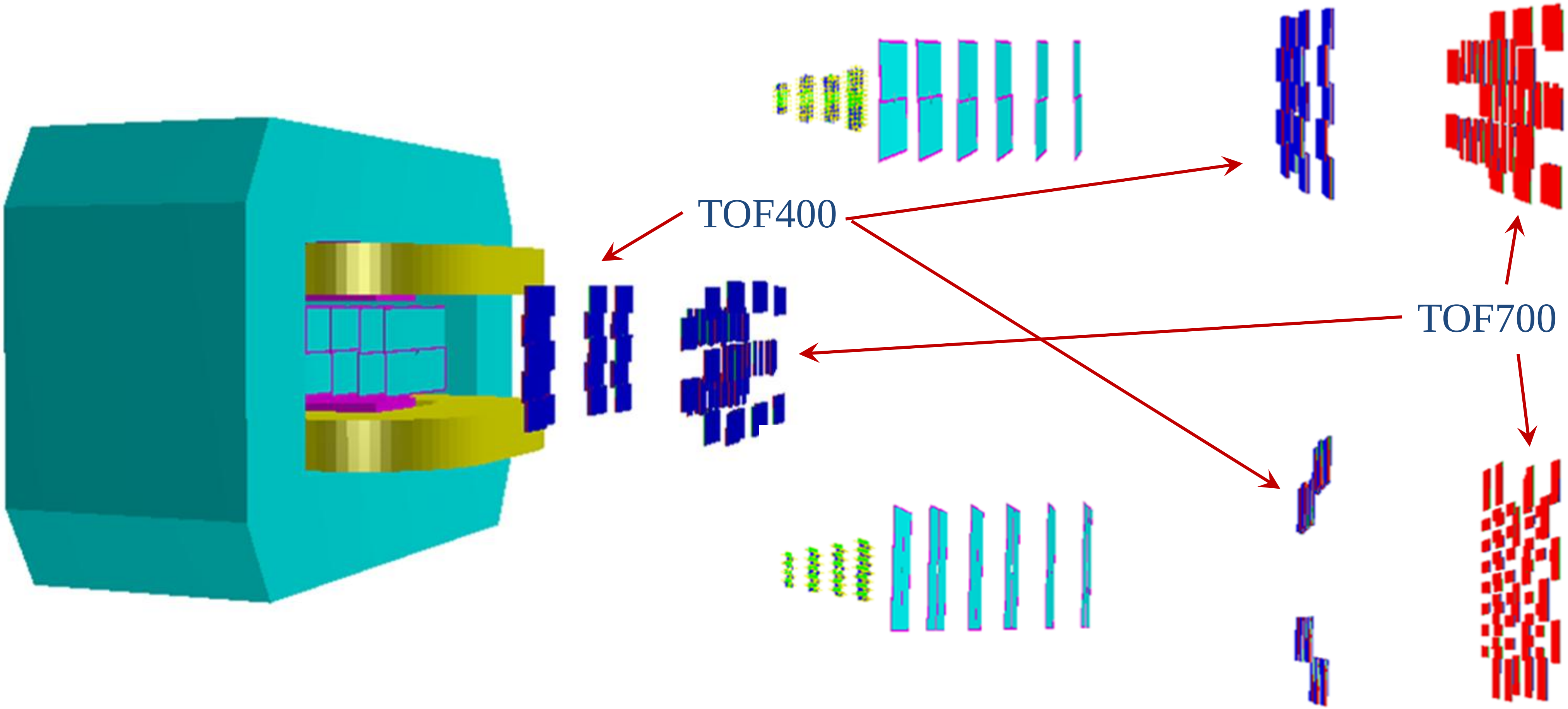




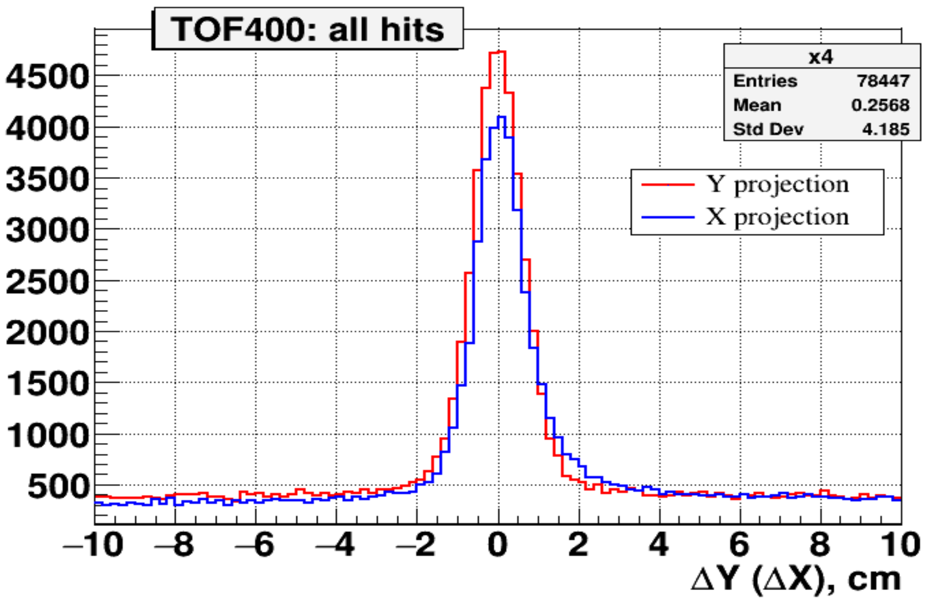


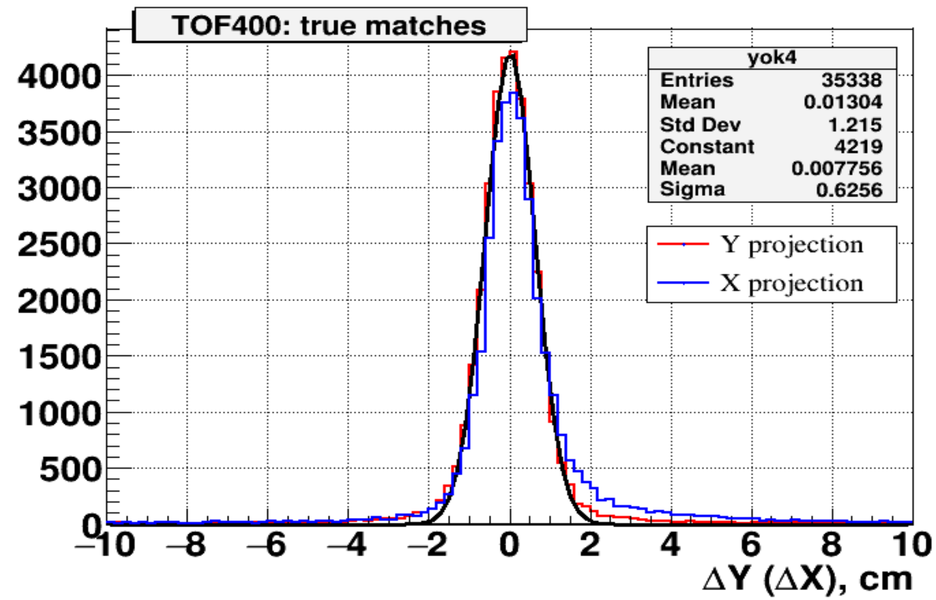
5M interactions

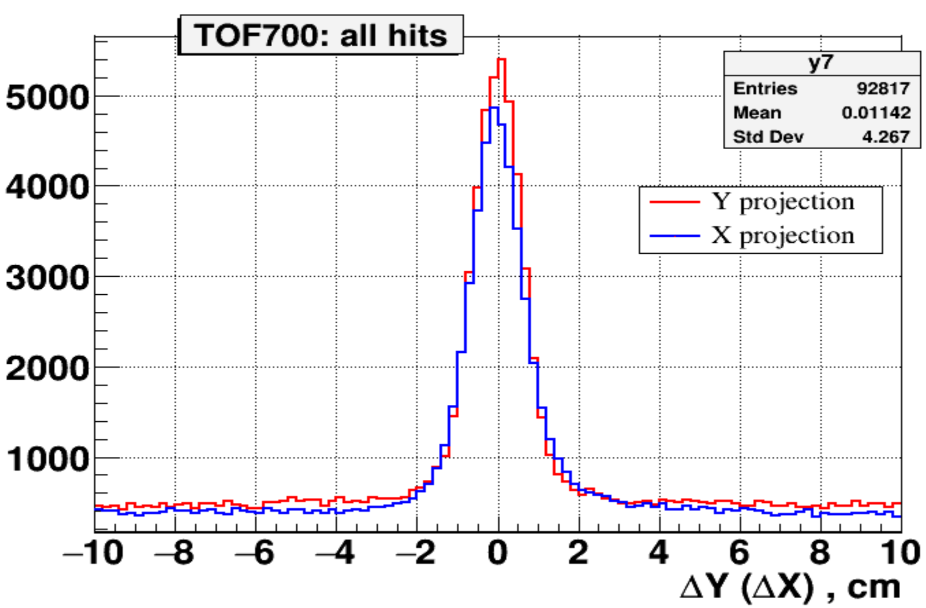
Detector geometry with TOF

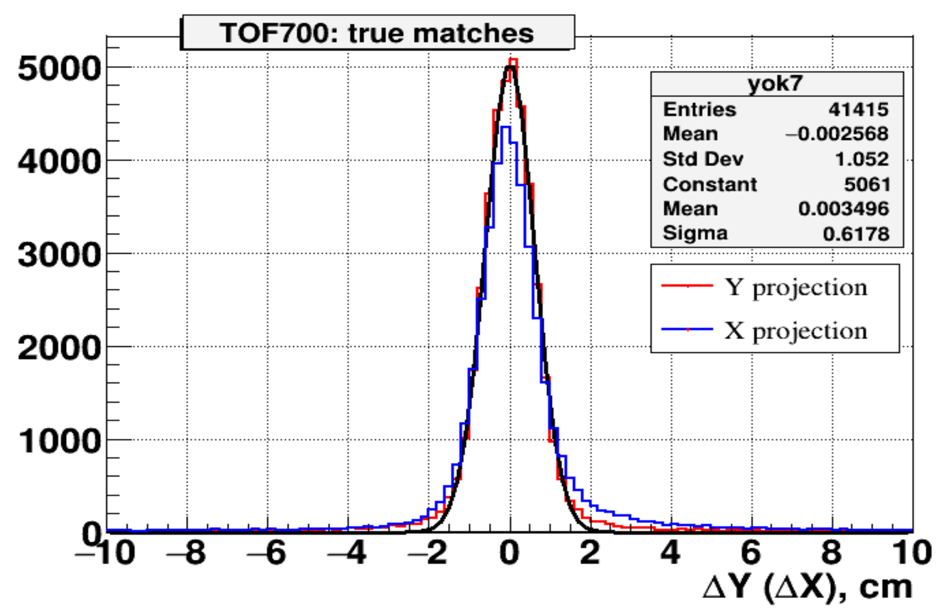


Matching with TOF

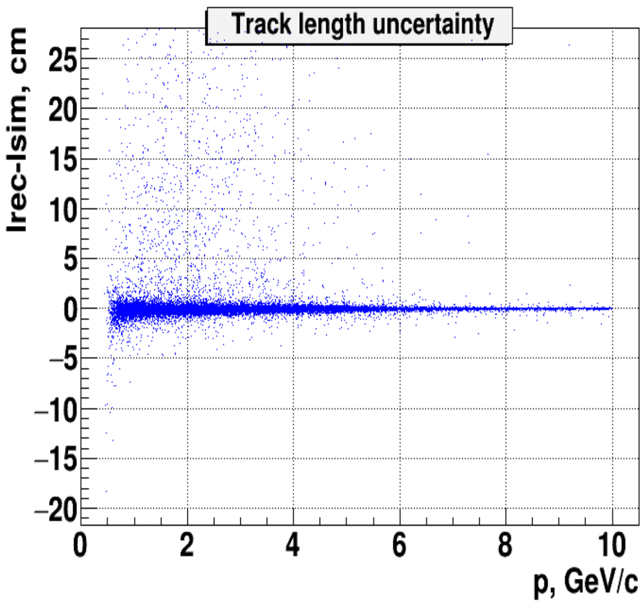


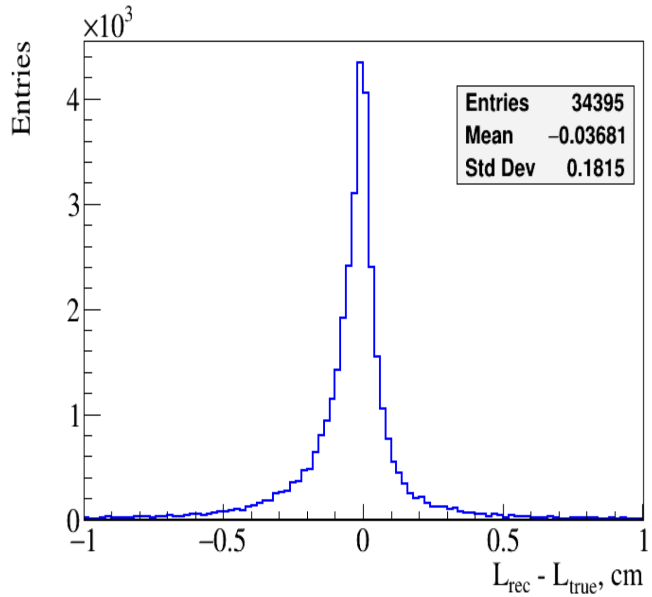


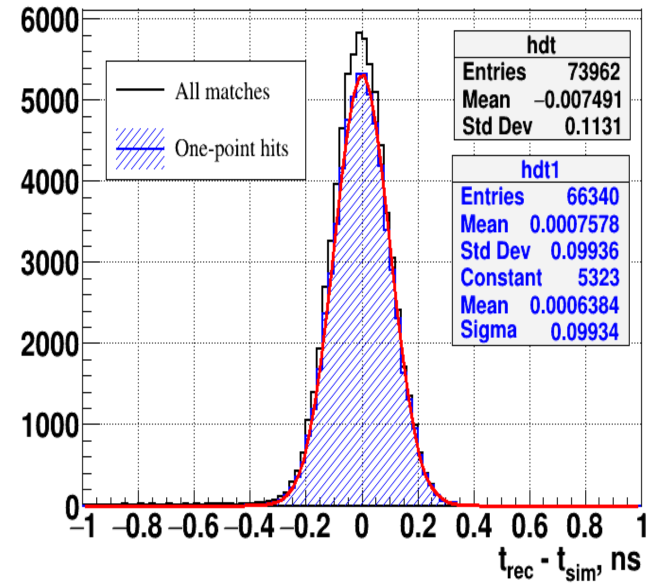


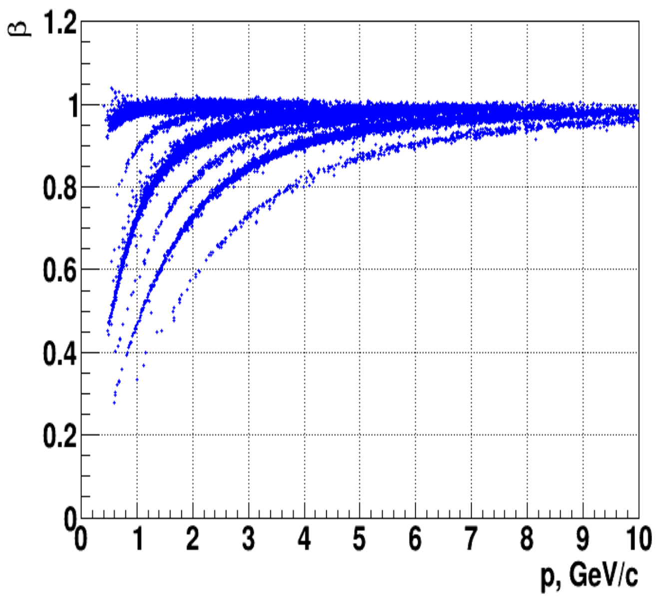


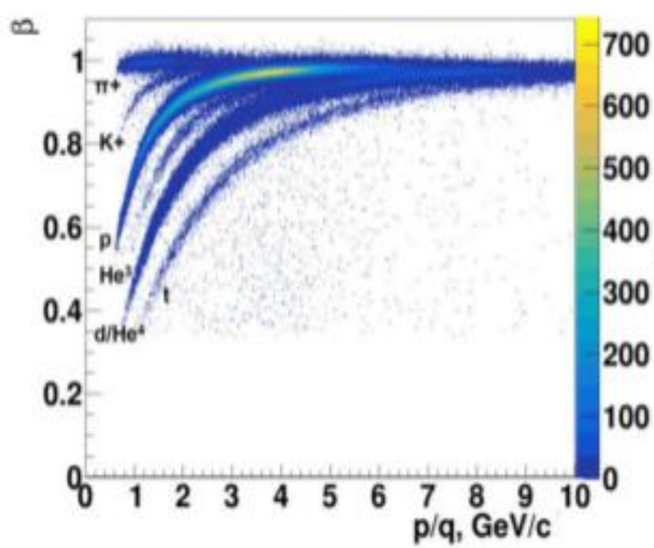
Particle identification with TOF

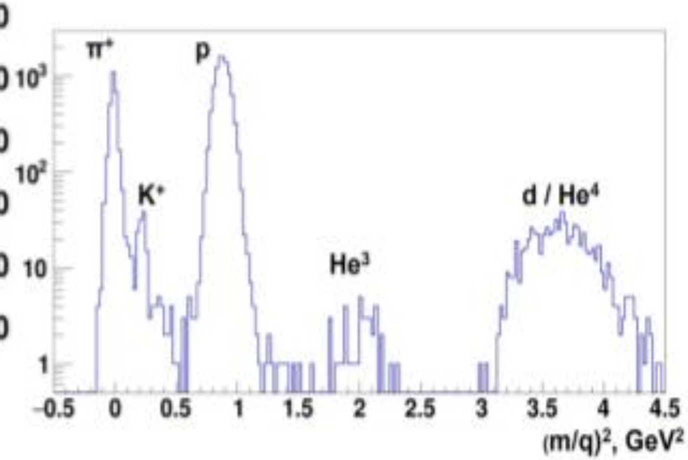




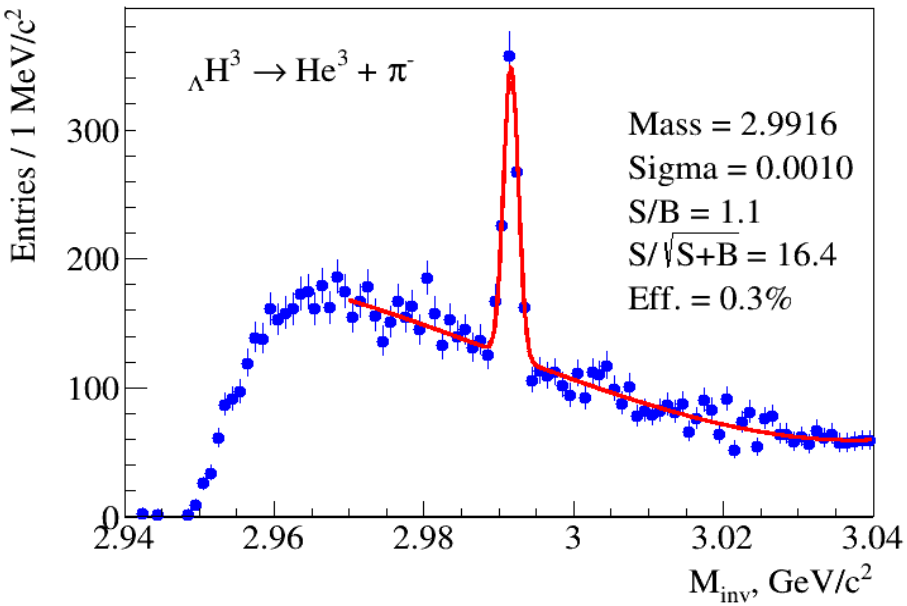


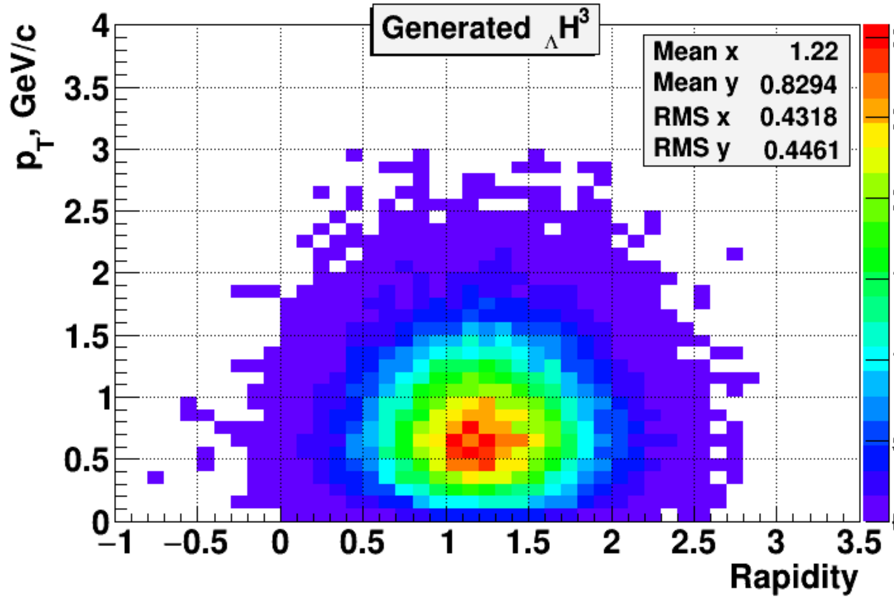


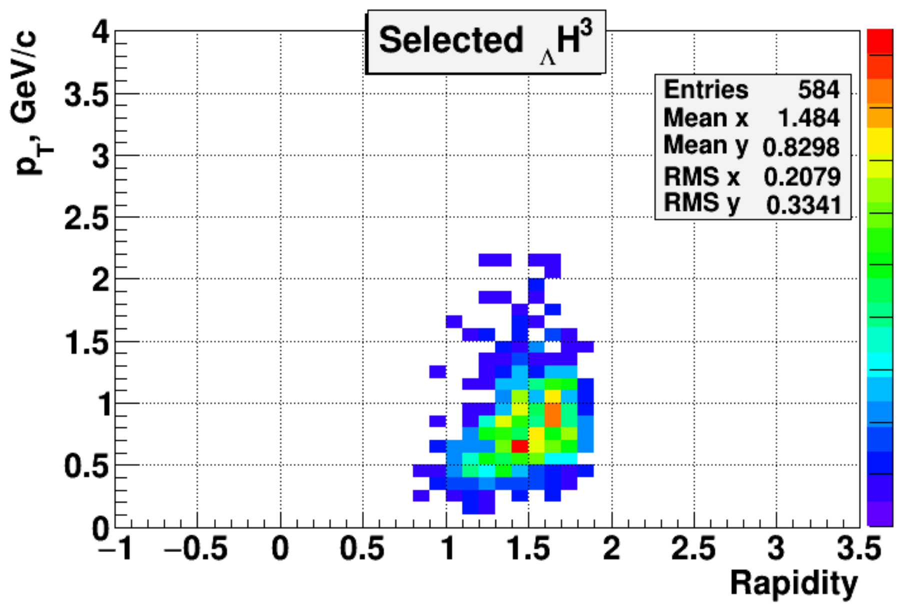




$_{\Lambda}H^3$ reconstruction in Run 8







Equivalent statistics
~140M events

Vector Finder motivation and history

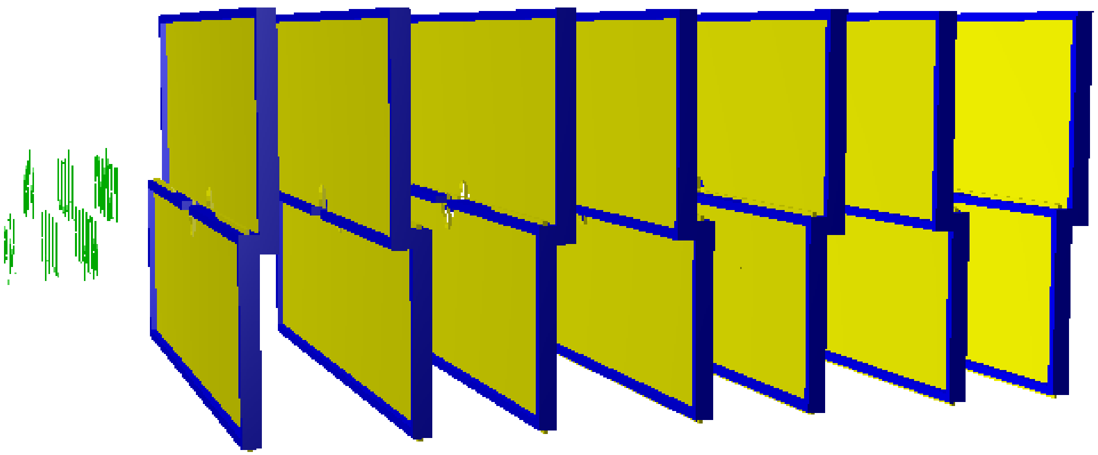
1. **CBM L1 (CAT) code is mainly used for track reconstruction at BM@N.**
2. **It is designed to be run on-line – might not be the most optimal for tracking efficiency.**
3. **It has been optimized (?) for the CBM STS configuration – might require extra tuning for different geometries.**
4. **It is not quite clear how to do the optimization – "grey box" for external user.**

Vector Finder was "inspired" by the CBM CAT approach and originally developed for the CBM MUCH system.

Later it was adapted for the MPD ITS system.

Currently it is evaluated and tuned for BM@N.

Detector geometry



Field: ~0.8 T

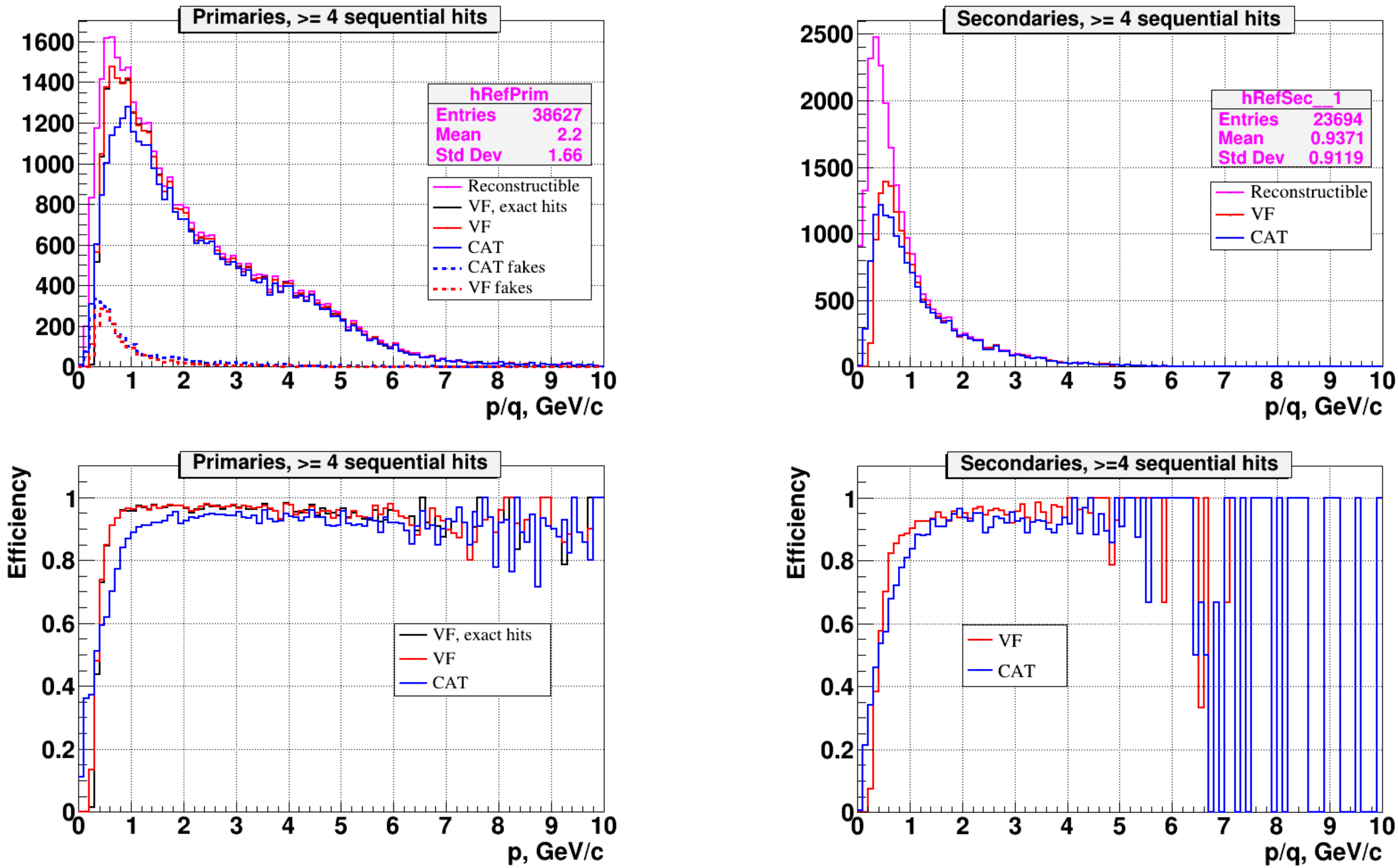
Data set

Detectors: Si (3 stations) + GEMs (7 stations)

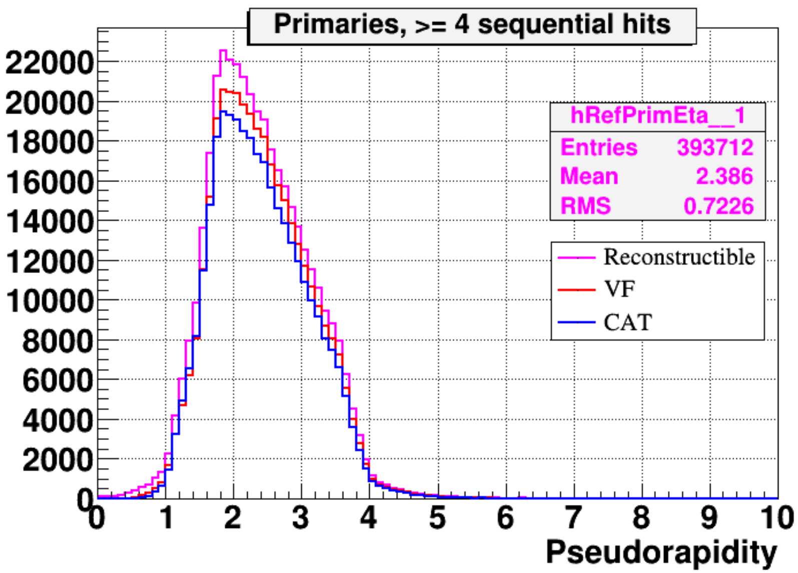
Generator: DCM-SMM, 1k Xe+Sn at T_0 = 3.9A GeV, min. Bias

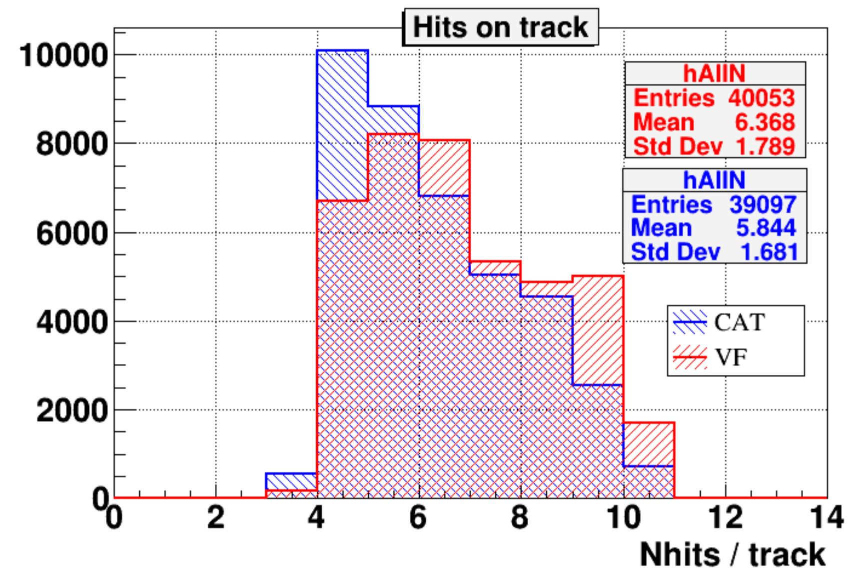
Magnetic field: B = 0.8 T

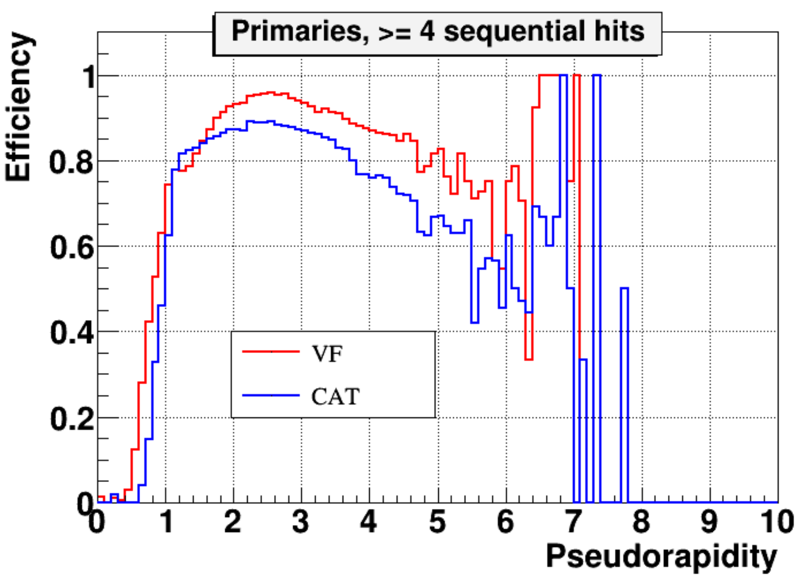
Tracking performance

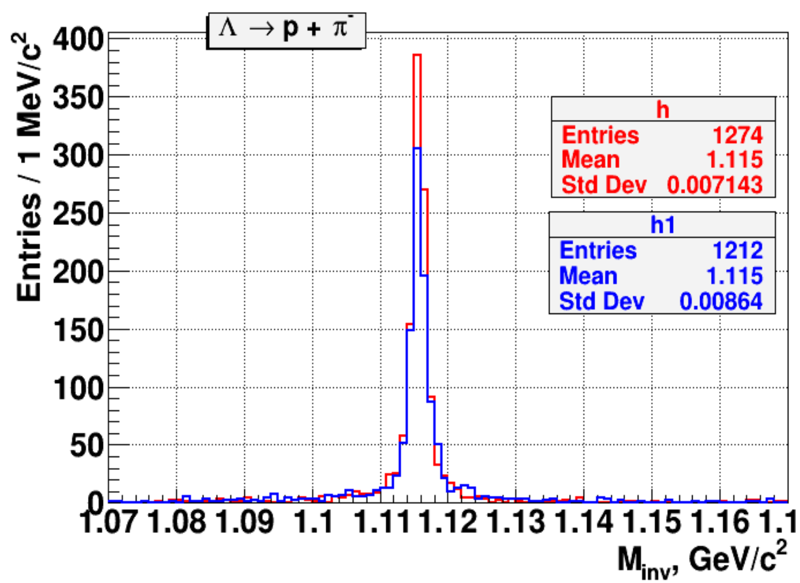


Tracking performance







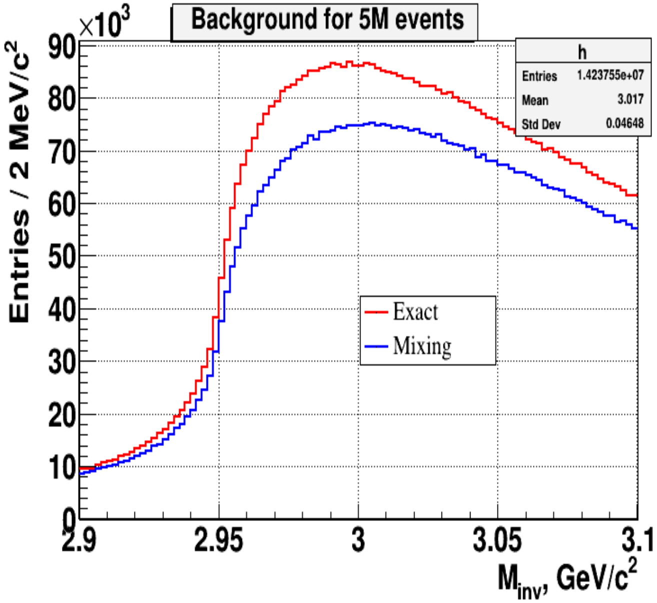


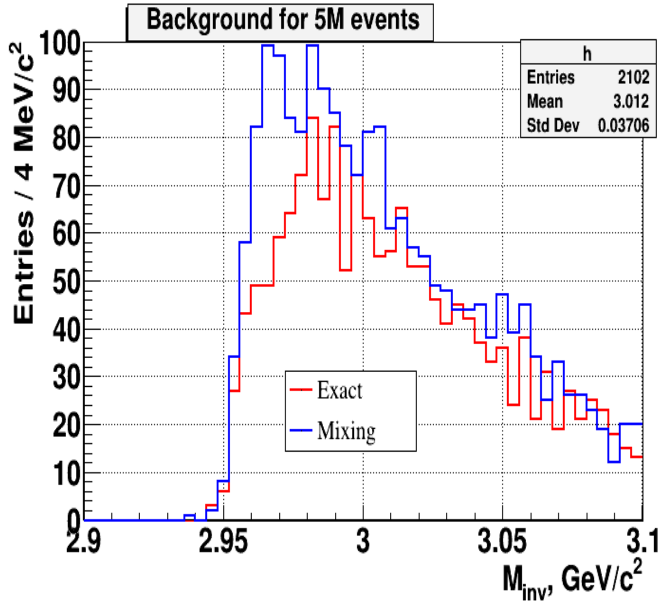
Summary

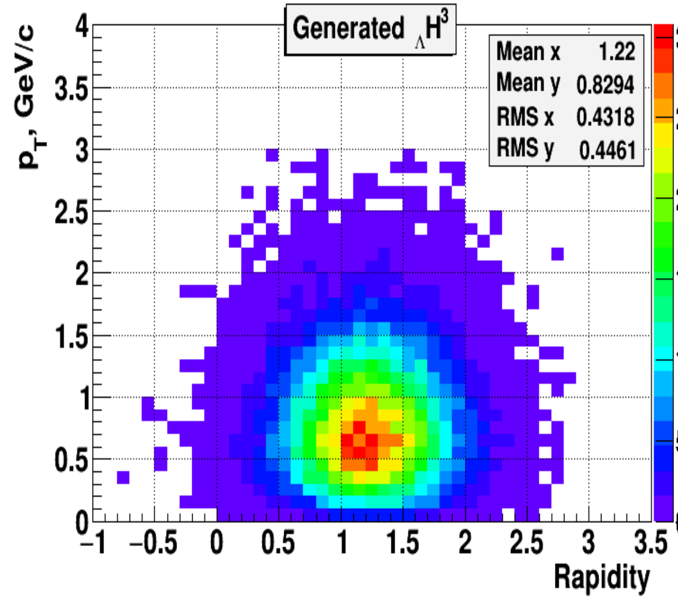
1. Detector geometry (detailed and simplified) is described in Monte Carlo.
2. Feasibility studies have been done for the simplified configuration.
3. Vector Finder demonstrates promising results. Currently it is being modified to properly handle the material budget.

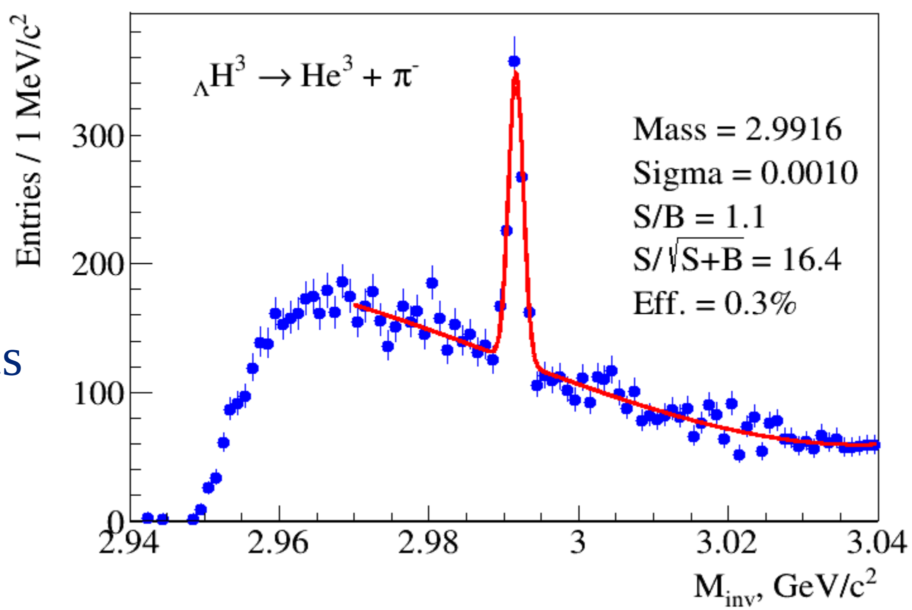
Back-up slides

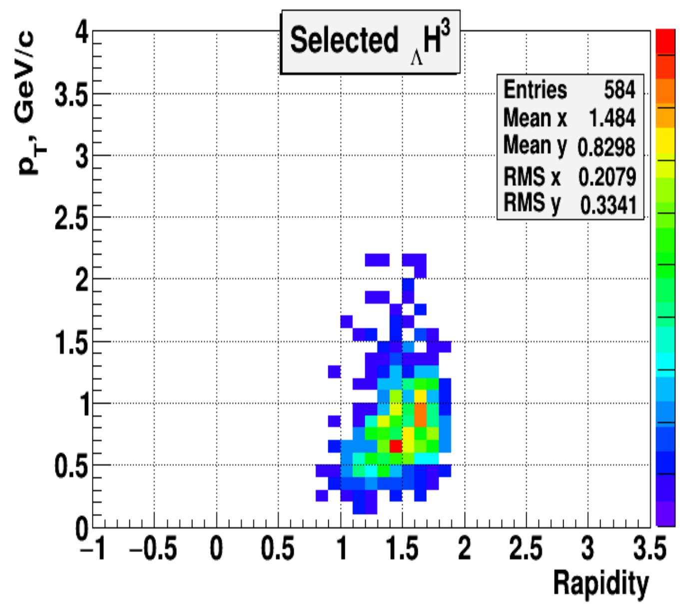
$_{\Lambda}H^3$ reconstruction in Run 8











Equivalent statistics
~140M events