Some features of ν_μ-CC interactions in GRAIN (… and in STT)

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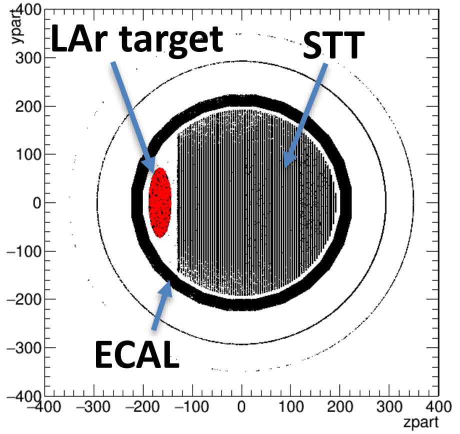
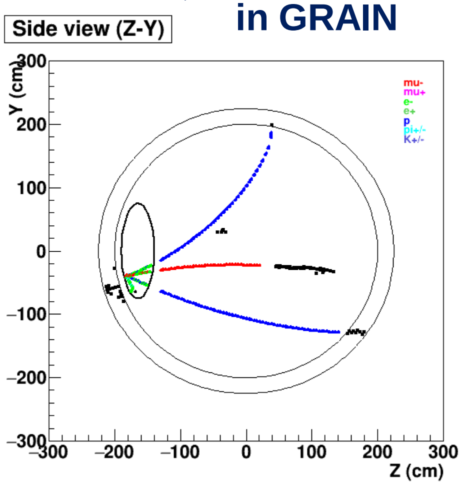
GRAIN design and simulation

- ✓ Detailed geometry, dimensions and structure of the active LAr detector currently in the design phase
- ✓ Layout with temporary geometry implemented in GEANT4 code
- ✓ FLUKA: implementation of current geometry layout in progress with a simplified detector response simulation
  - ➢ provided info: particle hits (position, time, energy deposit)

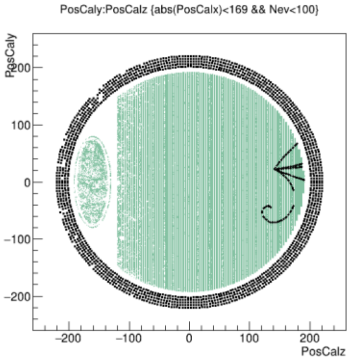
Used to study some **features of ν_μ interactions in the LAr target and STT**



CC-ν_μ interaction in GRAIN

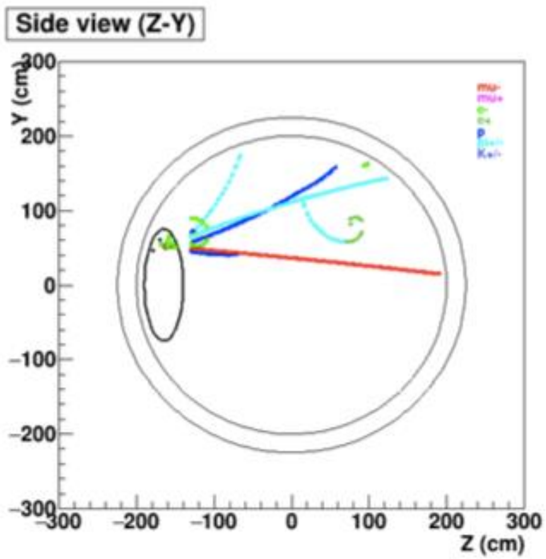


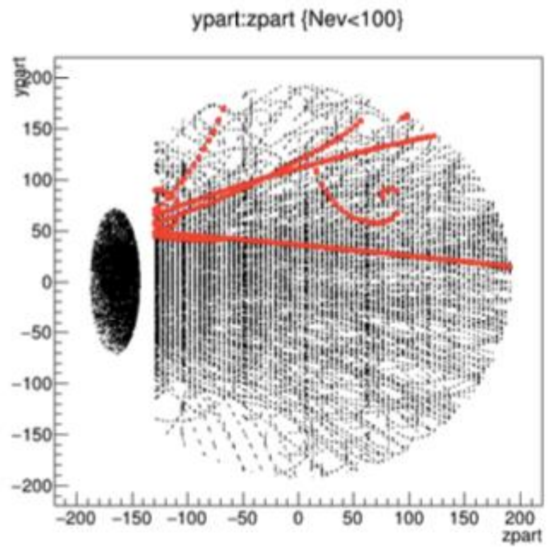
CC-ν_μ interaction in STT



Neutrino interactions in GRAIN (FLUKA)

Two samples of ν_μ - CC interactions in LAr target and in STT





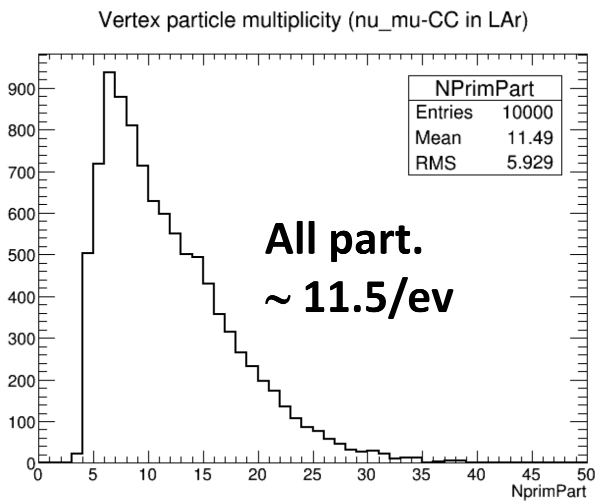
Some features

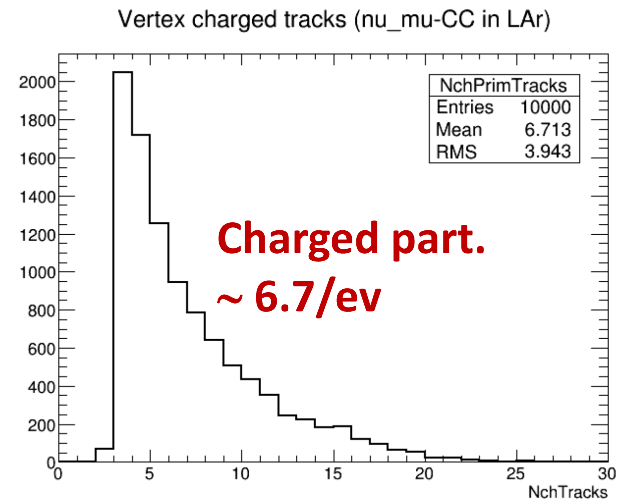
- ➢ Multiplicity and spectrum of generated particles
- ➢ E_ν fraction deposited in LAr (to be evaluated from light yield)
- ➢ Vertex (and tracks) reconstructed in LAr (from times and imaging)

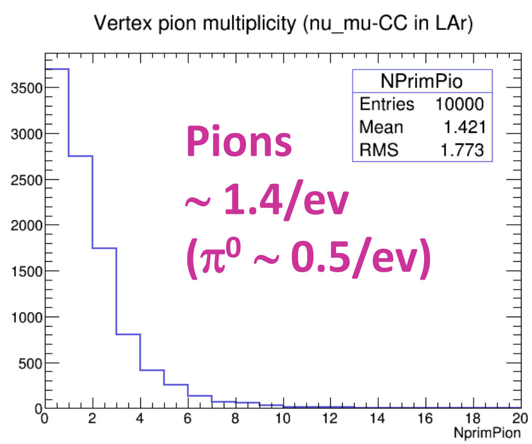
✓ Outgoing particles detected (and tracked) in STT and ECal

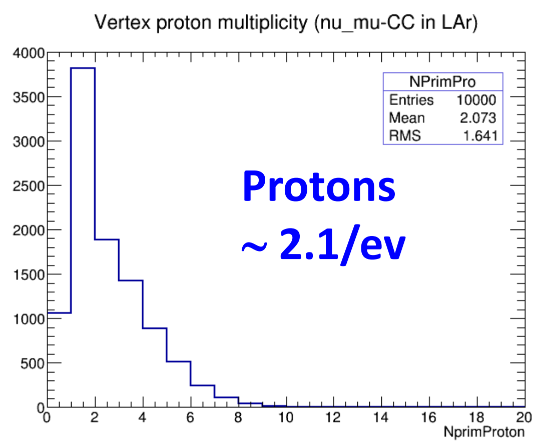
✓ For a few tracks, global transform method expected to work fine

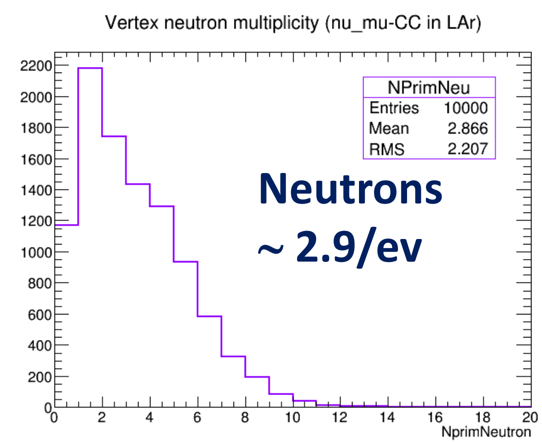
Primary particle multiplicities (ν-Ar in GRAIN)







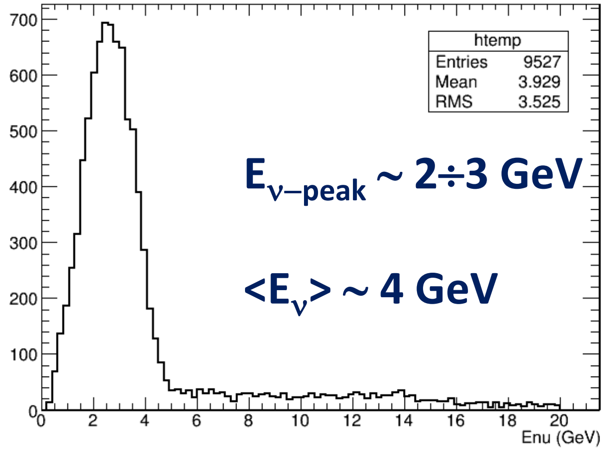




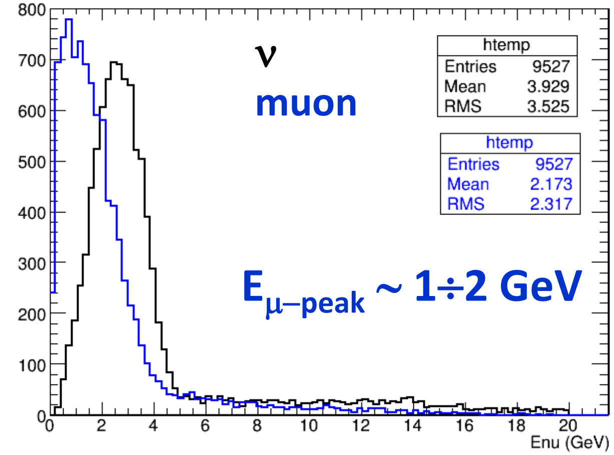
Nuclear fragments ~ 2.6/ev, Photons ~ 1.4/ev + 1 muon

Neutrino and other particle spectra – ν-Ar in GRAIN

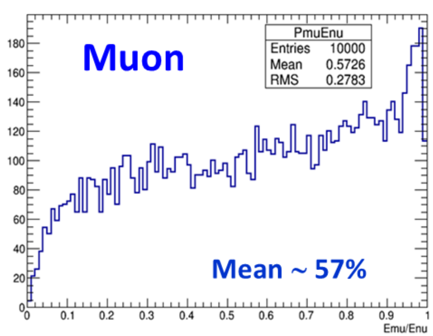
Interacting neutrinos



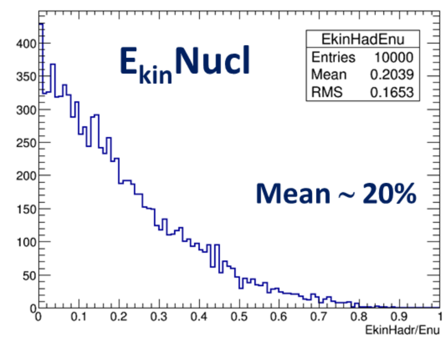
Spectrum of produced muons

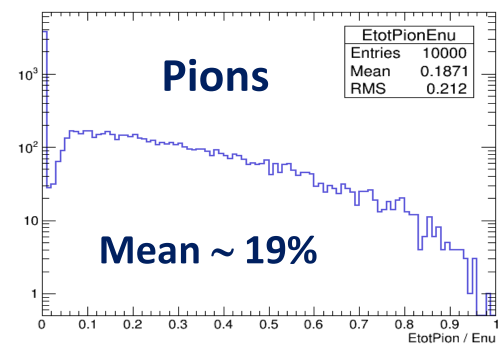


E_ν fraction carried out by produced particles:



Protons + neutrons

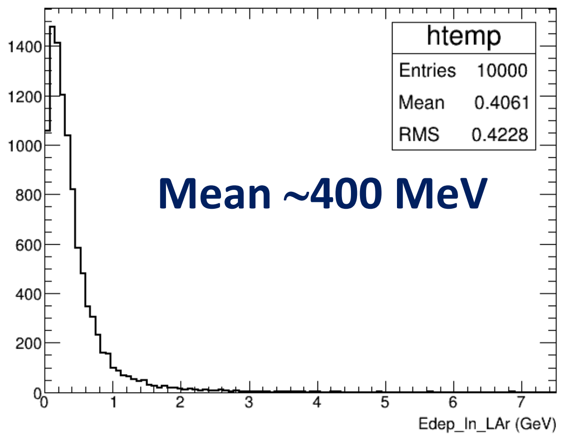


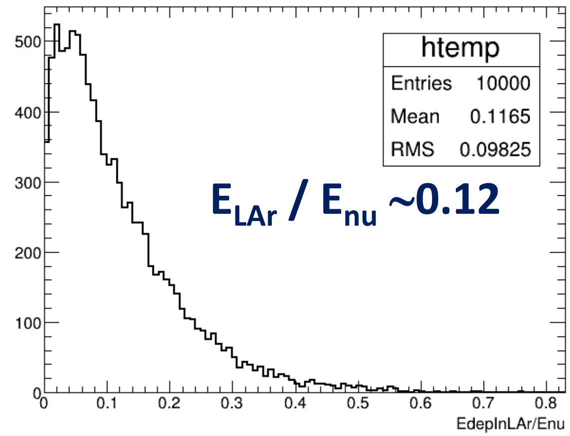


Energy deposited in LAr target

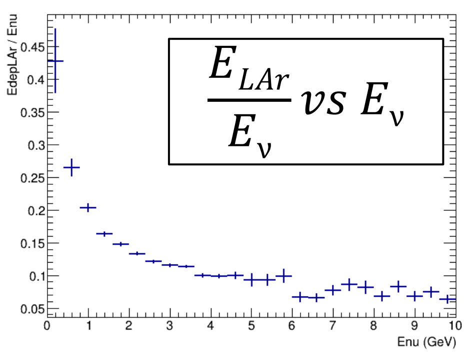
For E_ν reconstruction, the fraction deposited in LAr is not negligible

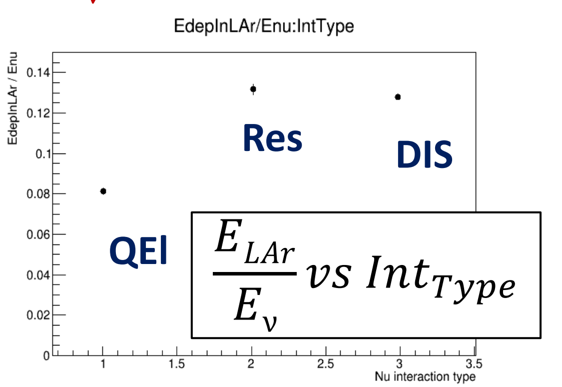
… to be estimated as a calorimetric measure

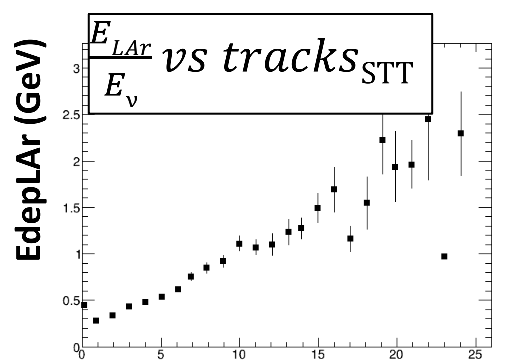




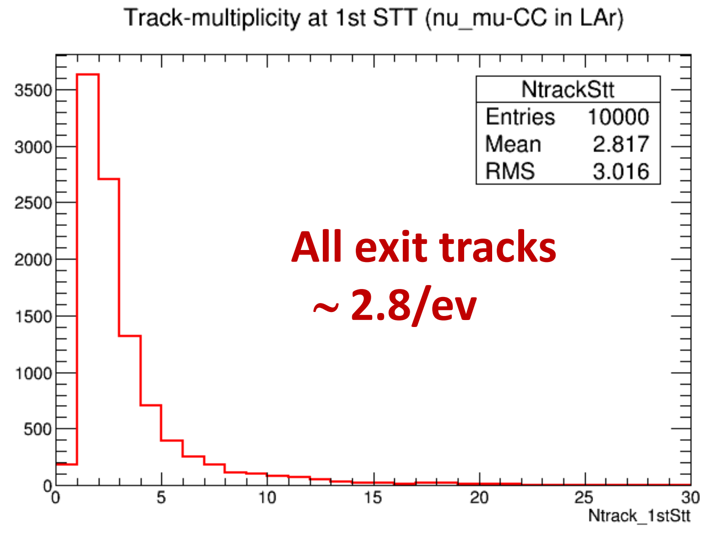
Correlation of $Edep_{LAr}/E_\nu$ with E_ν , CC-Interaction Type, tracks in STT







Multiplicities of tracks entering STT



A relatively low number of charged particles escaping GRAIN and tracked in STT (≥3 hits required in Y-Z view)

Tracks entering STT come from primary and secondary (δ rays) particles

Note: more tracks can appear in STT due to secondary interactions/decays

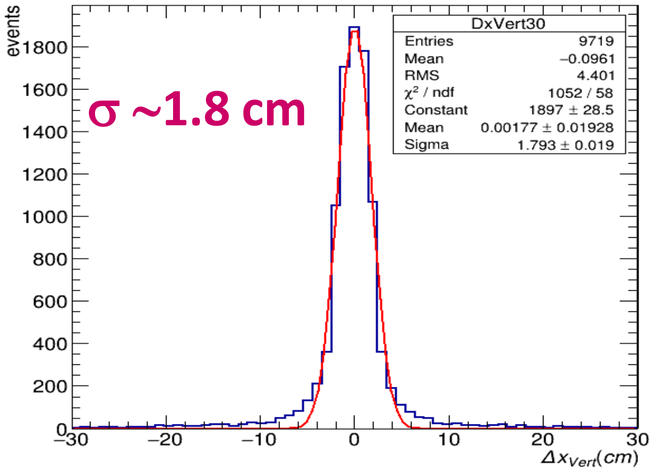
LAr "cleans up" events by absorbing low energy particles and nuclear frags

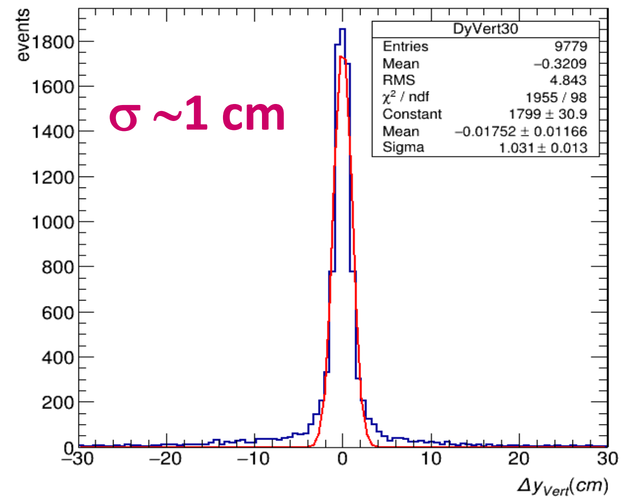
⇒ **Possibility to successfully reconstruct most events by applying global track finding algorithms (as the 'transform method')**

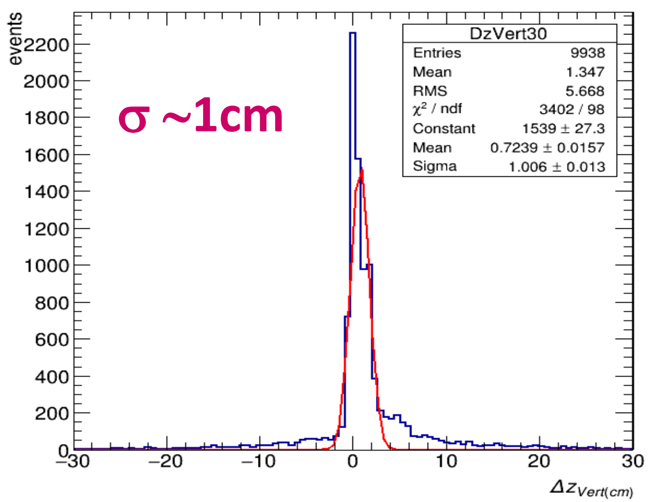
⇒ **Especially for high multiplicities, different and more sofisticated pattern recognition methods (Kalman filter algorithm, ..) are necessary**

Vertex reconstruction in LAr-target

Vertex "reconstructed" from hit positions with Edep weights







<u>Basic idea</u>:
tight correlation with scintillation light emission (~40,000 photons/MeV)

⇒ Vertex position from light collected by photo-sensor through lenses or coded masks (precision ~cm)

✓ Comparable precision from reco-track crossing

Track reconstruction (transform method)

Track-finding: global transform method → Vertex needed

- **Use of Vertex position (from MC hits) reconstructed in LAr**
- **"Reconstructed" Vertex used for coordinate transformation:**

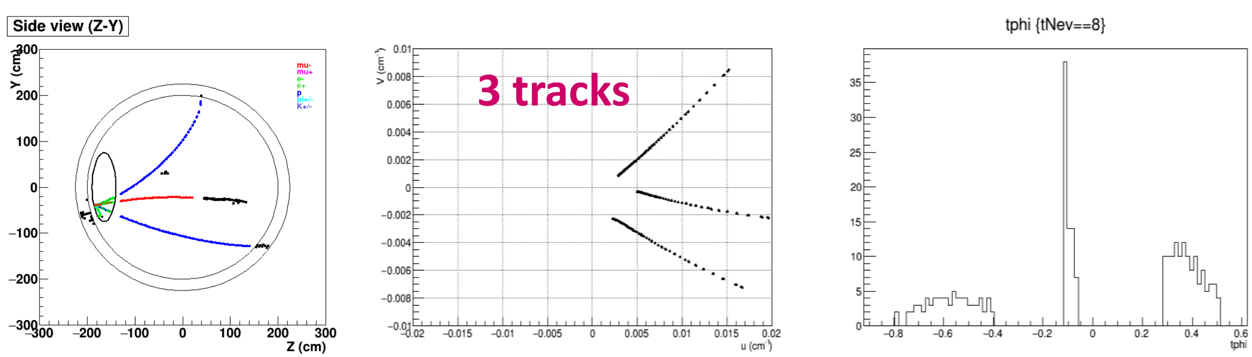
  $x \rightarrow u \qquad y \rightarrow v$

$$u = +(z-z_V) / [(z-z_V)^2 + (y-y_V)^2]$$
$$v = -(y-y_V) / [(z-z_V)^2 + (y-y_V)^2]$$

Vertex: (z_V, y_V)

- **Search for peaks in distribution of $\phi = \arctan(v/u)$**
- **Associate digits to tracks (without MC info!) and perform a circular fit**

Example:

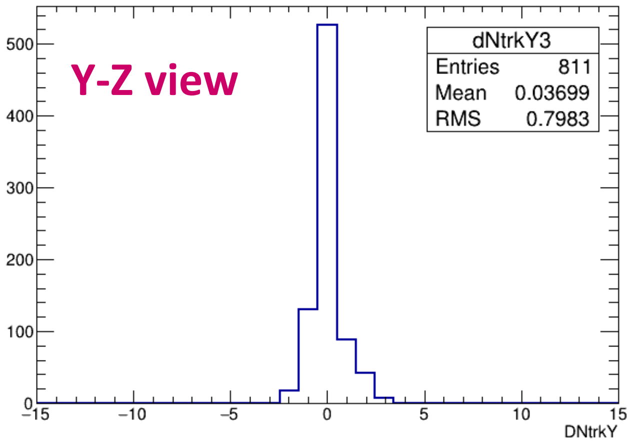


Reconstructed vs ‘real’ tracks entering STT

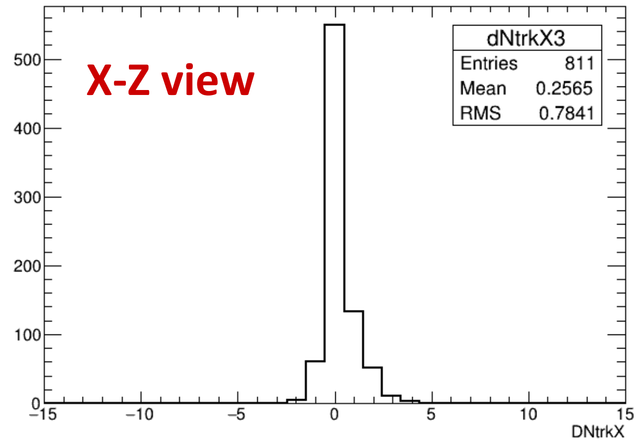
ΔNtrack = Difference btw Reco and MC tracks <u>entering</u> STT

Track multiplicity ≤ 3

Δ Ntrack

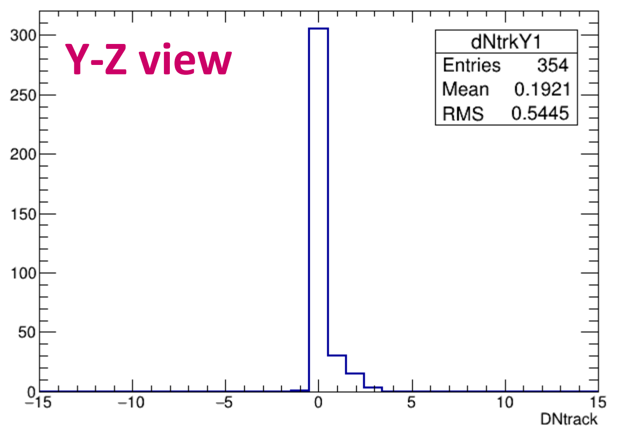


Δ Ntrack

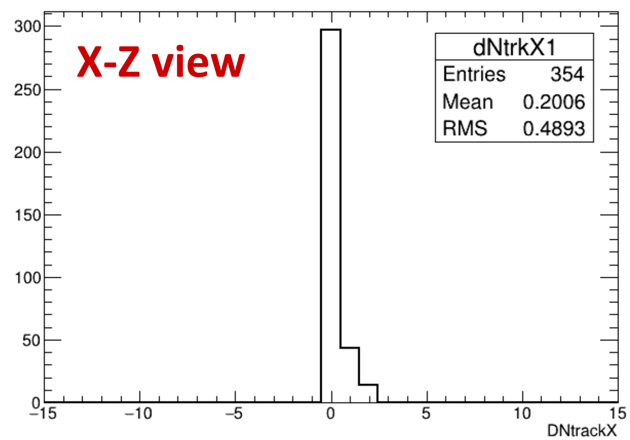


Single Track events

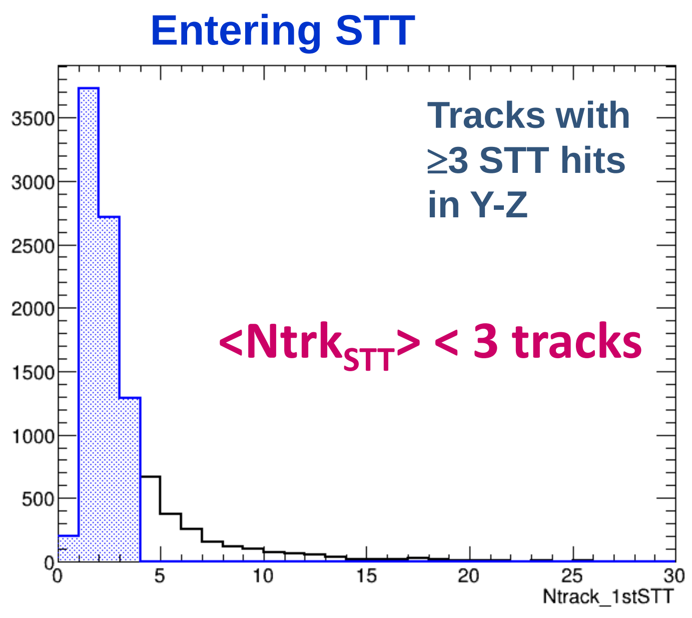
Δ Ntrack



Δ Ntrack



Track multiplicities in STT: a in-depth look



Most events with few tracks entering STT …

- ~ **78 % up to 3 tracks**
- ~ **65 % up to 2 tracks**
- ~ **38 % only 1 track**

Question:

Most charged particles not capable to enter STT ?

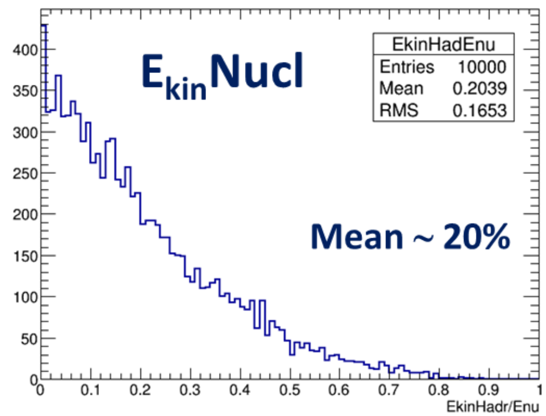
- Pions ?

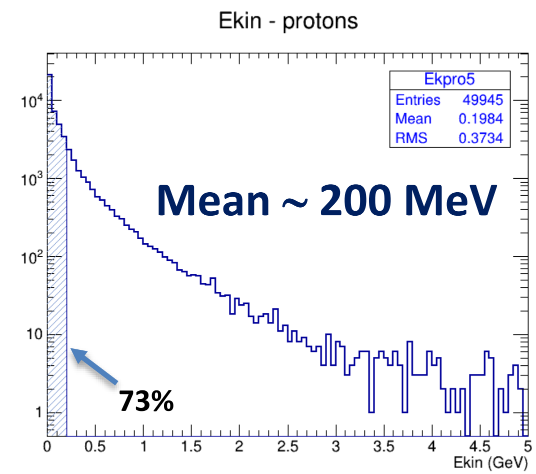
- Protons ?

Proton and pion spectra (ν-Ar in GRAIN)

E_ν fraction carried out by hadrons:

Protons + neutrons

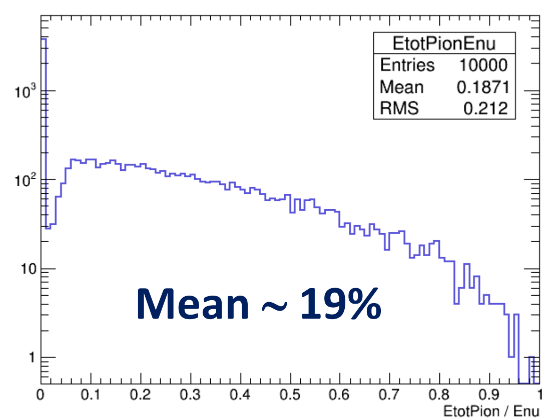


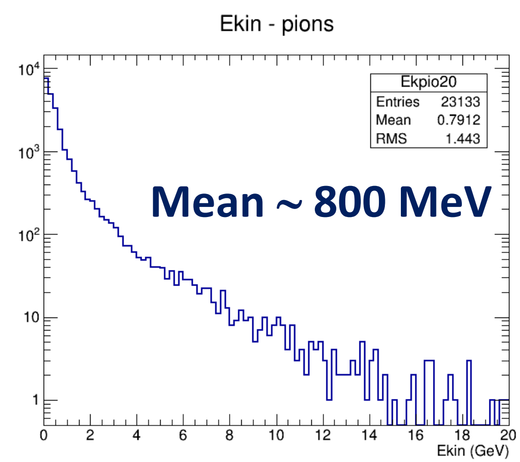


Proton energy spectrum

Almost 75% protons below 200 MeV

Pions



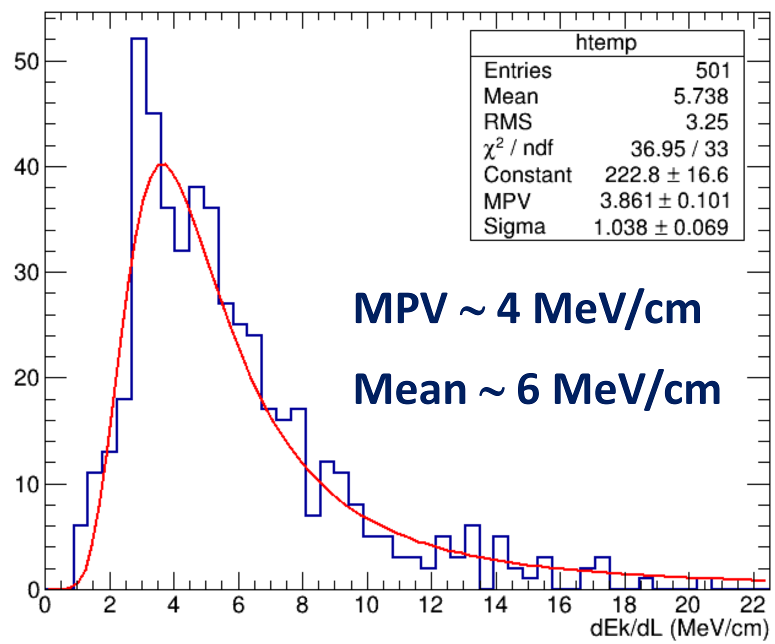


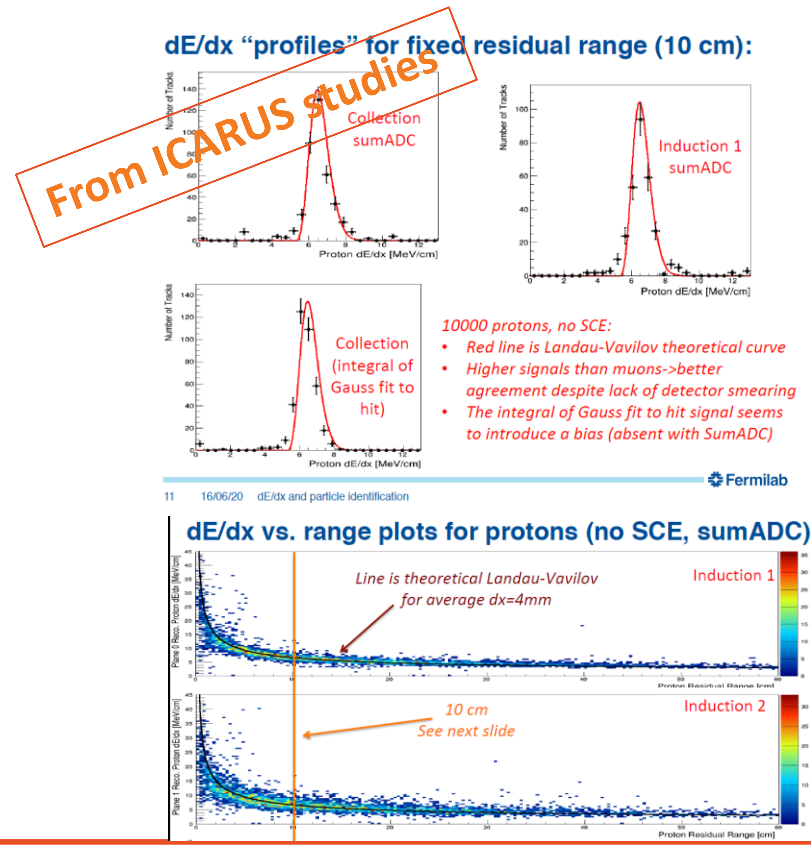
Pion energy spectrum

Proton energy loss in LAr

- **Energy loss in GRAIN: difference between P_{gen} (MC) and P_{track} (reco)**
- **Track-length in GRAIN: distance btw Vertex and 1st Hit of track in STT**

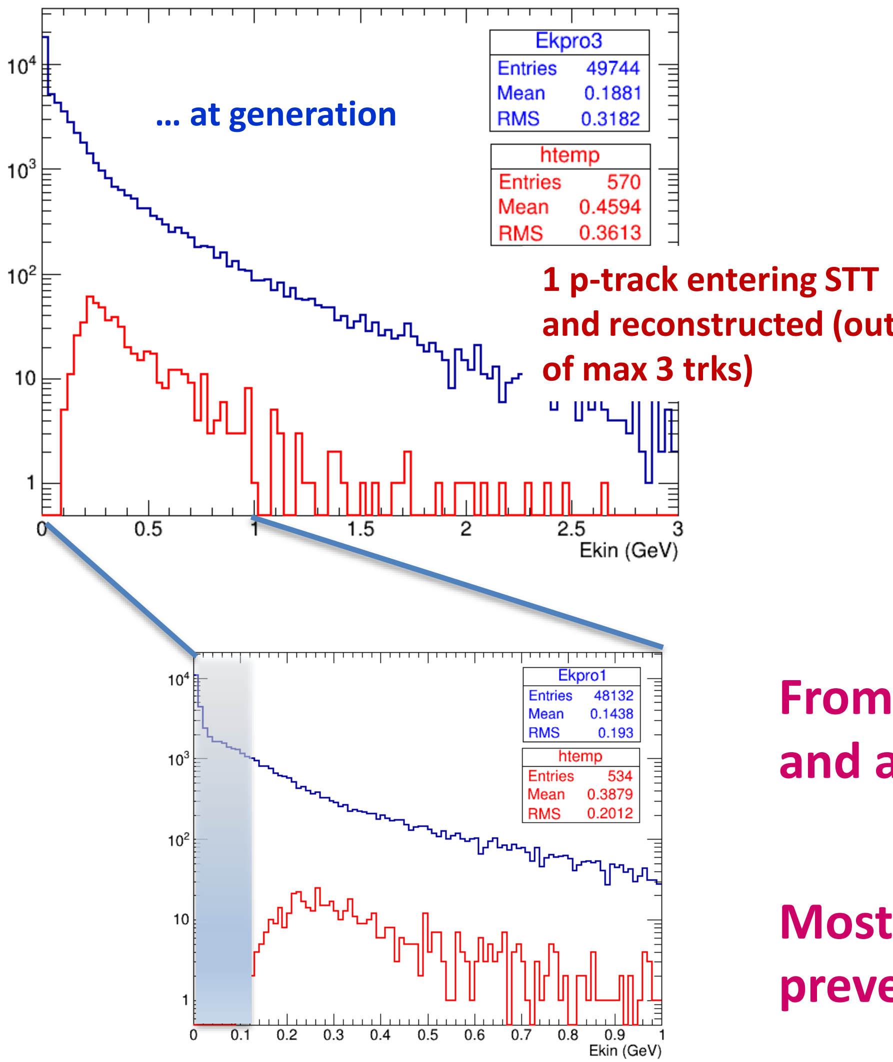
⇒ Energy loss per length unity in LAr, dE/dL (MeV/cm)

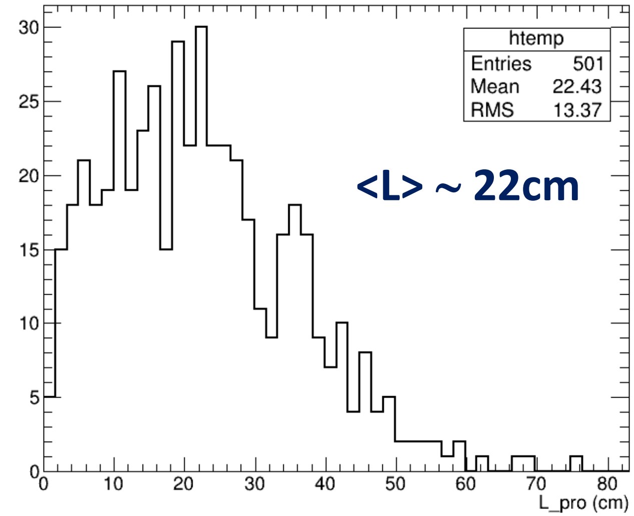




Proton spectra at generation and in STT

Proton spectrum …





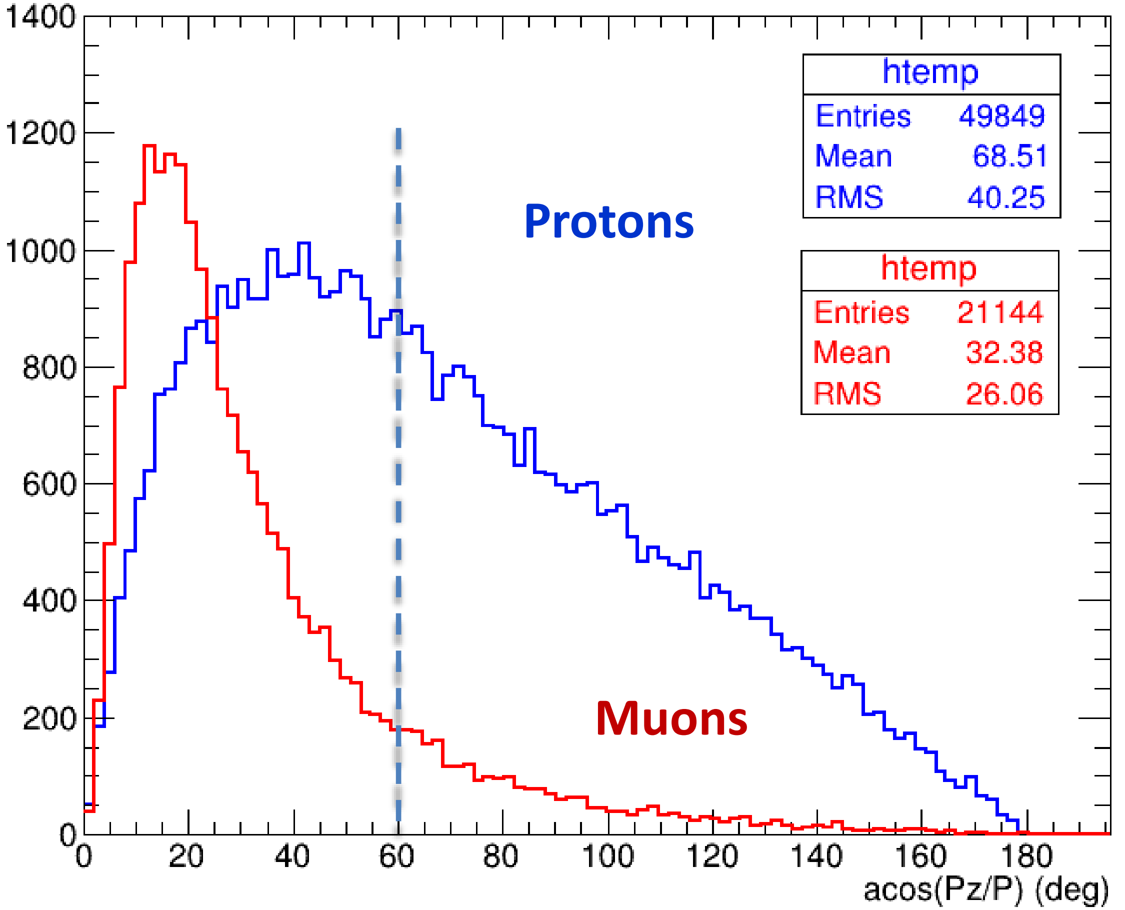
Proton path-length in LAr

From energy loss rate in LAr (6MeV/cm) and average path-length (22 cm)

⇓

Most Protons (below ~100-150 MeV) are prevented from reaching STT

Emission angle for protons and muons

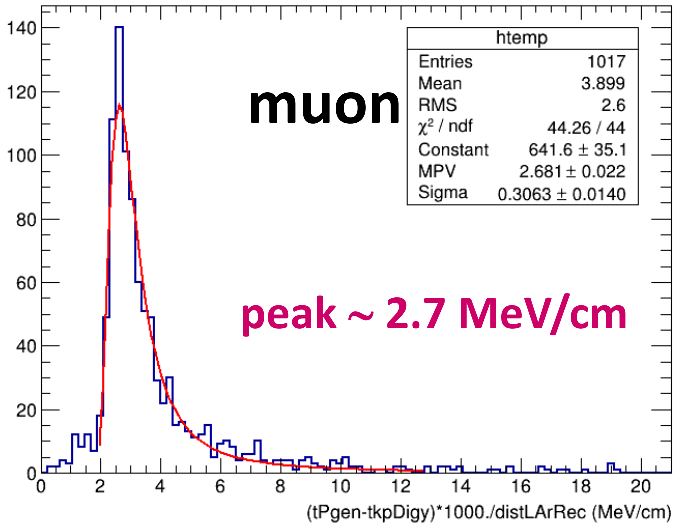


Large pT values also decreases STT acceptance for protons

<50% protons within $\theta_z < 60^\circ$

~25 % with E_{kin}>150 MeV

Muon energy loss in LAr

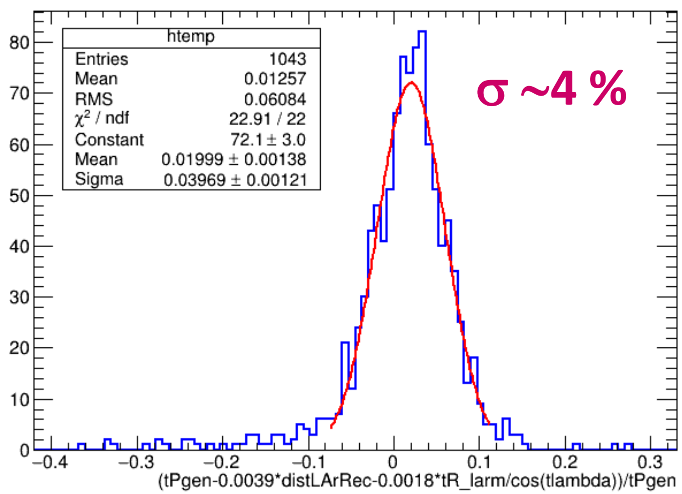


Estimated muon energy loss in GRAIN

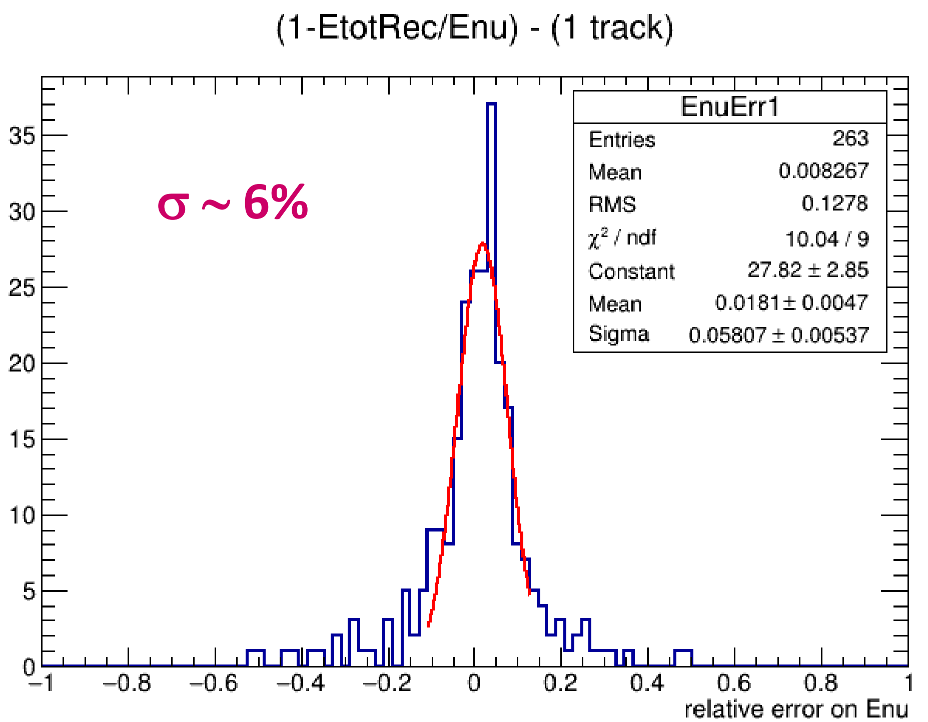
ΔE = LAr_path*<dE/dx>

with <dE/dx> = 3.9 MeV/cm

After correcting for ΔE (taking into account the typical path-length), the particle momentum at vertex can be reconstructed



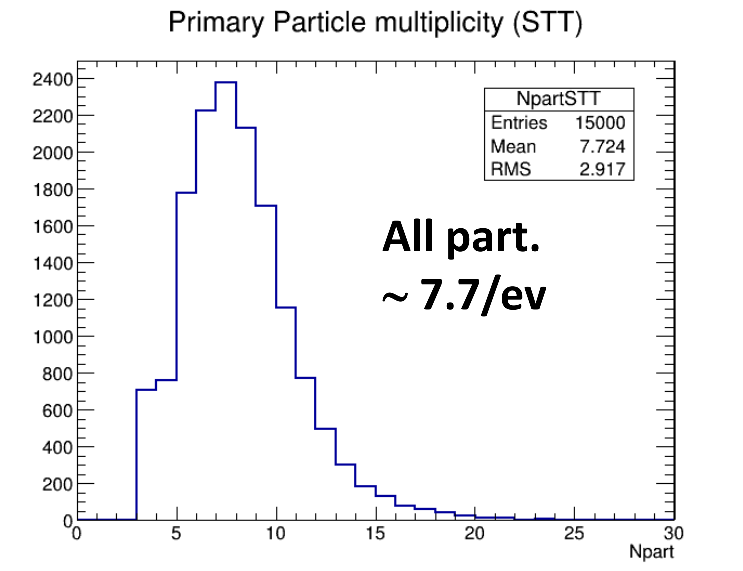
Single track events: ν Energy reconstruction

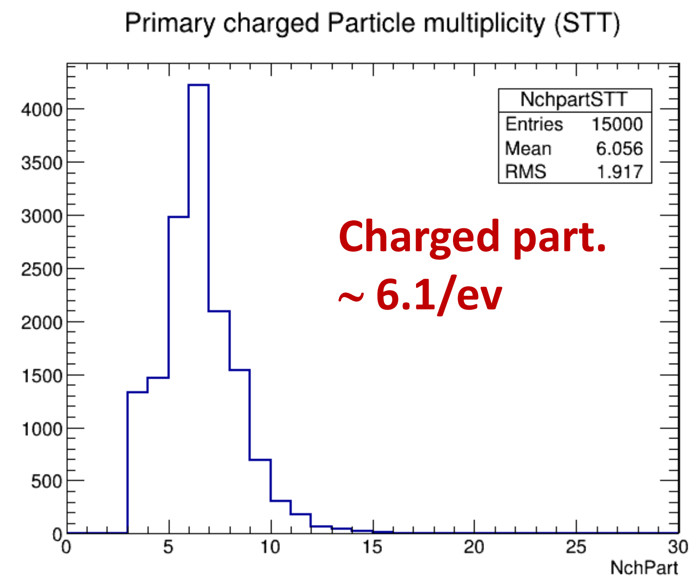


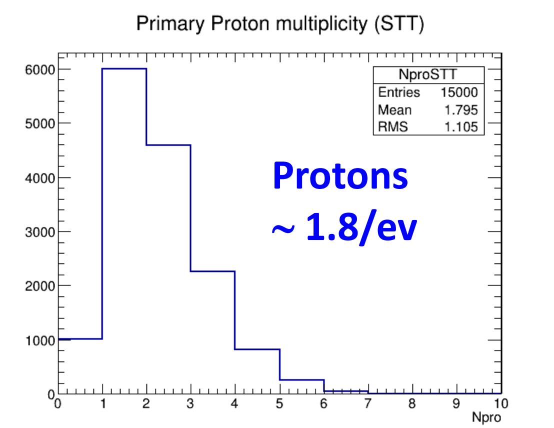
Preliminary

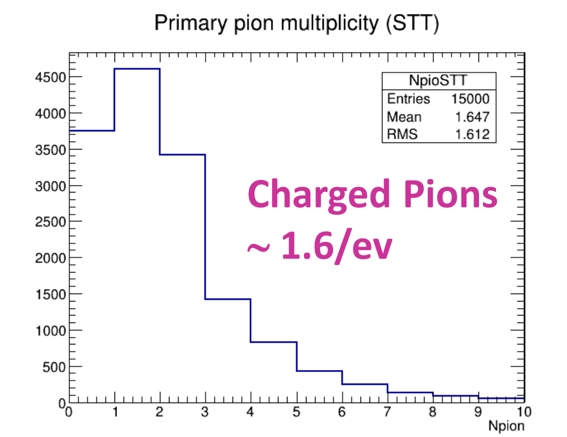
- Tracks succesfully matched in the 2 views ⇒ track in space (~75%)
- Assuming the energy deposited in LAr has been measured
- Off-track energy deposited in ECal taken into account
- Track ascribed to the muon (true in 95% of events, p in 4%, π± in 1%)

ν_μ interactions on H and C in STT

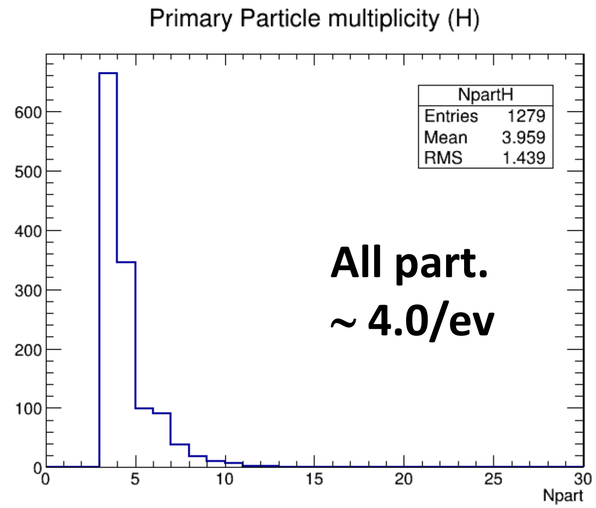


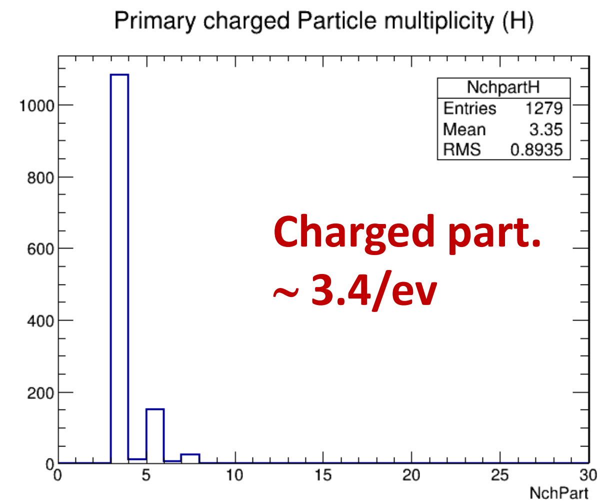


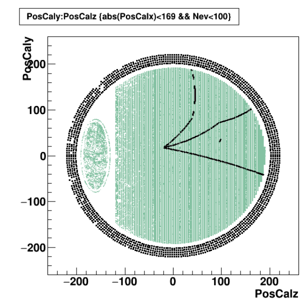




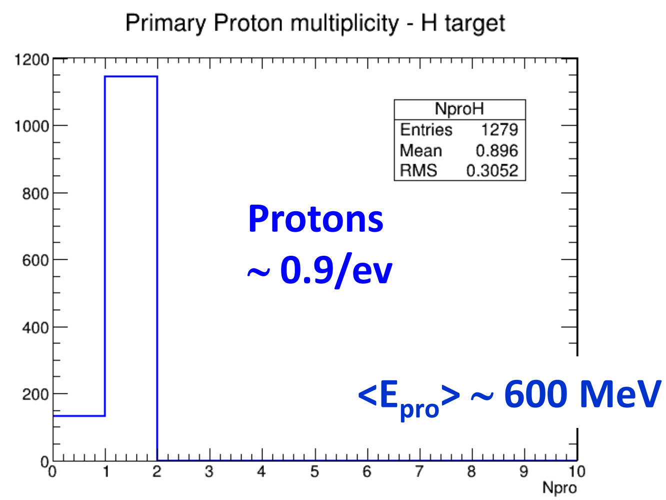
ν_μ interactions on H in STT

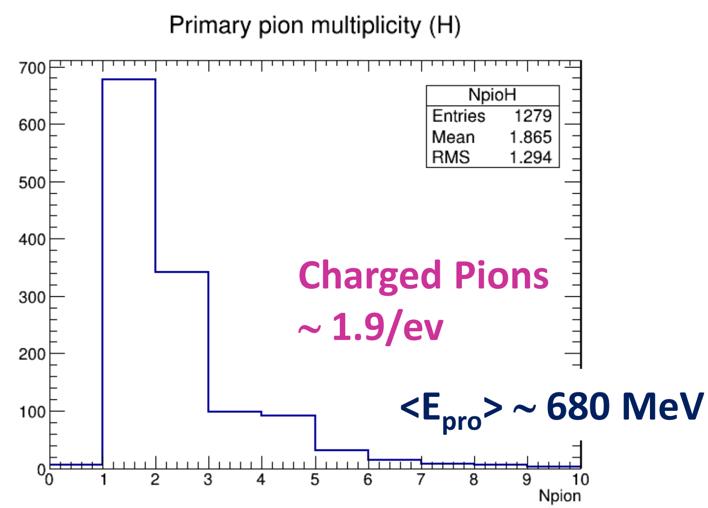




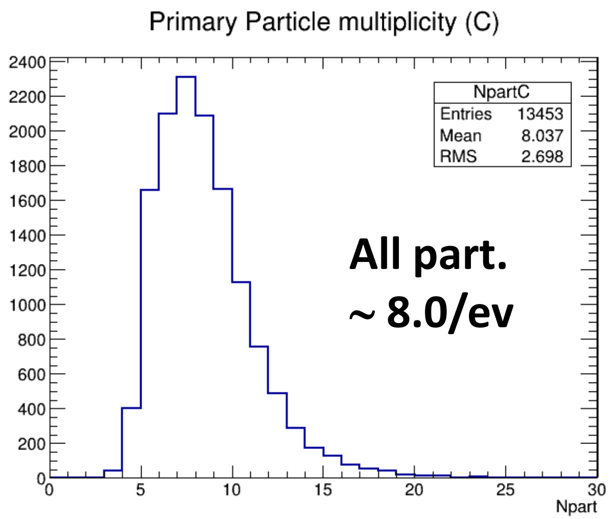


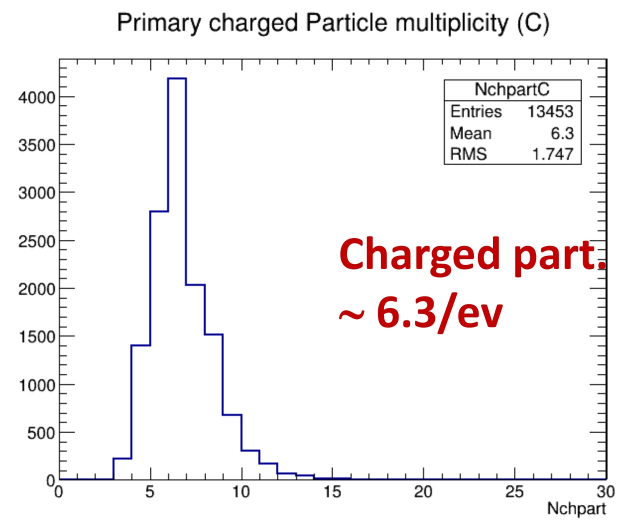
RES interaction on H
(~ 40% events on H)

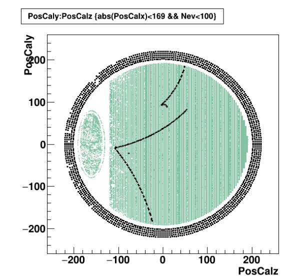




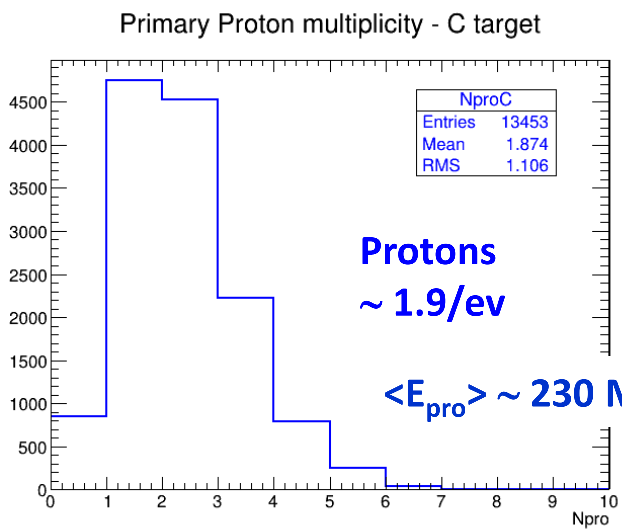
ν_μ interactions on C in STT



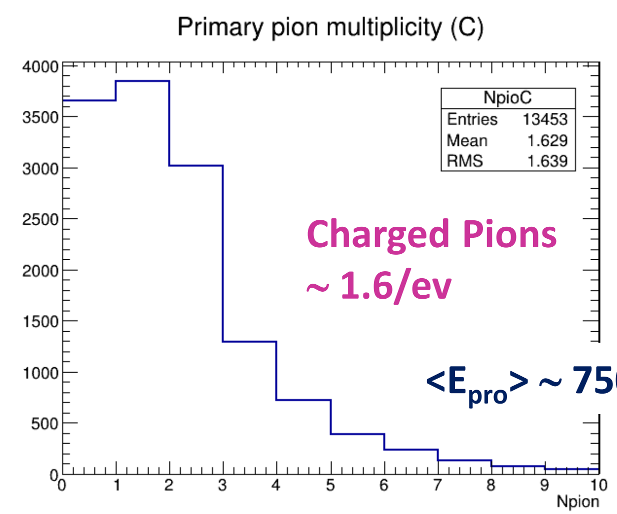




DIS interaction on C
(~ 40% events on C)



$<E_{pro}> \sim 230$ MeV



$<E_{pro}> \sim 750$ MeV

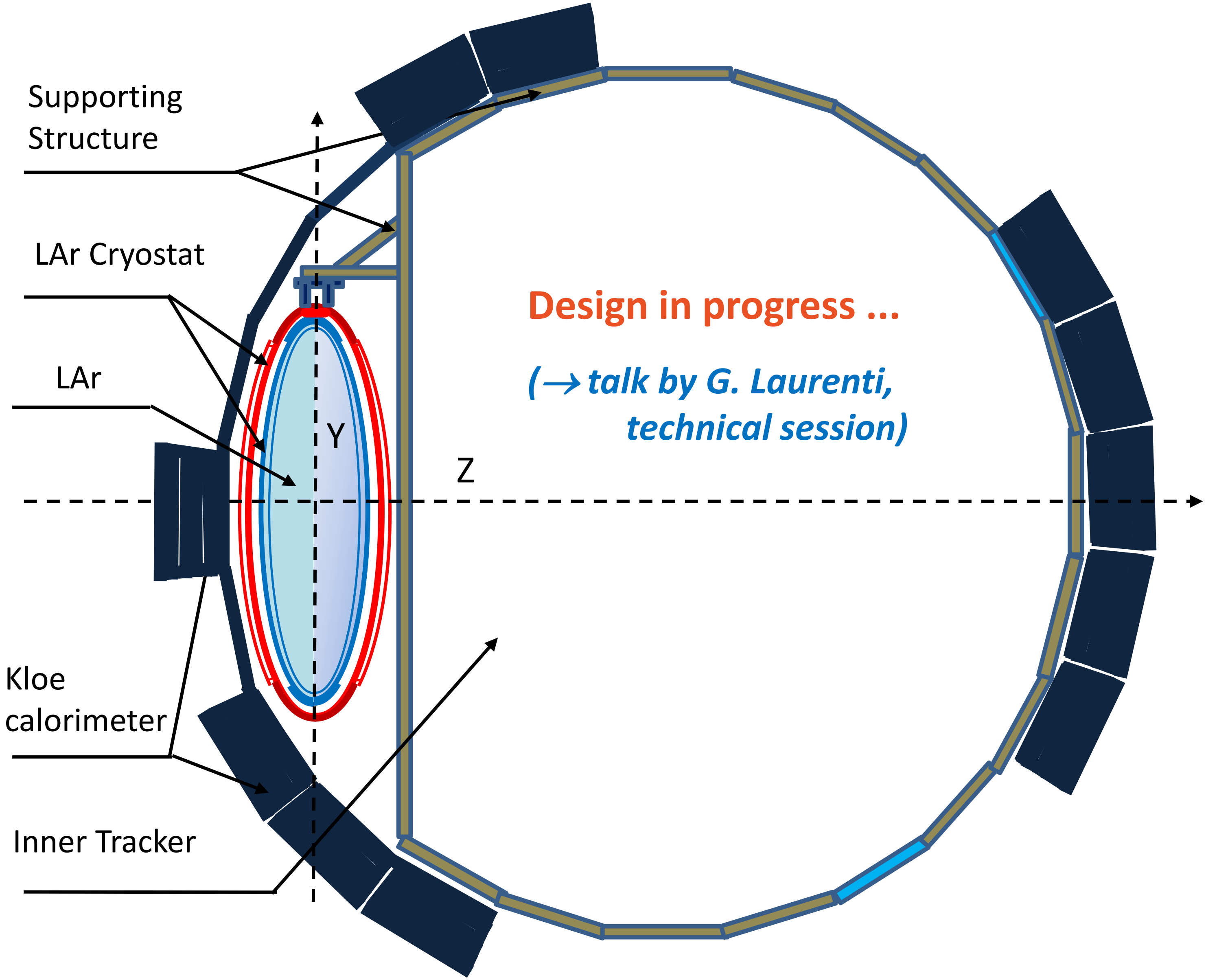
Conclusions e outlook

- Some features of ν_μ-CC interactions in LAr target (GRAIN) from FLUKA simulation
- Acceptance of outgoing charged particles in STT, track finding, global event reconstruction, ..
- Most events with low track multiplicity, so global track finding methods could be reliable. High track multiplicity events probably need more sophisticated track finding algorithms
- Some features of ν_μ-CC interactions in STT (H and C targets), peculiarities and differences w.r.t. interactions in LAr
- ….

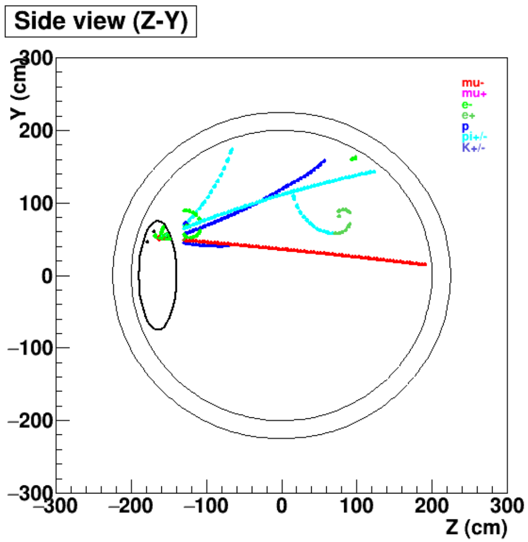
- Different interaction channels and event topologies: identification of event categories to be reconstructed with same tools or with the highest priority

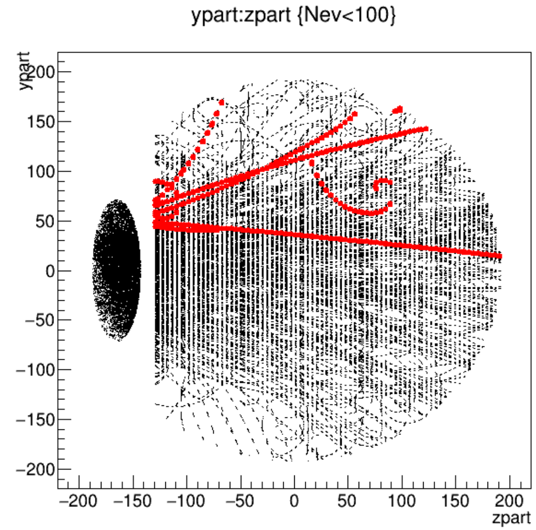
Backup

GRAIN inside SAND

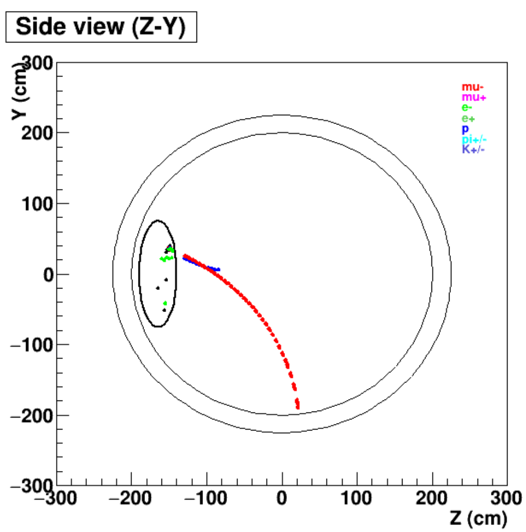


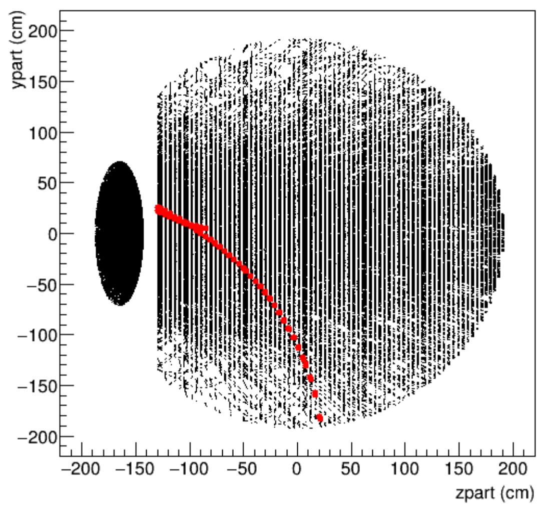
Problematic situations for transform method





Many tracks, eventually crossing each other



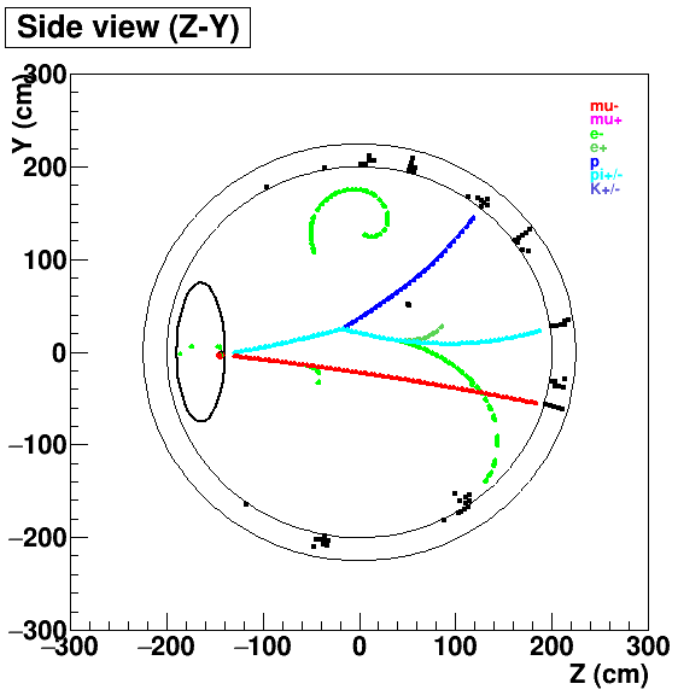


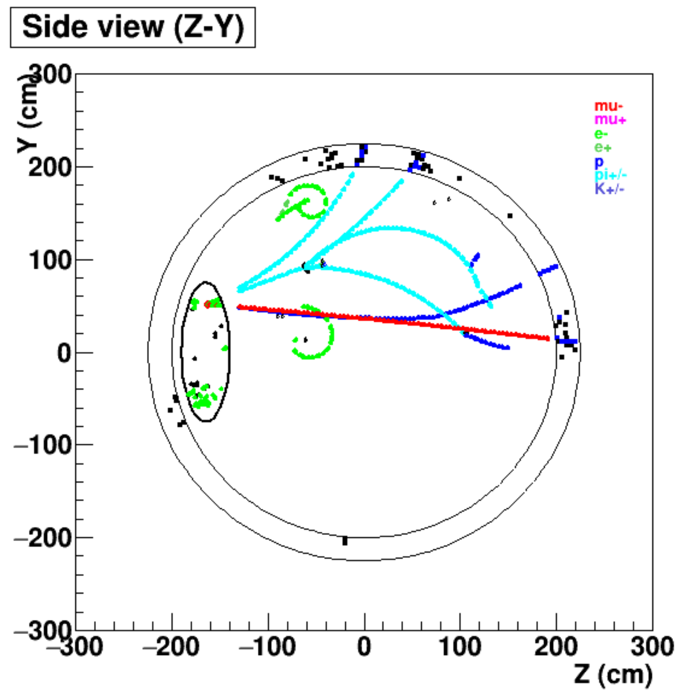
Superimposed tracks, although few

Track multiplicities in STT

The total track multiplicity in STT can be underestimated due to secondary vertices by interactions, decays, …

Some examples:

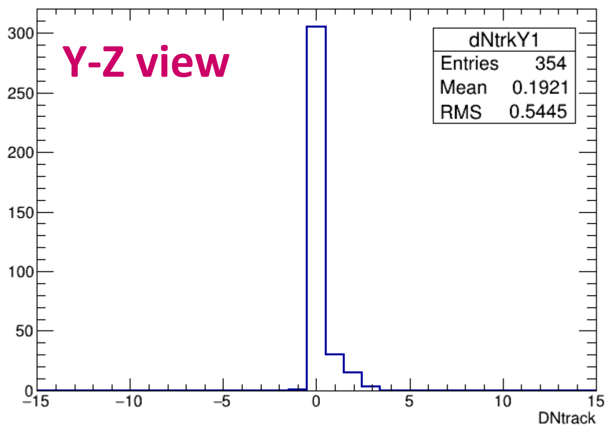




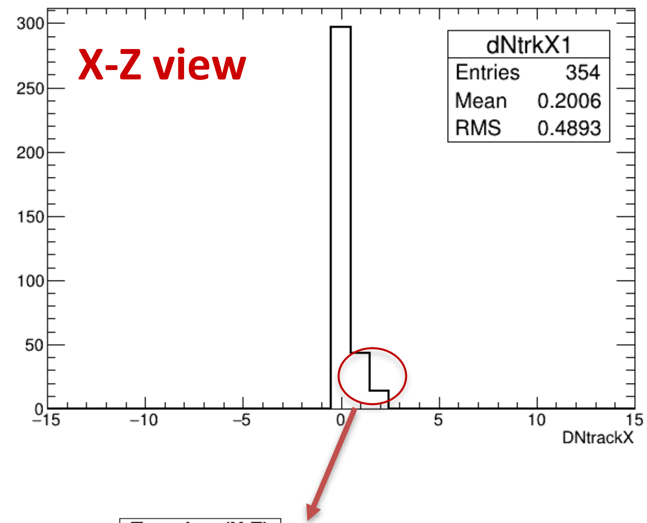
Single track events

Difference btw Reconstructed and MC (single) track entering STT:

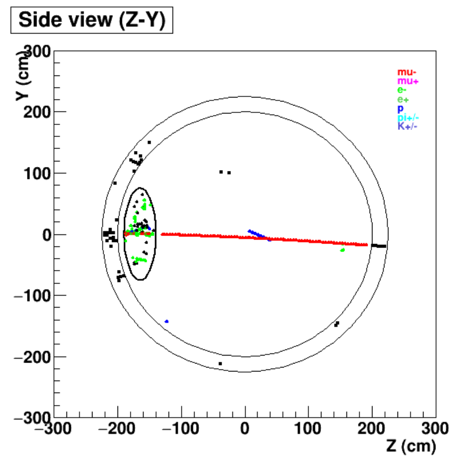
Δ Ntrack

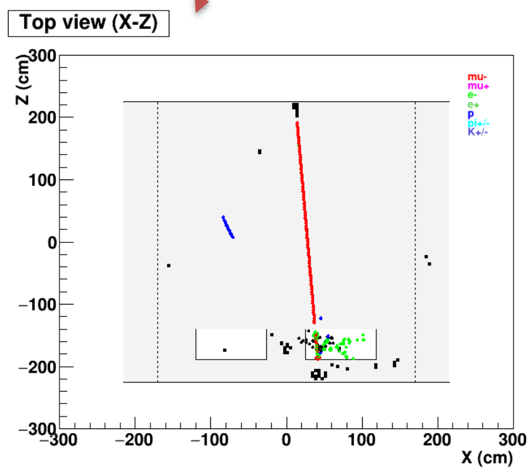


Δ Ntrack



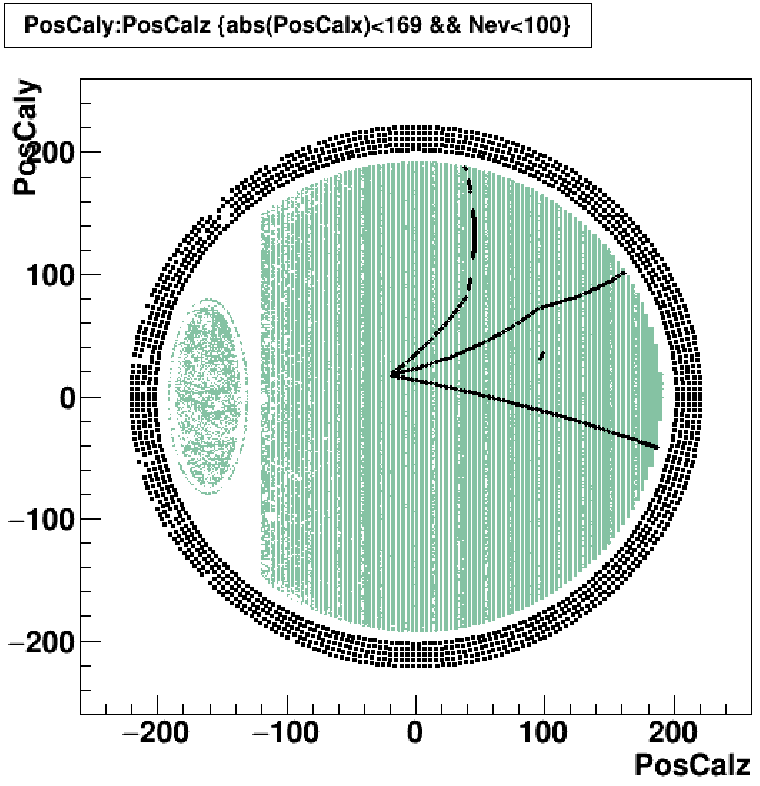
1 track in Y-Z view
2 tracks in X-Z view





ν_μ interactions on H and C in STT

RES interaction on H



DIS interaction on C