

CC π^0 Analysis

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Outline:

- Event sample selection.
 - Reminder of gamma candidates selection.
- Reconstructed particles plots.
- CC*Pi*0/CC*inc* x-section ratio.

Event sample selection

- Framework filters applied to Reconstruction:

- MRDMatchFilter** (CC definition filter).

--- 2nd reconstruction ---

- MuonMultiplicityFilter**: 1 and only 1 muon in the event.
 - TrackOnMuonTime**: non-muon tracks in 20 ns around muon time.

---ExtendedTacks---

- EndPointFilter**: **+/-135 cm for XY, 10-171 for Z**
 - MuCL**: **>0.005**
 - Disconnection**: **>12cm**
 - EC cluster energy in view 0** **>= 15MeV**

Combined to reject
tracks, not events

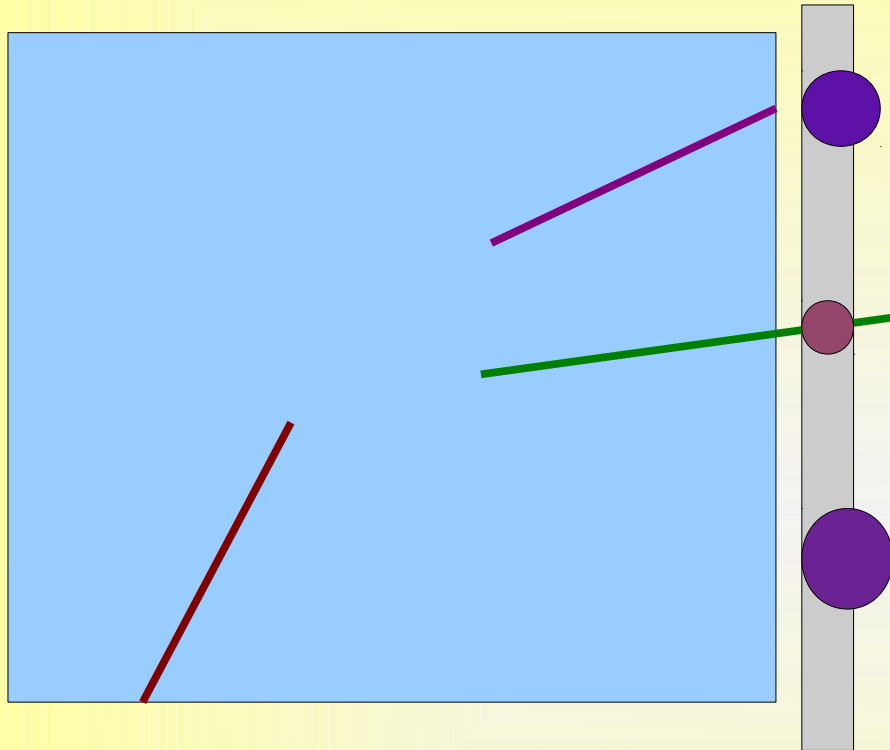
---MakeGammaCandidates---

- >=2 GammaCandidates**

---MakPi0Candidates---

- 1 Pi0Candidate**
 - GammaOpeningCosine < .96**

EndPointFilter



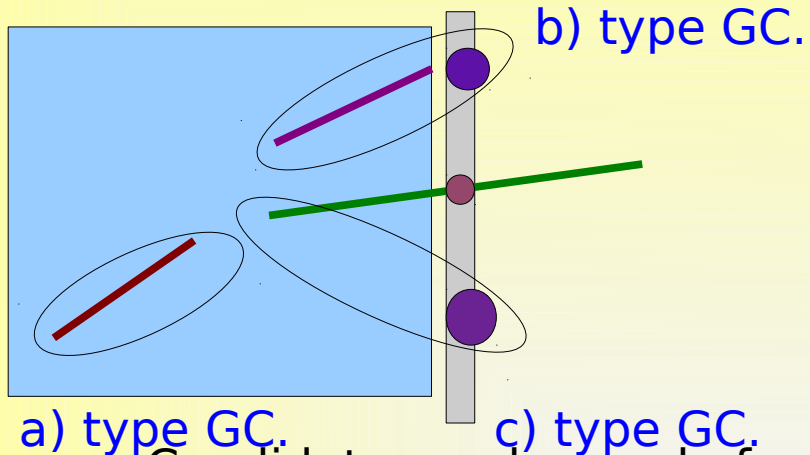
- **EndPoint of the track is always considered the farther edge from the event vertex (InitEdge of the muon), no matter the 'real' direction of the track.**

- **EndPoint filter set at (-135, 135) cm for XY (10 cm from the edge of SciBar) and (10, 171) for Z.**

- **SciBar contained even is not accurate given that it is allowed for the tracks to exit SciBar in the downstream direction.**

- Red track will be rejected even if it's an in-coming track (from DIRT, for instance).
- Magenta and green tracks will be accepted, cause they exit from the downstream edge of SciBar, towards the EC.

GammaCandidates



• GammaCandidate can be made from

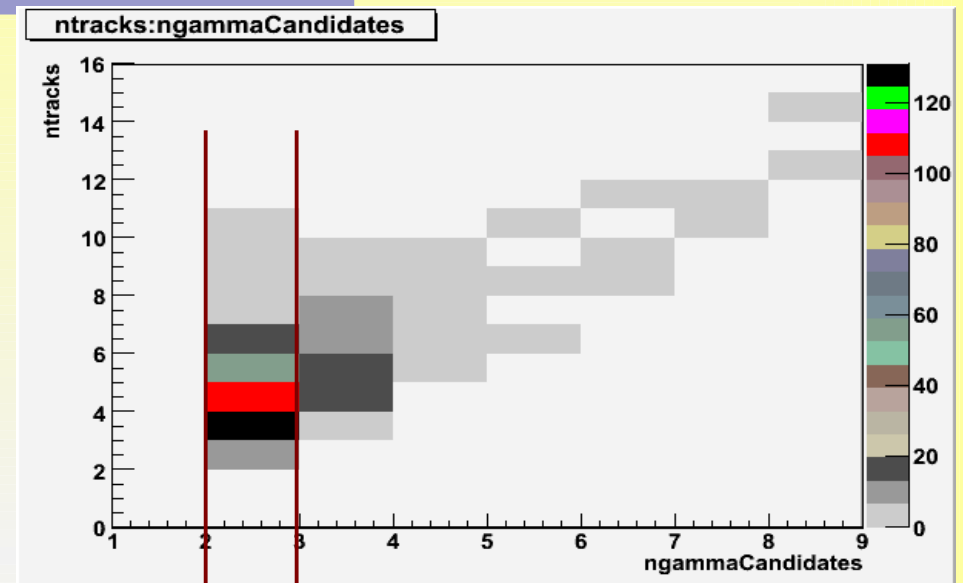
- **a)** 1 SciBar extended track;
- **b)** 1 SciBar extended track + associated clusters;
- **c)** set of clusters without a SciBar associated track.

• For type a) and b), Gamma edges and direction are taken from the SciBar Track.

- MuCL rejection: scibar tracks with $\text{MuCL} < 0.005$ are not GammaCandidates.
- SciBar tracks with distance to vertex < 12 cm are not GammaCandidates.
- Tracks leaking out from SciBar in any direction but the EC are also rejected

• In gamma candidate type c) only unmatched clusters are considered.

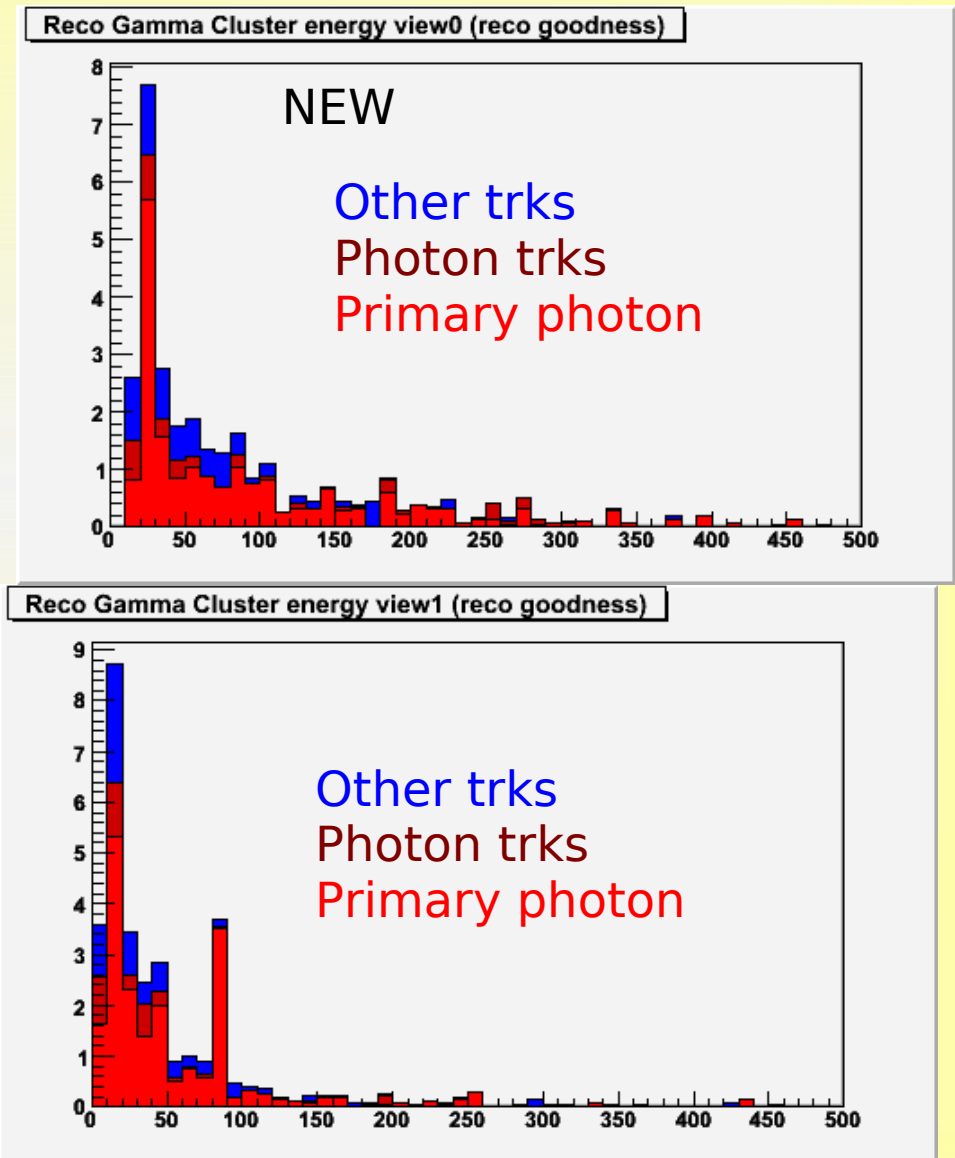
- At the current status, type c) are only made when only exists one non-matched cluster per view.
- Event vertex (muon init edge) is taken as init edge of the gamma and the cluster position defines the end edge.
- Cluster energy $\geq 15\text{MeV}$ in view 0.



The 2 GC sample contains mostly events with 3, 4 and 5 extended tracks

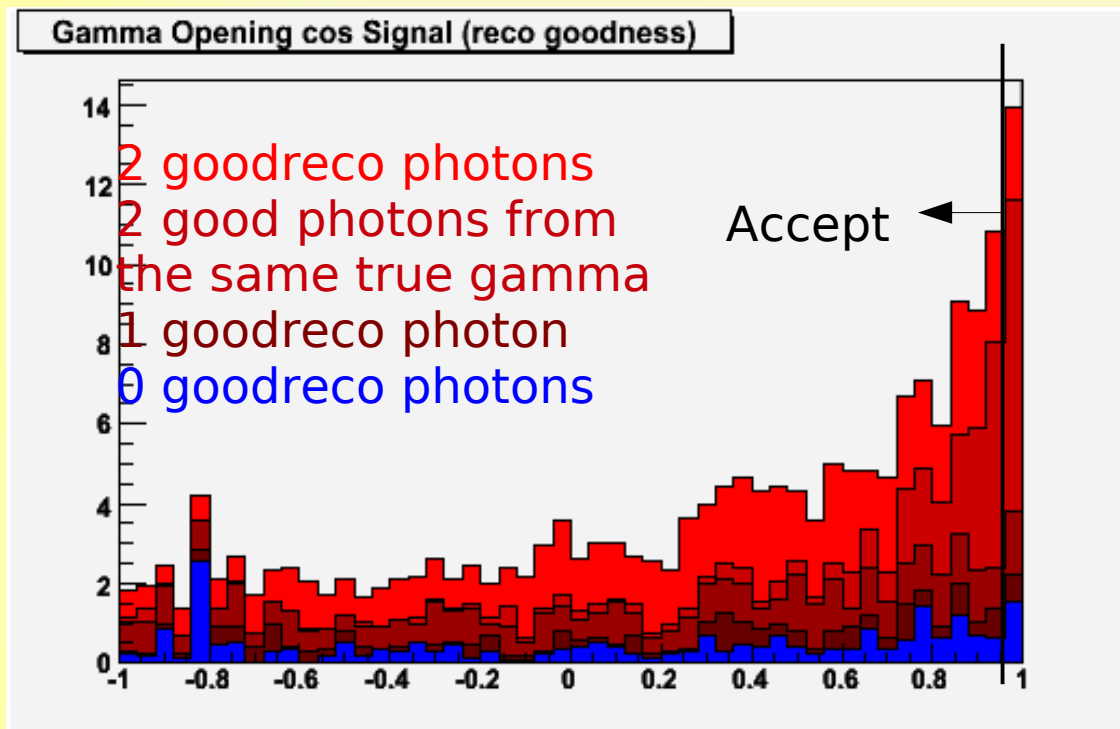
Gamma candidates Type c)

- Cluster energy per view for GC type c) (gamma conversion in EC).
 - Create a GC Type c) if exists only one free cluster per view.
- Require 15 MeV minimum energy in the clusters in view 0 to consider it for a gamma candidate.
- Need to think how to manage events with more than one free cluster per view.



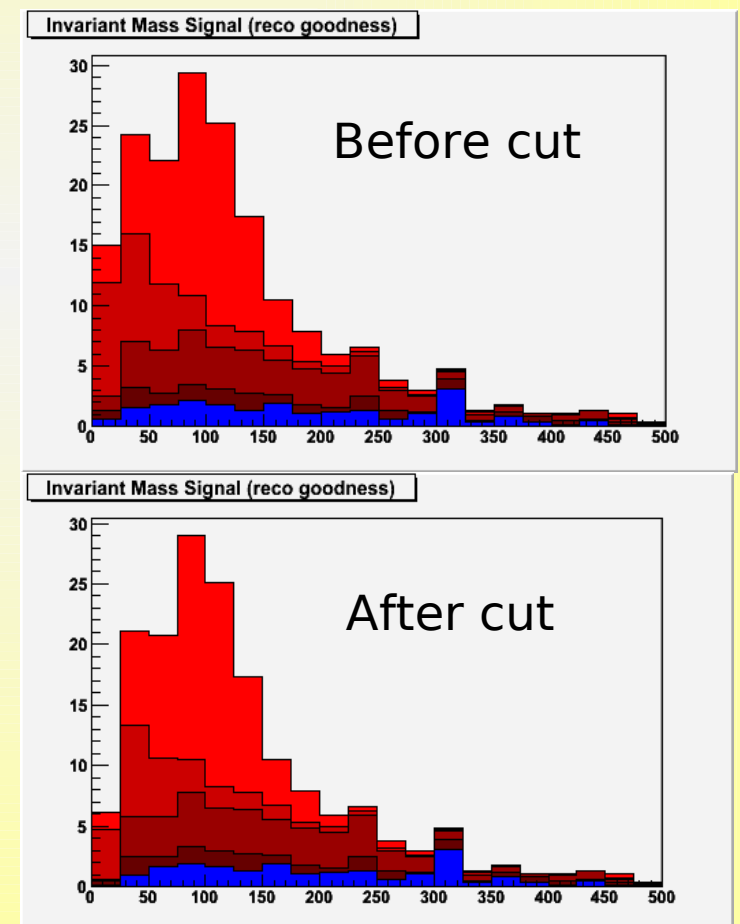
GammaOpeningAngle

- GammaCandidates coming from the same photon have very small opening angle between them. We can remove the low-mass tail by cutting on the GammaOpeningAngle.



Cut set at $\text{gamma_opening_cos} < .96$ using Eff*Pur maximization.

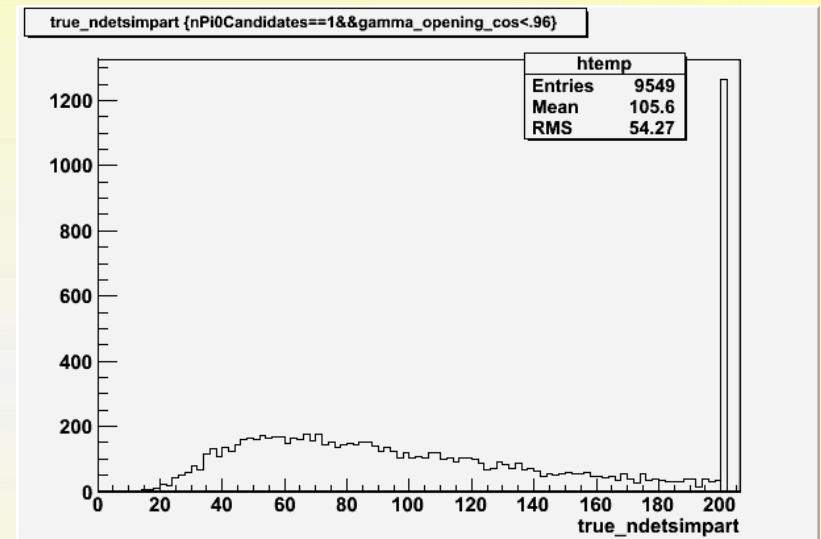
Plots of the signal contribution in terms of reco goodness.



Signal definition change

- **Found events that reaches the limit of the MC stored information, set at 200 MCparticles.**
If the limit is reached, no other particle truth information is stored in the event whilst all the **tracking and energy depositions are correct for all particles.**

- Given the high track multiplicity and the presence of EM showers in my selected events, turns out that a large amount of such events reaches the limit of 200 MCparticles.
- My previous signal definition implied the existence of a muon and a pi0 in DetSimParticle list with the initial position coinciding with the DetSimVertex position. And sometimes the info of those particles is not stored because the limit.



- As a workaround, I'm using in the following plots and tables the MC information at a generator level, defining my **signal as a muon and a neutral pion staying alive at the end of the NEUT processing.**
 - In previous meetings I've presented the plots with the background divided on background that contains pi0's and background without pi0's. In the following, the background is everything is not signal, and includes events with secondary pi0's.
- **Only way to fully correct it is to re-process the MC** (central value detector simulation + framework jobs) **removing the limit.**

Cut summary table:

MRDMatchNulnt:									
Cut sample	Data	Total MC	Signal	SB bkg	MRD/EC	DIRT	COSMIC	Purity	Efficiency
MRDMatch	30271	30271.0	2060.8	27065.6	790.2	178.4	176.0	6.81%	25.45%
1 Muon	29069	28920.8	1712.6	26090.3	781.8	167.2	168.9	5.92%	21.15%
Trk on muon time	28118	28683.9	1697.6	25907.9	759.7	166.1	152.6	5.92%	20.96%
GC>=2	428	566.3	269.3	266.7	2.5	25.7	2.2	47.55%	3.33%
1 Pi0C	336	400.9	188.1	196.5	2.1	14.0	0.2	46.91%	2.32%
Open angle	308	371.4	174.1	181.8	2.1	13.1	0.2	46.89%	2.15%

POTNulnt:									
Cut\sample	Data	Total MC	Signal	SB bkg	MRD/EC	DIRT	COSMIC	Purity	Efficiency
MRDMatch	30271	27930.7	1901.5	24973.1	729.1	164.6	162.4	6.81%	25.45%
1 Muon	29069	26684.9	1580.2	24073.2	721.4	154.3	155.8	5.92%	21.15%
Trk on muon time	28118	26466.3	1566.4	23905.0	700.9	153.3	140.8	5.92%	20.96%
GC>=2	428	522.6	248.5	246.1	2.3	23.7	2.0	47.55%	3.33%
1 Pi0C	336	369.9	173.5	181.3	1.9	13.0	0.2	46.91%	2.32%
Open angle	308	342.7	160.7	167.8	1.9	12.1	0.2	46.89%	2.15%

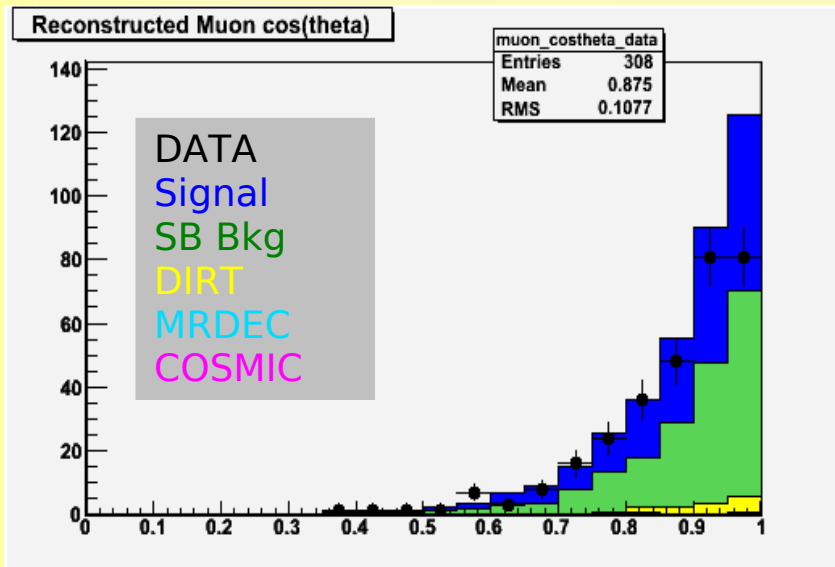
Slight CCPi0 data deficit alleviated by using POT normalization for MC rather than mrdmatch normalization.

Plot approval:

- I propose the following particle reconstruction plots for approval (Slides 11 to 14).
 - The analysis has improved significantly, almost doubling the statistics.
 - After the correction of the MC issue I expect minor changes if any on the cuts
 - may change the signal/bkg contents, but not the DATA points and not the MC shape/total normalization.

Muon reconstruction

MRDmatch normalized

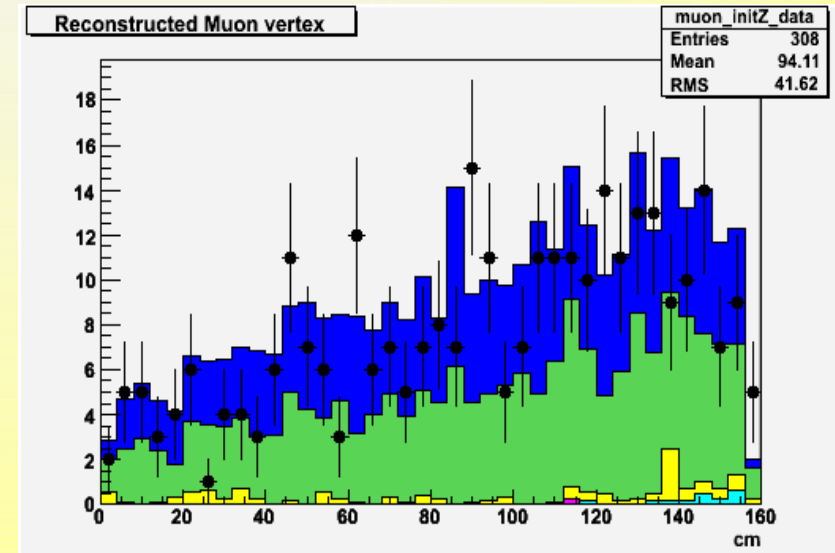
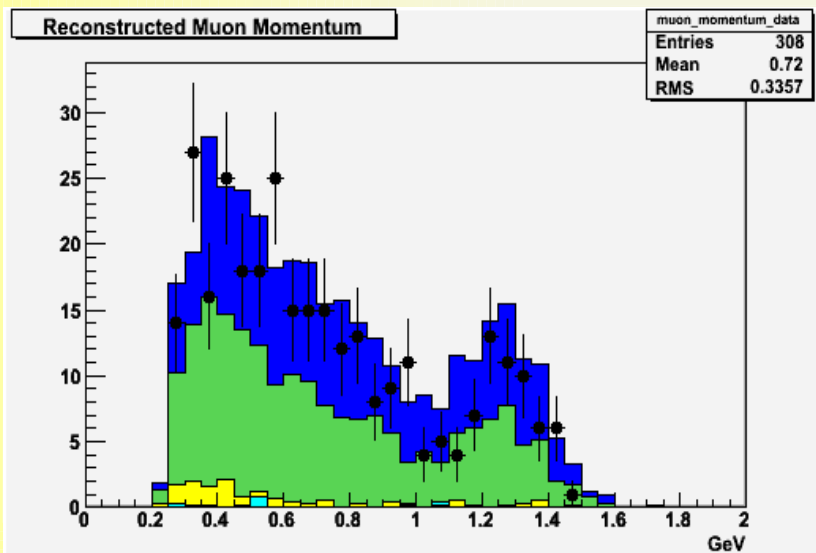


- Small DIRT background contribution. MRDEC and COSMIC backgrounds barely visible.

- Momentum bump at 1.2 GeV due to muons escaping from MRD.

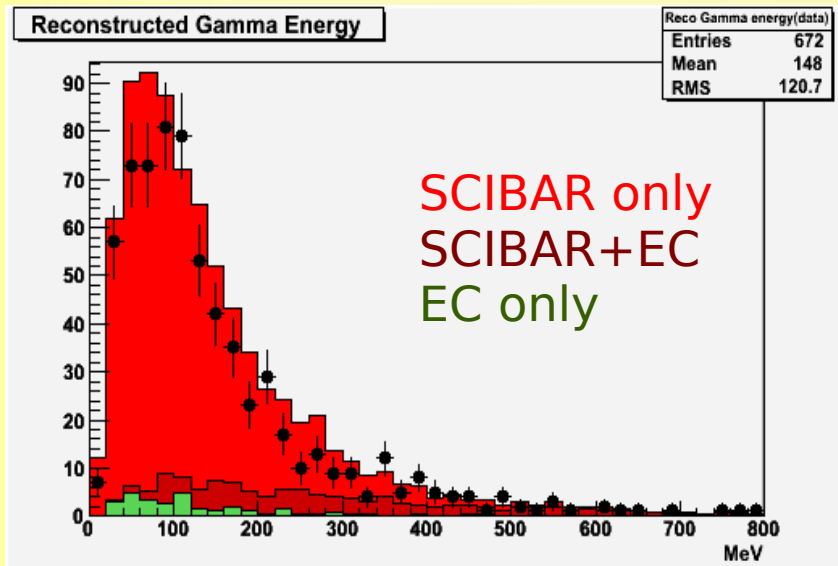
- DATA/MC deficit concentrated in forward muon direction.

- Shape agreement for muon momentum and vertex position distributions.



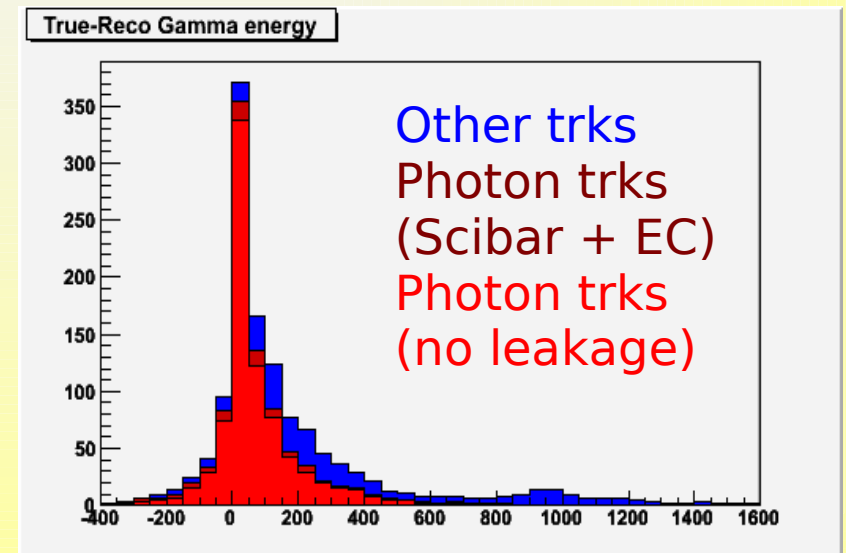
Photon reconstruction

MRDmatch normalized



In addition to gamma candidates in scibar only and scibar+ec, i'm also adding gamma candidates in EC only.

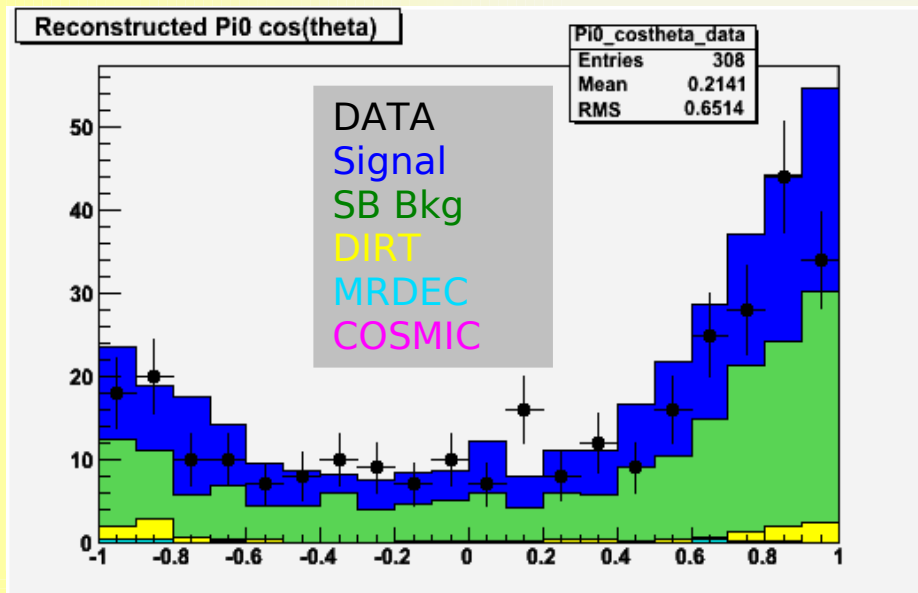
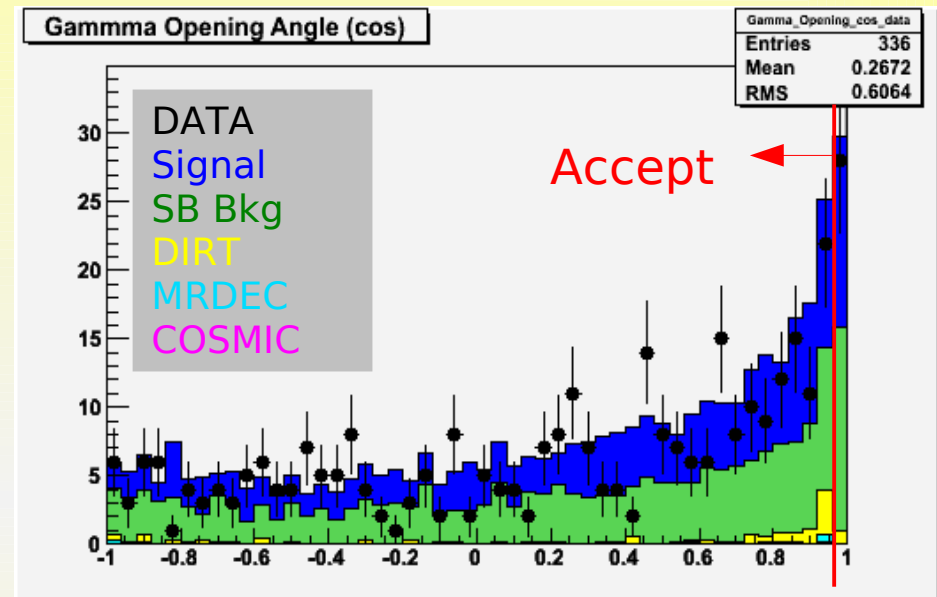
- 148 MeV mean photon energy
- True - Reco energy for correctly matched photons: 76 MeV (152 RMS)
- Notice photon high purity because photons are found also in background events.



Pi0 reconstruction

MRDmatch normalized

- Events with small opening angle between gammas are rejected. Use to be the same photon reconstructed as 2GC.
- Pi0 produced mostly forward and at all angles.

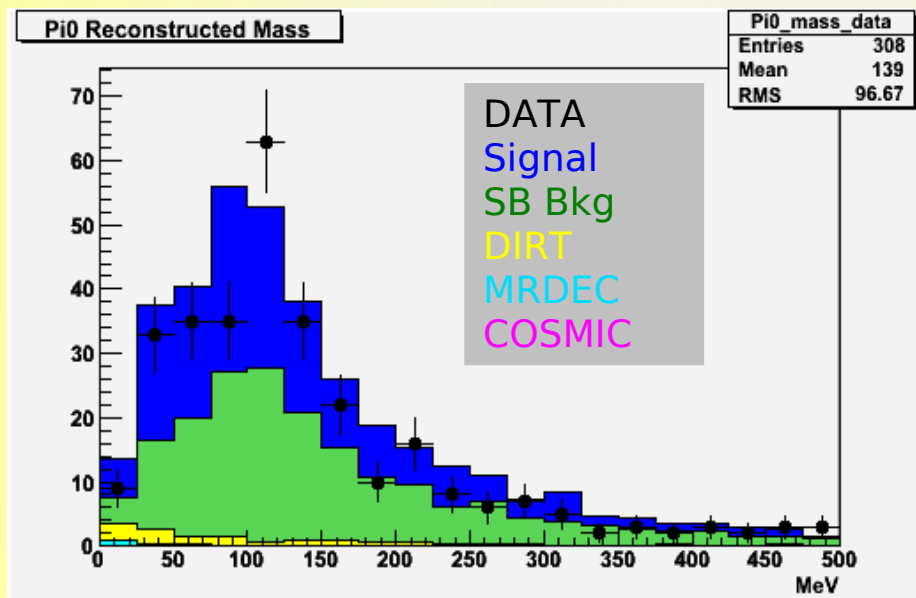
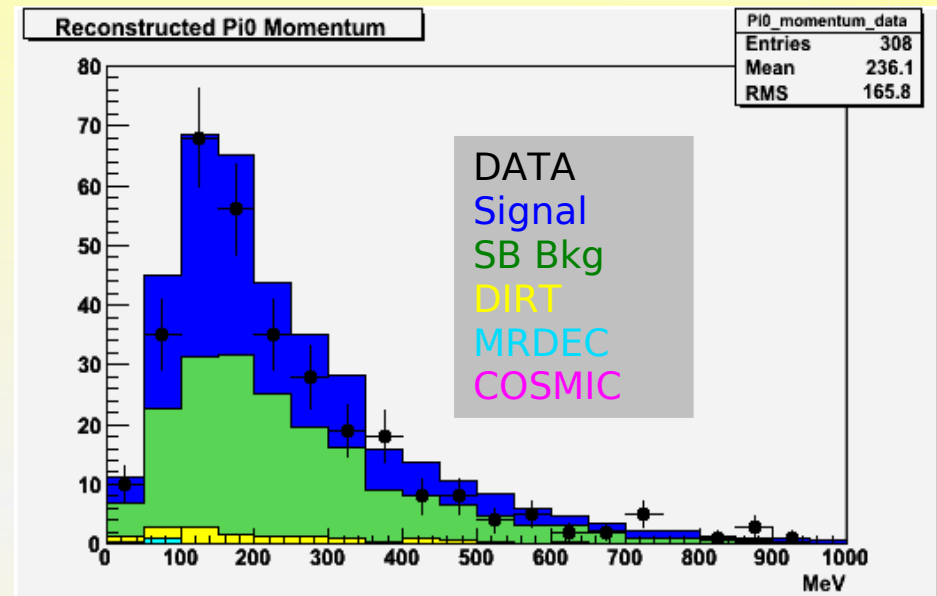


Good agreement between DATA and MC.

Pi0 reconstruction

MRDmatch normalized

- Good agreement in shape for the reconstructed quantities.



- Visible peak near pi0 mass in the reconstructed invariant mass plot.
- Notice that the background also peaks near pi0 mass. This is caused by secondary Pi0's.

CCPi0/CCinc x-section ratio

$$\frac{\sigma_{CC-\pi^0}}{\sigma_{CC-inc}} = \frac{\frac{N_{CC-\pi^0(DATA)} - N_{CC-\pi^0(normalized\ backgrounds)}}{\epsilon_{CC-\pi^0(signal)}}}{\frac{N_{CC-inc(DATA)} - N_{CC-inc(normalized\ backgrounds)}}{\epsilon_{CC-inc(signal)}}}$$

- CCPi0/CCinc x-section ratio using **mrdmatch** normalization for the background subtraction:

$$\star 0.053 \pm 0.008(stat.)$$

- CCPi0/CCinc x-section ratio using **POT** normalization for the background subtraction:

$$\star 0.060 \pm 0.008(stat.)$$

- ★ To compare with **TrueMC** x-sec ratio:

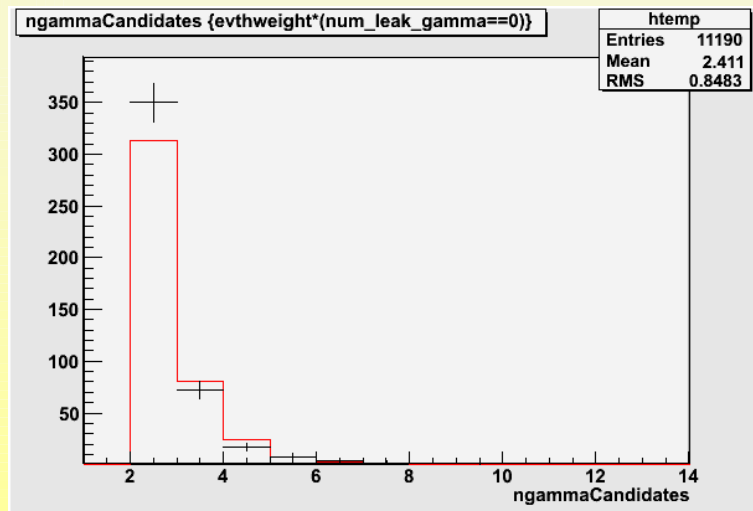
$$\star \#CCpi0 \text{ events}/\#CCinc \text{ events}=0.083$$

Summary

- ★ With respect to previous collaboration meeting
 - ★ Track based event selection now mature.
 - ★ New cut to reject poorly reconstructed signal events.
 - ★ Added ECMRD and COSMIC backgrounds.
- ★ Clear signal found in data, good agreement with MC in all kinematic distributions except for forward muons. Causing an overall DATA/MC deficit.
- ★ Ratio of CCpi0/CCinc cross section measured using mrdmatch normalization for background subtraction
 - ★ **CCPi0/CCinc=0.053±0.008(stat.)**
 - ★ to be compared with a MC expectation of 0.083
- ★ Bug found in storing MC particle truth information in Detector Simulation. Will require new MC production to handle properly₁₆

Looking forward

- Perform a new MC production and see how it affects my analysis.
- Try to verify with DATA
 - Background estimation for CC pi0 sample.
 - Signal efficiency estimation for CCpi0 sample.
- Compare results with past experiments (ANL, BNL, K2K, etc).
- Deal with events that contains more than one Pi0Candidate.

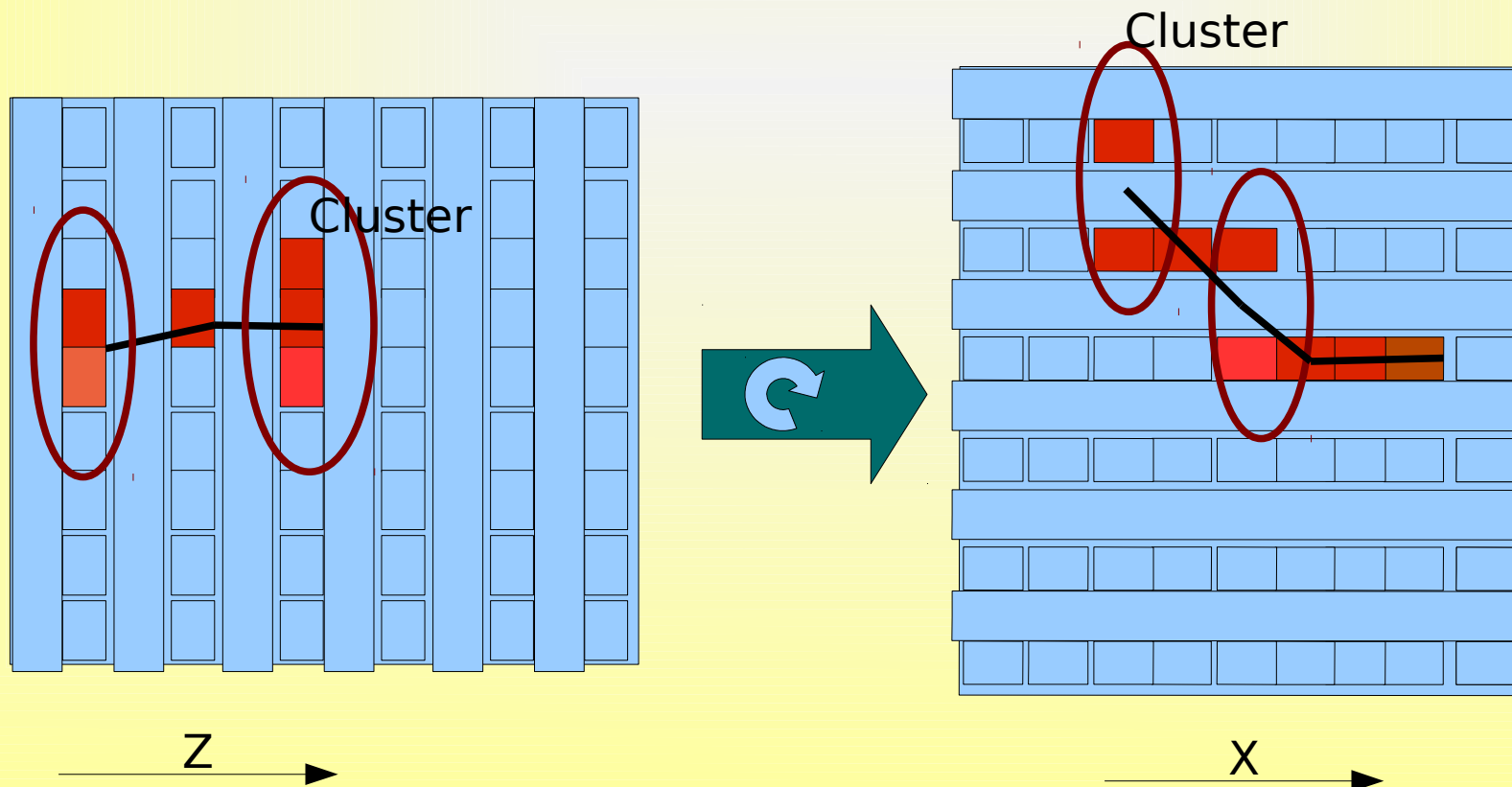


Backup Slides

sbtcat

The T in sbtcat comes from applying sbcat in the transversal direction in order to be able to reconstruct high angle tracks.

The main idea is to switch layers and channels in the sbcat. That means that the clusters will be constructed in the Z direction (in channel lines) and will be connected in X (Y). That should allow us to reconstruct large angle tracks.

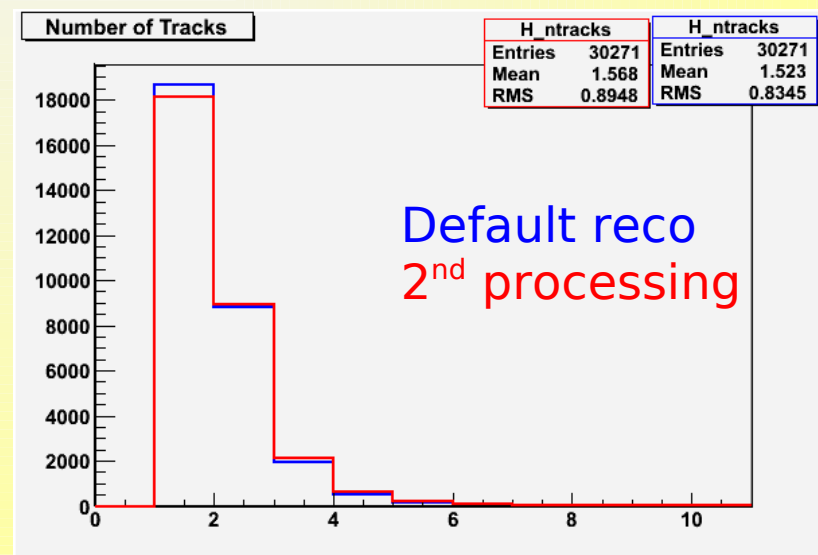


2nd reconstruction: sbcat + sbtcat

In order to increase the number of multi-track events, particularly the ≥ 3 track events, I've been developing and applying a '2nd reconstruction'.

2nd reconstruction consists in to run sequentially sbcat and sbtcat over the MRDMatched events. The way to implement it is to seek for hits that has not been used for the 3DTrack reconstruction in the default processing and run sbcat again using only such hits. Then, we look for hits still not being used for the 3DTracks from the default reconstruction nor for the 2DTracks in the 2nd sbcat processing. And then we run sbtcat over them.

Eventually, the 2nd sbcat will produce one or more new projections, and also sbtcat if there are more unused hits. We run again Match2DTracks over the new created projections in order to get new 3DTracks that comes from projections created either by 2nd sbcat run or sbtcat.



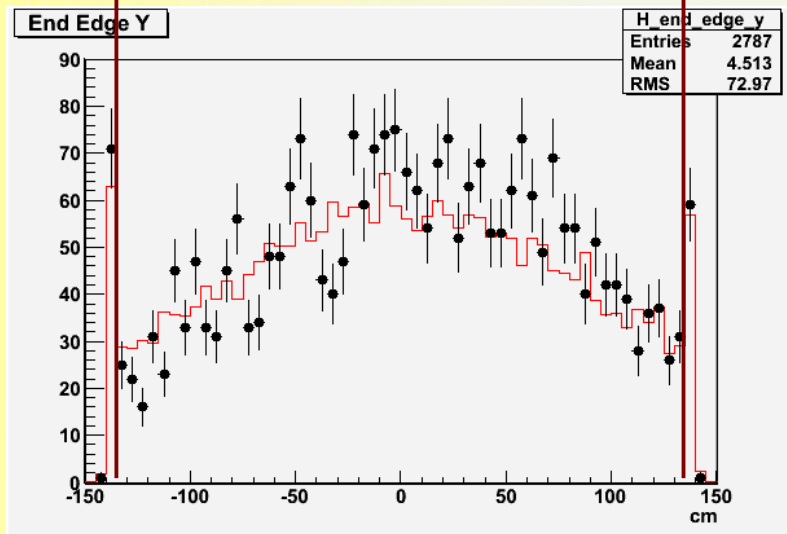
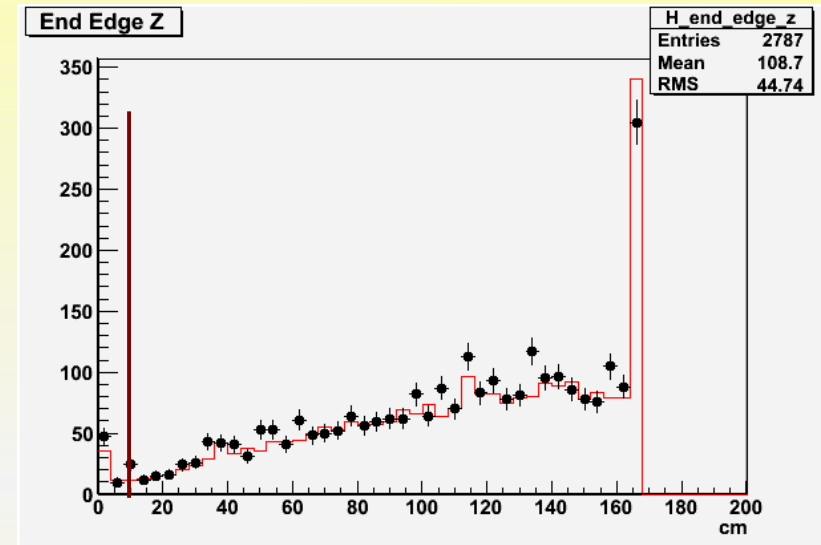
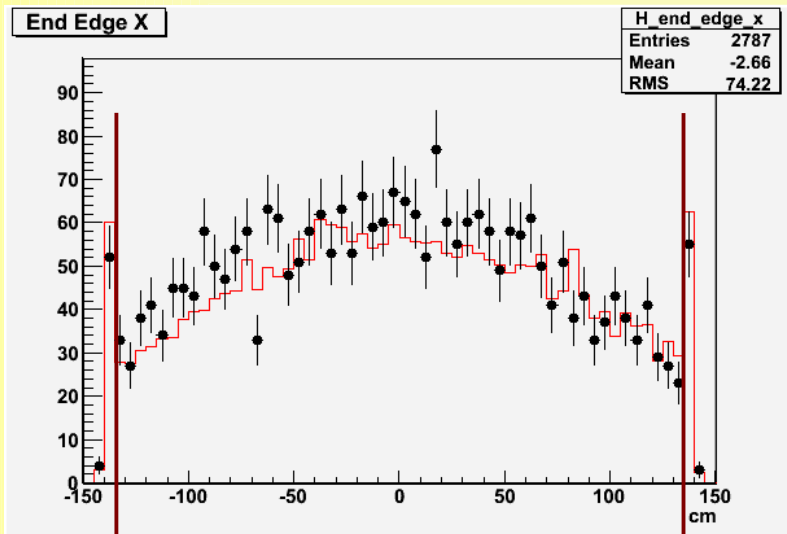
EndPointFilter

- Is a containment requirement that uses the EndEdge of the track to reject particles scaping from a given FiducialVolume SciBar.
 - All tracks are considered for the filter.
 - Filter not rejecting tracks heading the EC.
 - Helps to improve the energy reconstruction.

Values for the FV are chosen in accordance of the ExtendedTrack radius (explained in the next slide).

EndPointFilter

**All plots are SciBar-MC
MRDmatch normalized**



- Set to assure containment and to remove DIRT events.

- Init edge of the track is set to the closest edge to the event vertex (InitEdge of the muon).

- Cut set at (-135, 135) cm for XY and (10, 171) for Z.

ExtendedTrack tuning parameters

- ExtendedTrack rcp have the following parameters:
 - Rcproj_lenght_threshold (parameter not changed)
 - Radius:** distance from the track to look for hits to add to the track.
Standard value 20cm, chosen value: 10 cm
 - Chi²** max of the fit for the new extendedtrack.
standard value 50, chosen value: 10
 - Time difference between tracks (not change observed)
 - MuCL (not significant change observed)
 - Pe threshold (not significant change observed)

Muon reconstruction

MRDmatch normalized

- Muon bump at 1.2GeV due to muons escaping the MRD.

