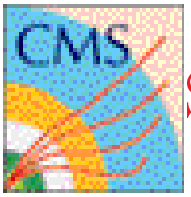

Simulation of the CSC Track Finder

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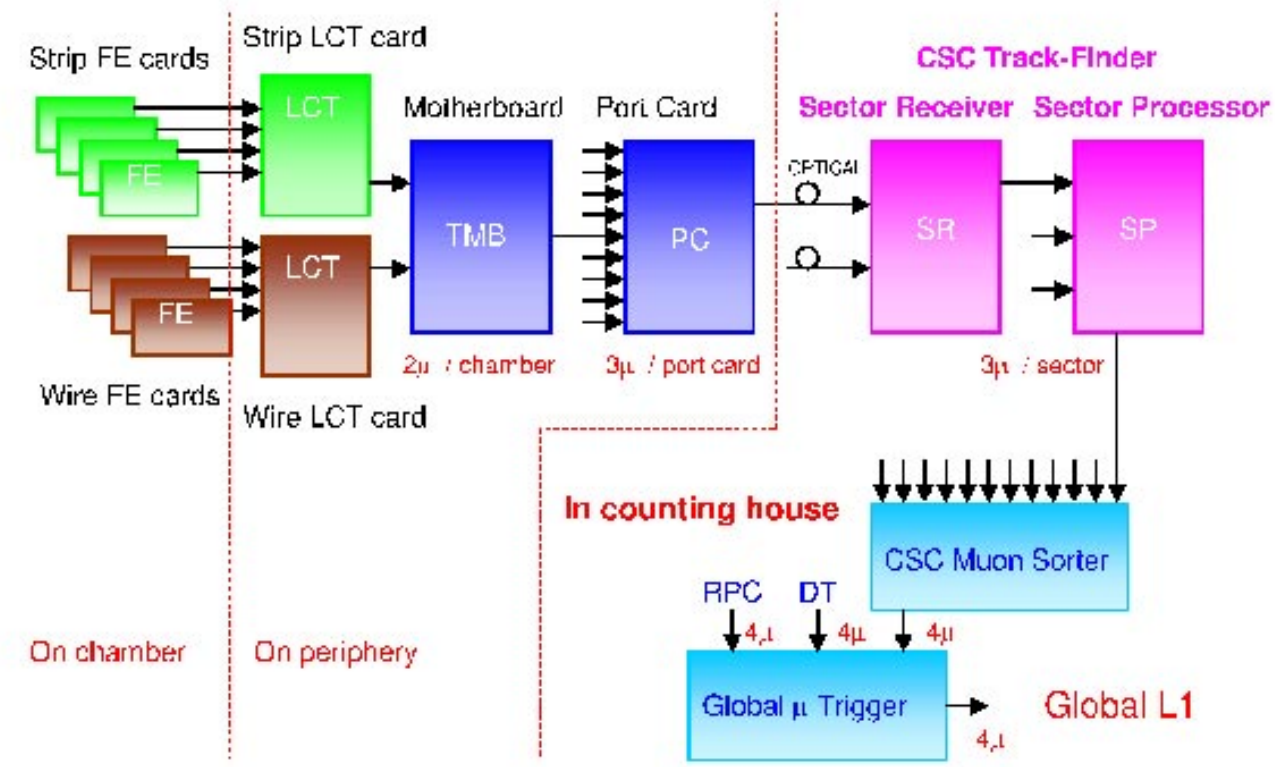
PNPI

CSC Sector Processor Review
July 1999

- Report on the results from the studies of the CSC Track Finder simulation
- CSC Track Finder simulation is written in Fortran
- Interface with the ntuple produced by CMSIM
- Emulate as close as possible to the design of the hardware
- Most results from the Endcap Track Finder simulation. Some new results from the Overlap+Endcap Track Finder simulation

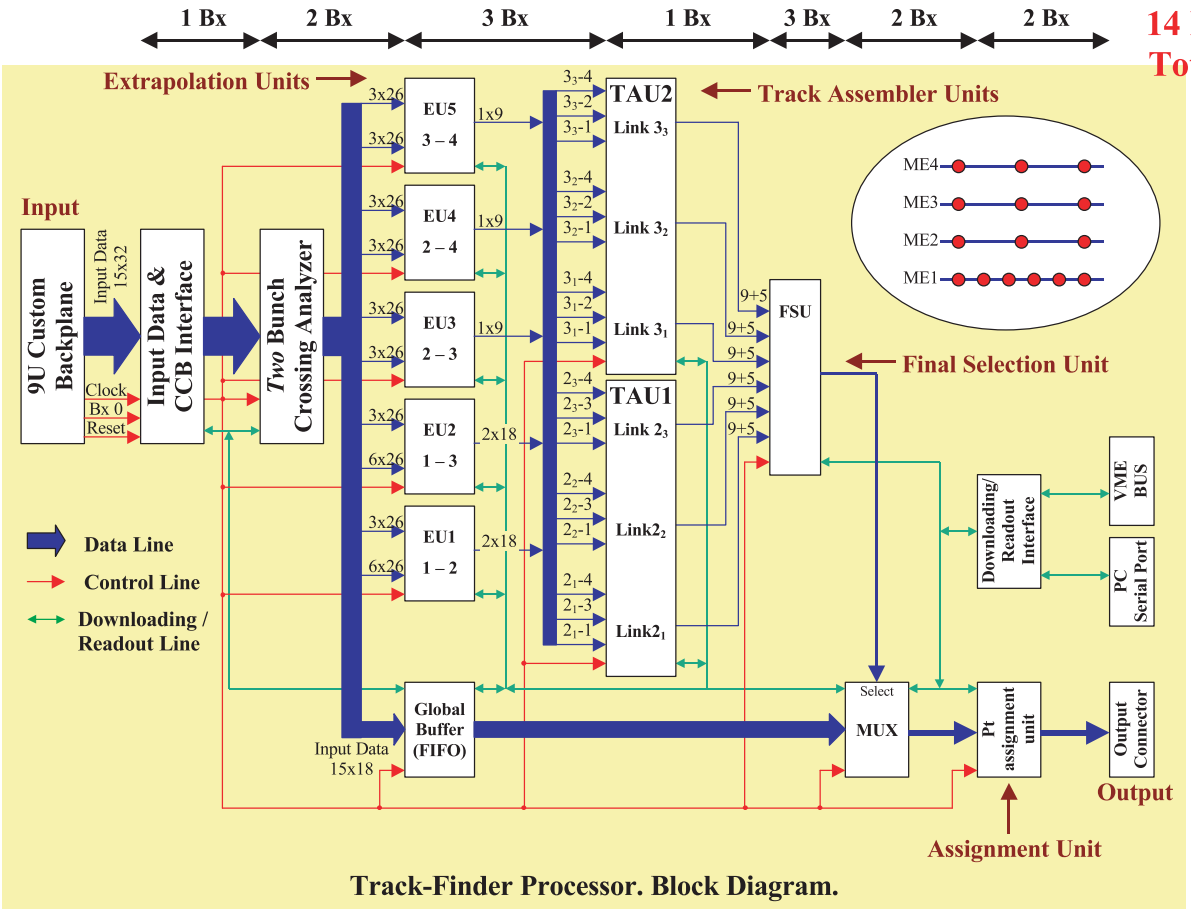
CSC Muon Trigger Scheme



Sector Processor / Muon Track Finder

- handle the track primitives (LCTs) in a 60° sector
- link LCTs into tracks
- Measure Pt, ϕ and η
- Send 3 best track candidates to the Muon Sorter

Sector Processor Block Diagram



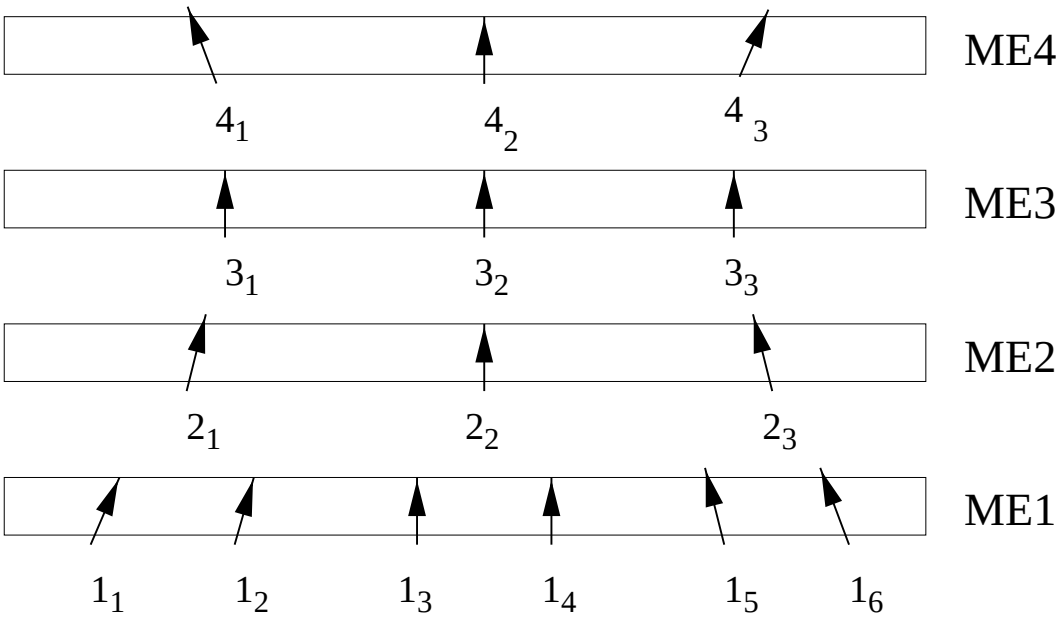
Track-Finder Processor. Block Diagram.

Figure 7: Block diagram of the Sector Processor architecture.

- Two Bunch Crossing Analyzer : Analyze LCTs received in different bunch crossings (NOT in simulation)
- Extrapolation Unit (EU) : Links LCTs in two CSC stations together
- Track Assembler Unit (TAU) : Use the extrapolation results to form tracks
- Final Selection Unit (FSU) : Selects 3 best track candidates
- Assignment Unit : Determines the Pt of the selected track candidates

Extrapolation Unit

(For Endcap Track Finder)



- Perform all combinations of extrapolations :
  $1_i \leftrightarrow 2_k$, $1_i \leftrightarrow 3_k$, $2_i \leftrightarrow 3_k$,
  $2_i \leftrightarrow 4_k$, $3_i \leftrightarrow 4_k$,
  no $1_i \leftrightarrow 4_k$

Extrapolation Unit in Detail

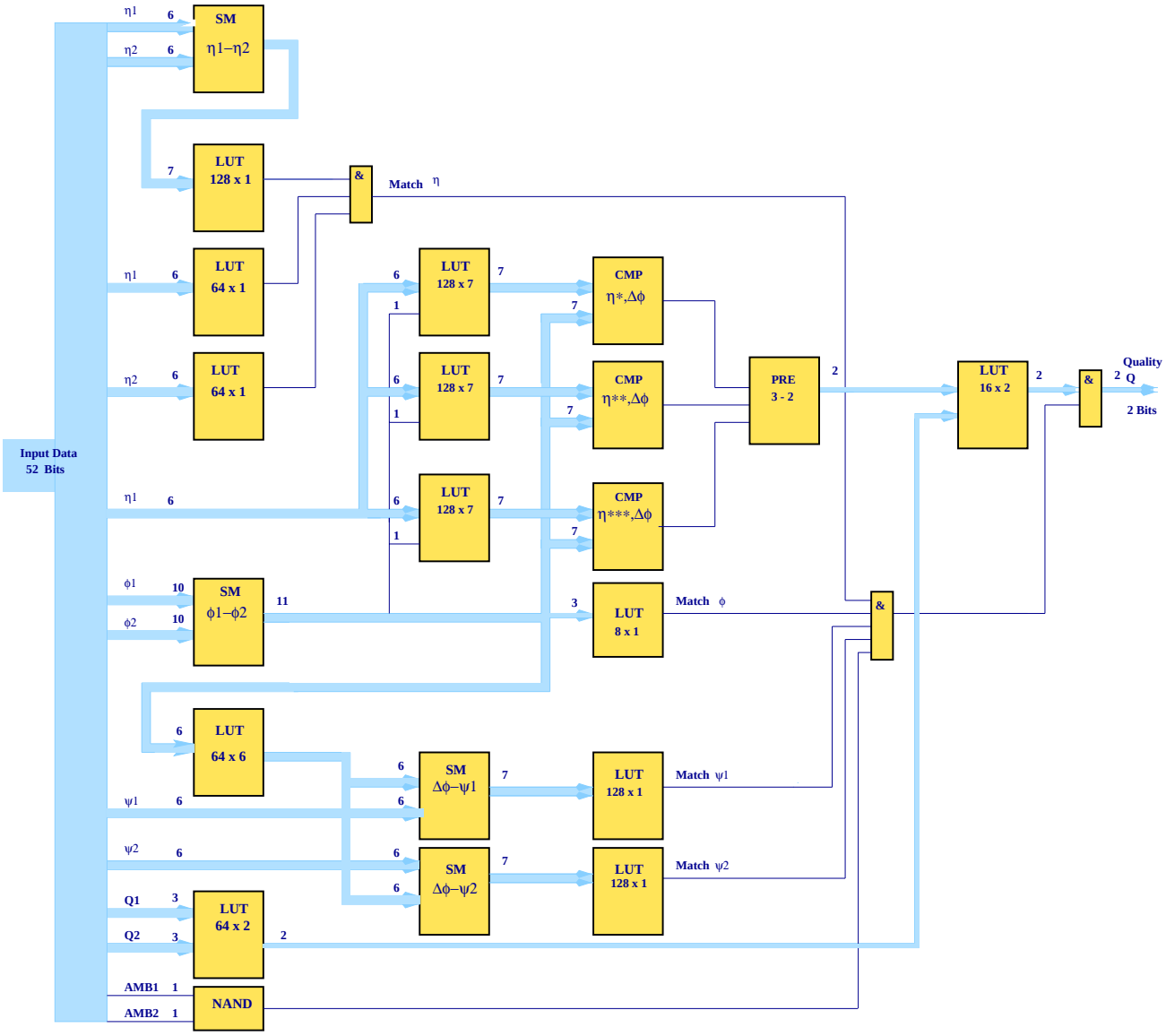
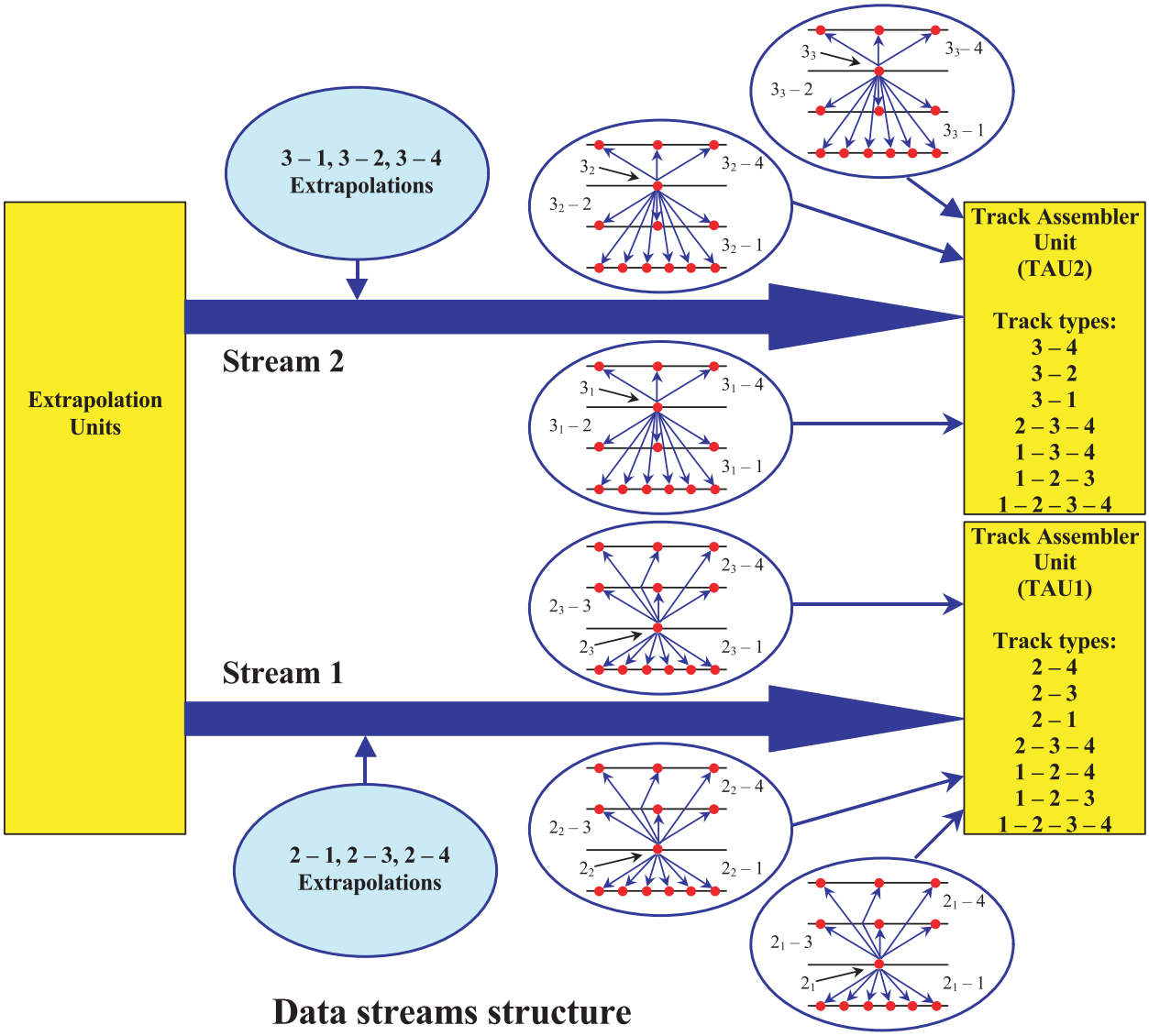


FIG.2. EXTRAPOLATION UNIT. BLOCK DIAGRAM.

- Track primitives are matched in η
- Coarse Pt is assigned based on the difference in the angle ϕ of the two track primitives
  (classified as either : Low Pt, Medium Pt, High Pt)
  Only for extrapolations ME1-ME2, ME1-ME3. (Pt resolution is poor for the other extrapolations)

- A simple version of the ϕ road finder is simulated. Only looks at the relation between the bending angle Ψ and the sign of $\Delta\phi$
- Accelerator Muon bits are used to reject halo muons
- Results of the extrapolation are in the form of Quality codes

Data Streams to Track Assembler Units

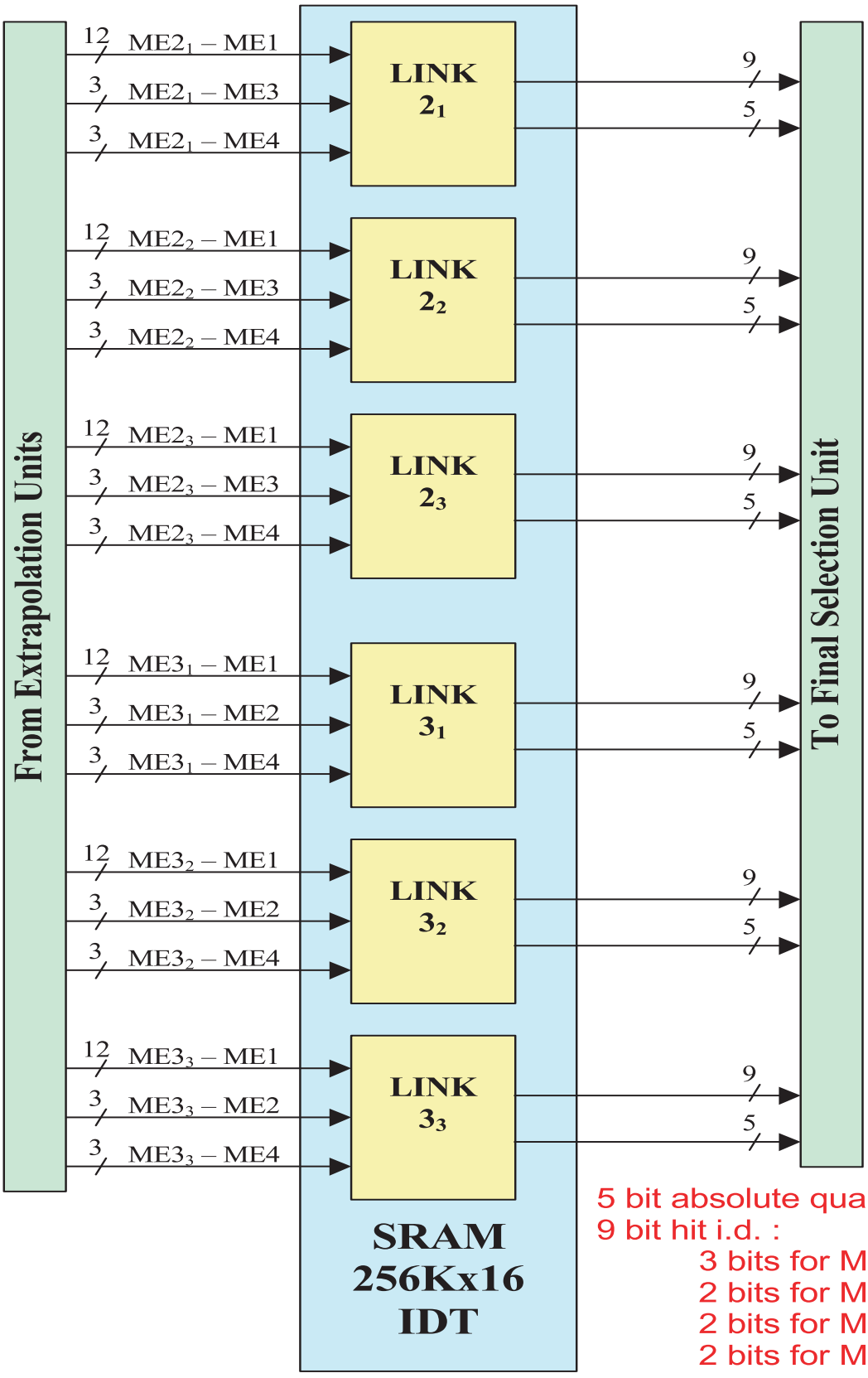


Data streams structure

- Results from extrapolations are sent to TAUs in 2 Streams
  - Stream 1 : $1 \leftrightarrow 2,\ 2 \leftrightarrow 3,\ 2 \leftrightarrow 4$ $\Rightarrow$ TAU 1
  - Stream 2 : $1 \leftrightarrow 3,\ 2 \leftrightarrow 3,\ 3 \leftrightarrow 4$ $\Rightarrow$ TAU 2

Track Assembler Units (TAU 1 and 2)

Block Diagram of the Track Assembler Unit



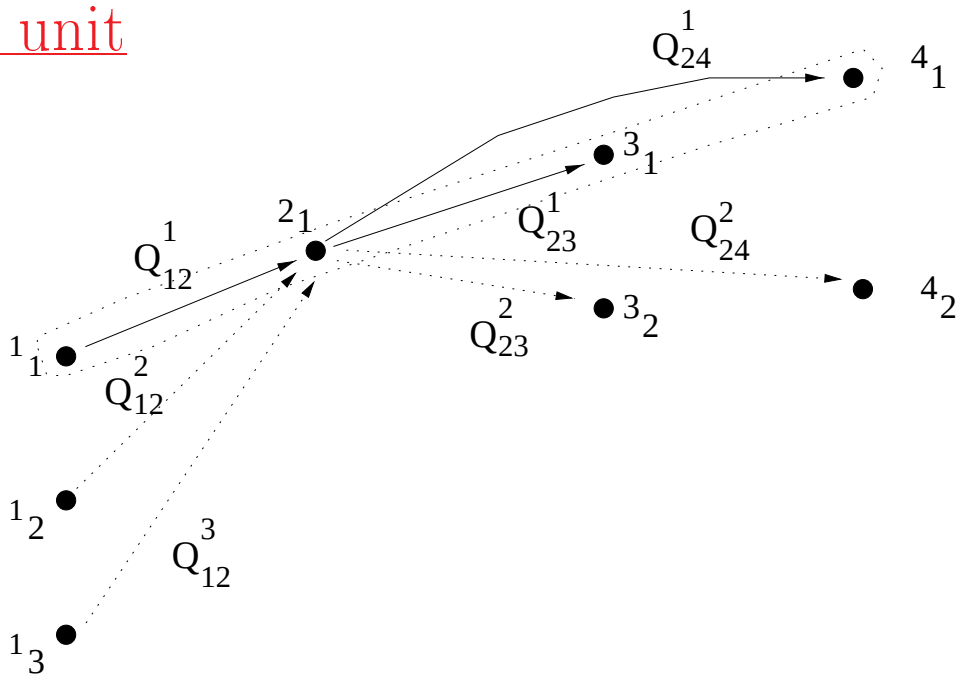
5 bit absolute quality &
9 bit hit i.d. :
- 3 bits for ME1
- 2 bits for ME2
- 2 bits for ME3
- 2 bits for ME4

- Quality of the extrapolations are sent to LINK units
- In TAU 1 (TAU 2) each LINK unit handles all the extrapolations to a single LCT in Station 2 (Station 3)

  Possible extrapolations going into one LINK unit

  $1_1 \to 2_1$ $\quad$ $3_1 \to 2_1$ $\quad$ $4_1 \to 2_1$
  $1_2 \to 2_1$ $\quad$ $3_2 \to 2_1$ $\quad$ $4_2 \to 2_1$
  $1_3 \to 2_1$ $\quad$ $3_3 \to 2_1$ $\quad$ $4_3 \to 2_1$
  $1_4 \to 2_1$
  $1_5 \to 2_1$
  $1_6 \to 2_1$

LINK unit



- LINK unit is programmed to select extrapolations with highest qualities to form tracks
- Example for the above case :

  $Q^1_{12} > Q^2_{12}$, Q^3_{12}

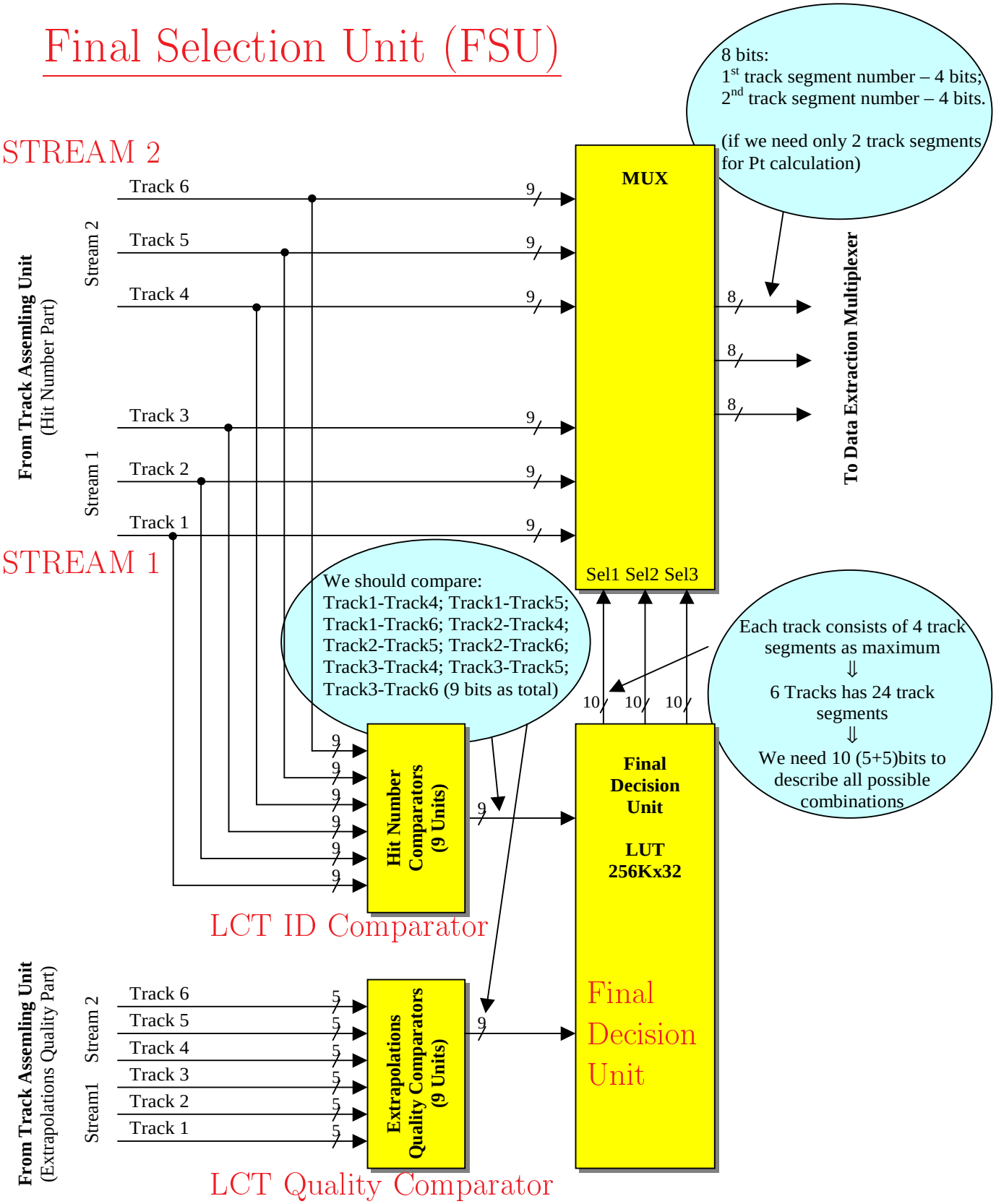
  $Q^1_{23} > Q^2_{23}$

  $Q^1_{24} > Q^2_{24}$

  $\Rightarrow$ form a track using LCTs 1_1, 2_1, 3_1 and 4_1

- Each LINK unit will form one track
- Three possible tracks from each TAU

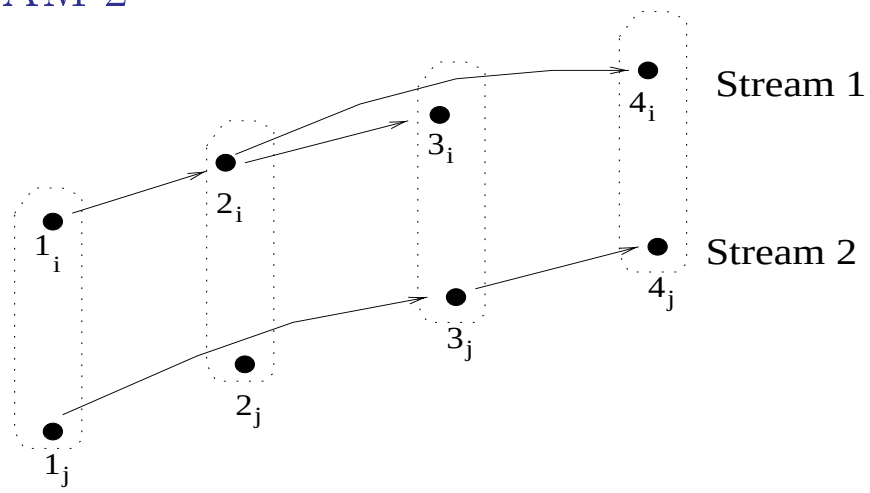
Final Selection Unit (FSU)



Final Selection Unit

In the FSU of the TF simulation :

- LCT Quality Comparator : compares the qualities of the tracks found in STREAM 1 to the tracks found in STREAM 2
- LCT ID Comparator : compares the LCT IDs of the tracks found in STREAM 1 to the tracks found in STREAM 2



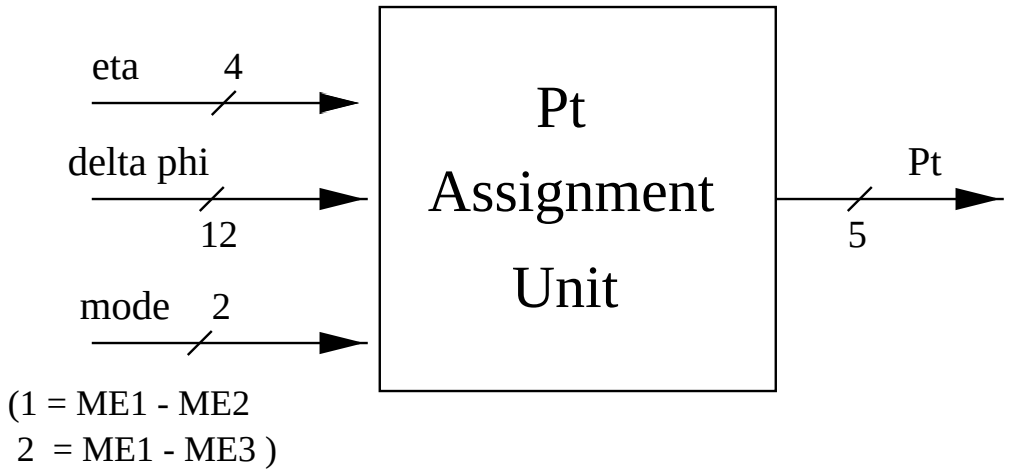
ID Comparator is programmed to consider two tracks are "identical" if both tracks share at least one common LCT

- Results from the comparators are sent to Final Decision Unit to select 3 unique tracks of highest quality. (These 3 track candidates should then be forwarded to the Muon Sorter)

- NOTE : In the actual hardware design both Quality and ID Comparators compare the qualities and the LCT IDs of each track found in STREAM 1 and STREAM 2 to all the other tracks found in both STREAMS.
  $\Rightarrow$ 15 bits instead of 9 bits going from each comparator to the Final Decision Unit.

Pt Assignment Unit

- A simple two-station Pt assignment unit
- Only compute the Pt for two modes
  - Pt from $\Delta\phi$ measured between ME1-ME2
  - Pt from $\Delta\phi$ measured between ME1-ME3
- Pt has nonlinear scale



Results from the Simulation

The results were obtained from simulations using old CSC LCT simulation

Extrapolation Efficiency for Single Muon Events

		%	
Pt = 3 GeV		ME1-ME2	ME1-ME3
successful extrapolation	=	93.4	81.3
Low Pt	=	77.1	58.1
Medium Pt	=	14.5	19.5
High Pt	=	1.8	3.7
Pt = 5 GeV			
successful extrapolation	=	99.1	98.1
Low Pt	=	44.8	46.4
Medium Pt	=	53.2	46.8
High Pt	=	1.2	4.9
Pt = 50 GeV			
successful extrapolation	=	99.4	99.4
Low Pt	=	0.02	0.01
Medium Pt	=	0.9	1.1
High Pt	=	98.4	98.2

(Note :The CSC chamber efficiency was not taken into account)

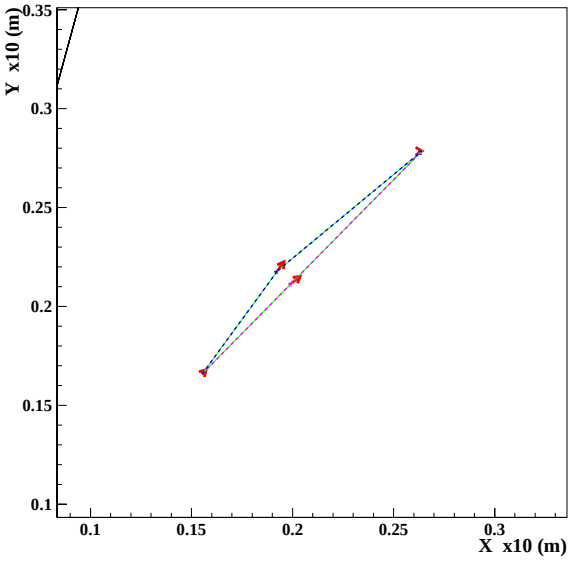
Extrapolation Efficiency of Single halo-μ events :

P = 100 GeV (Total # Evts = 9142)		%
successful extrapolation	=	0.01
Low Pt	=	0.00
Medium Pt	=	0.00
High Pt	=	0.01

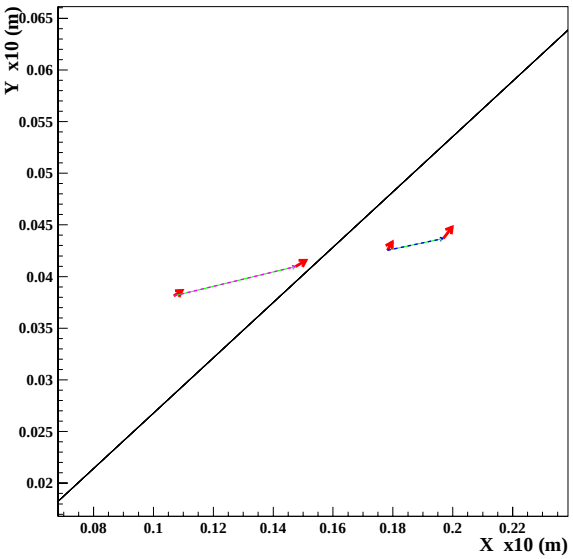
Final Selection Unit

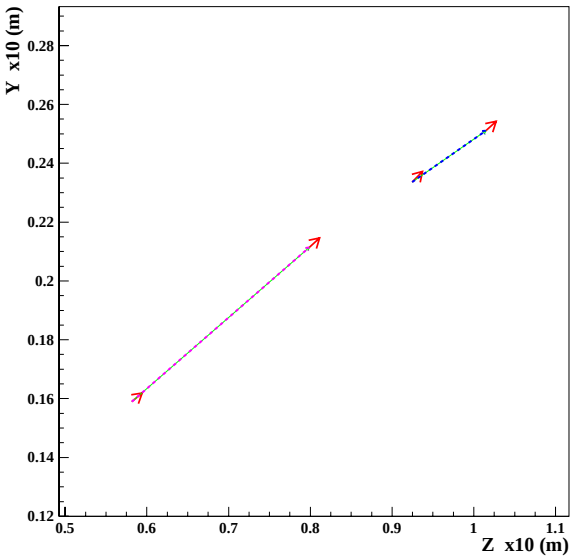
Efficiency of FSU on single muon events

- High efficiency for high Pt muons ($\sim 100\%$)
- $\sim 0.5\%$ of events FSU found > 1 track.
  - Extra LCTs due to bremsstrahlung, delta rays

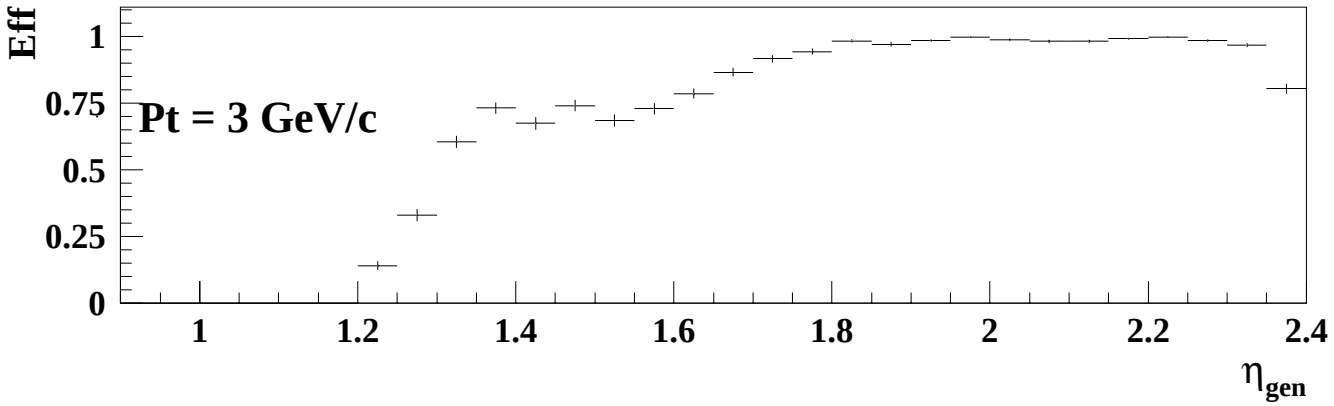


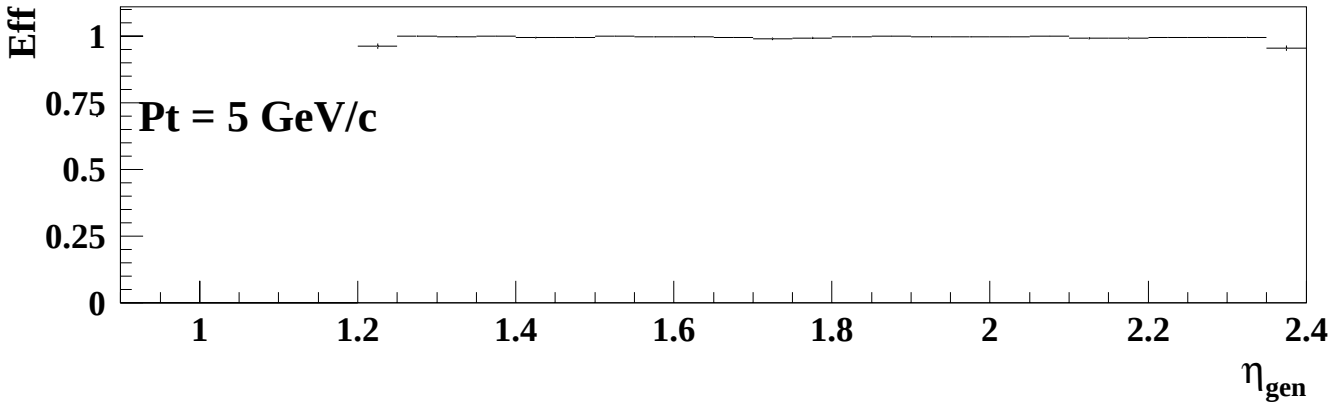
  - Broken track due to sector boundary, failed extrapolation

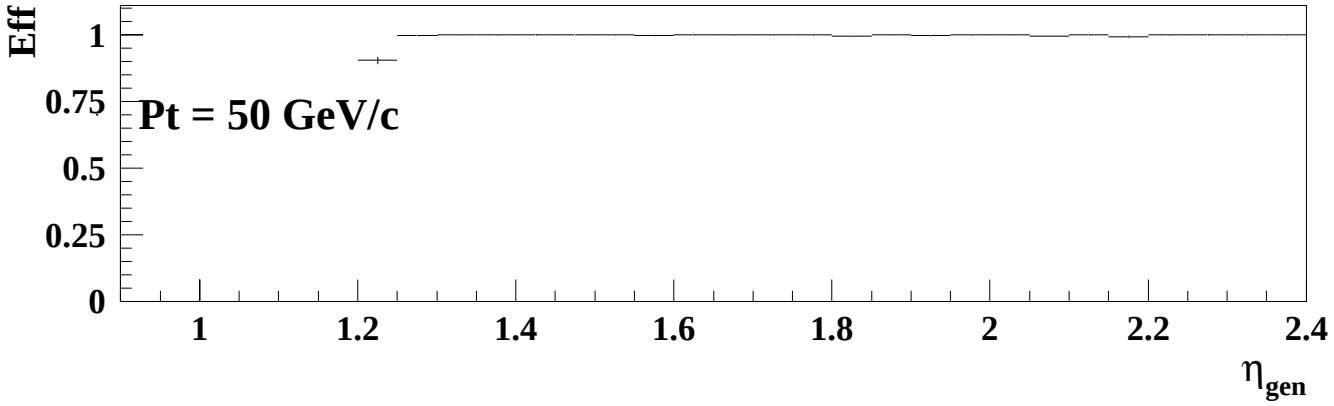




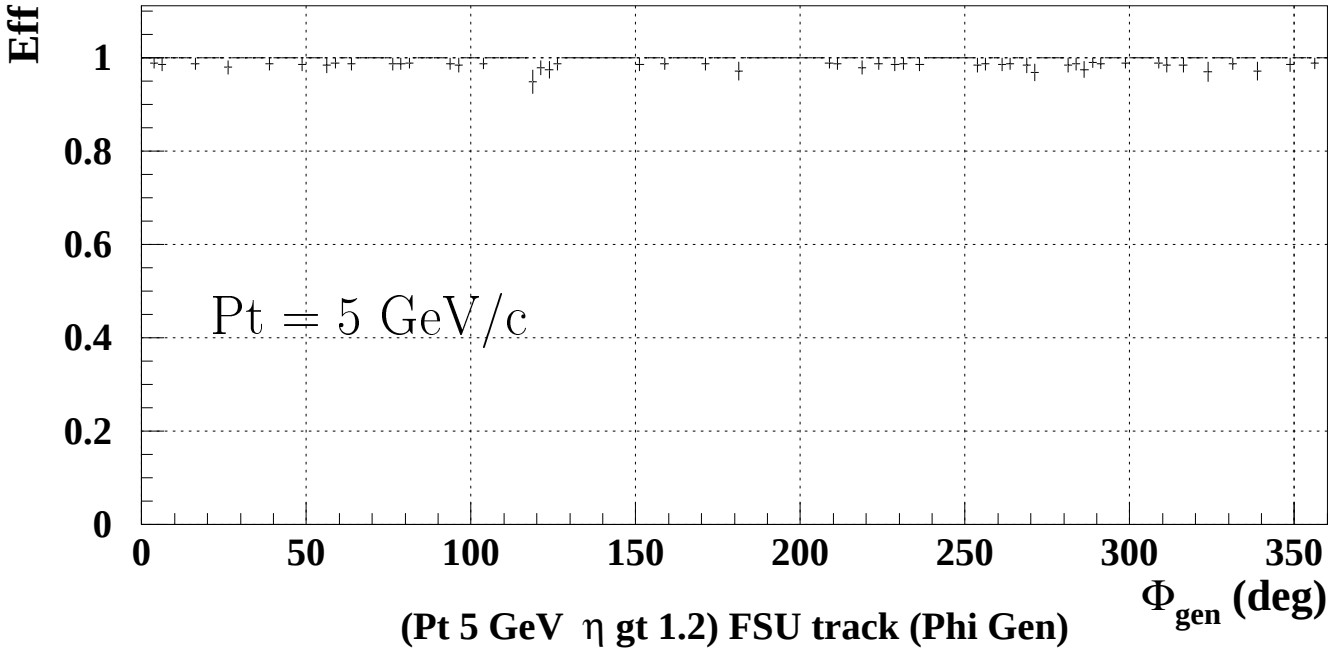
Single Muon Track Finding Efficiency

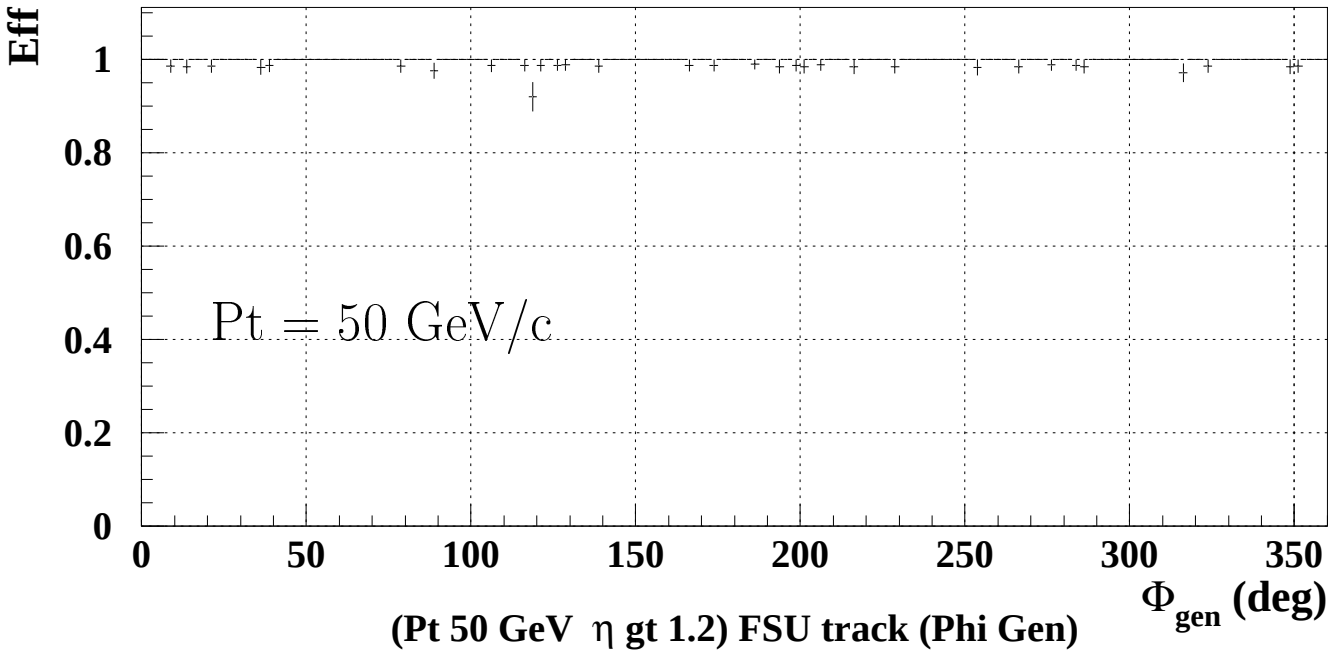




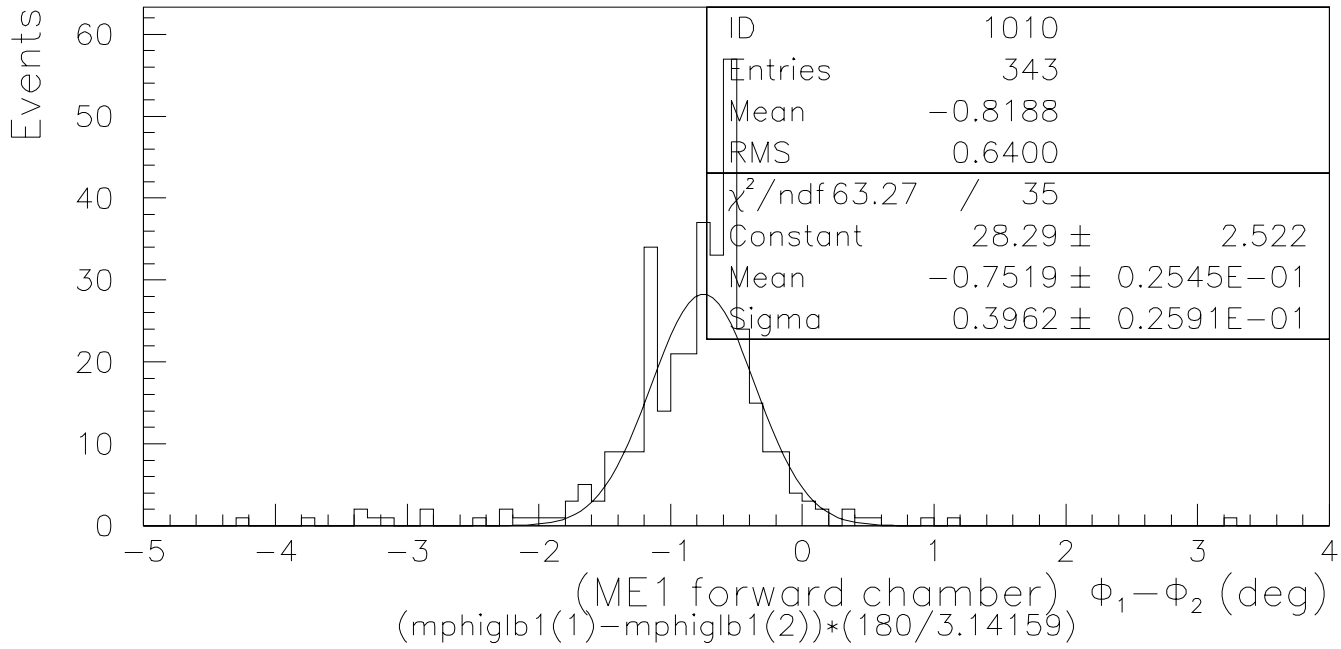


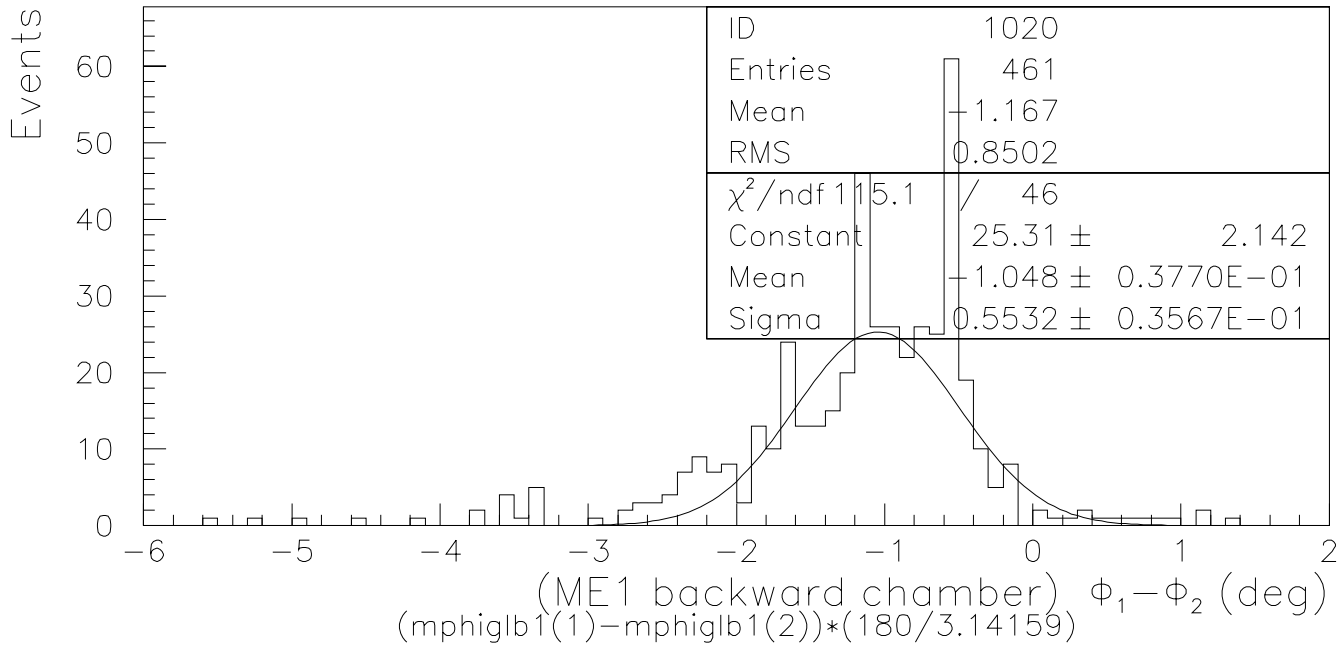
For $\eta > 1.2$

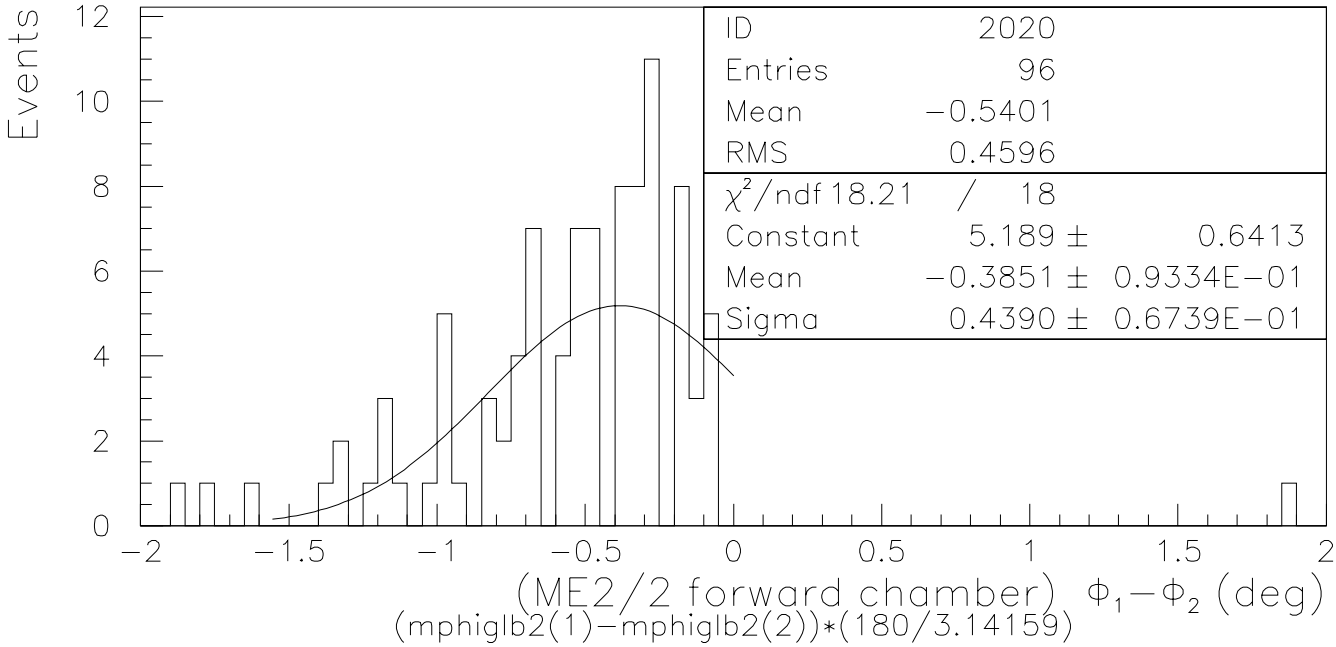

Eff
1
0.8
0.6
0.4
0.2
0
Pt = 5 GeV/c
0
50
100
150
200
250
300
350
Φgen (deg)
(Pt 5 GeV η gt 1.2) FSU track (Phi Gen)

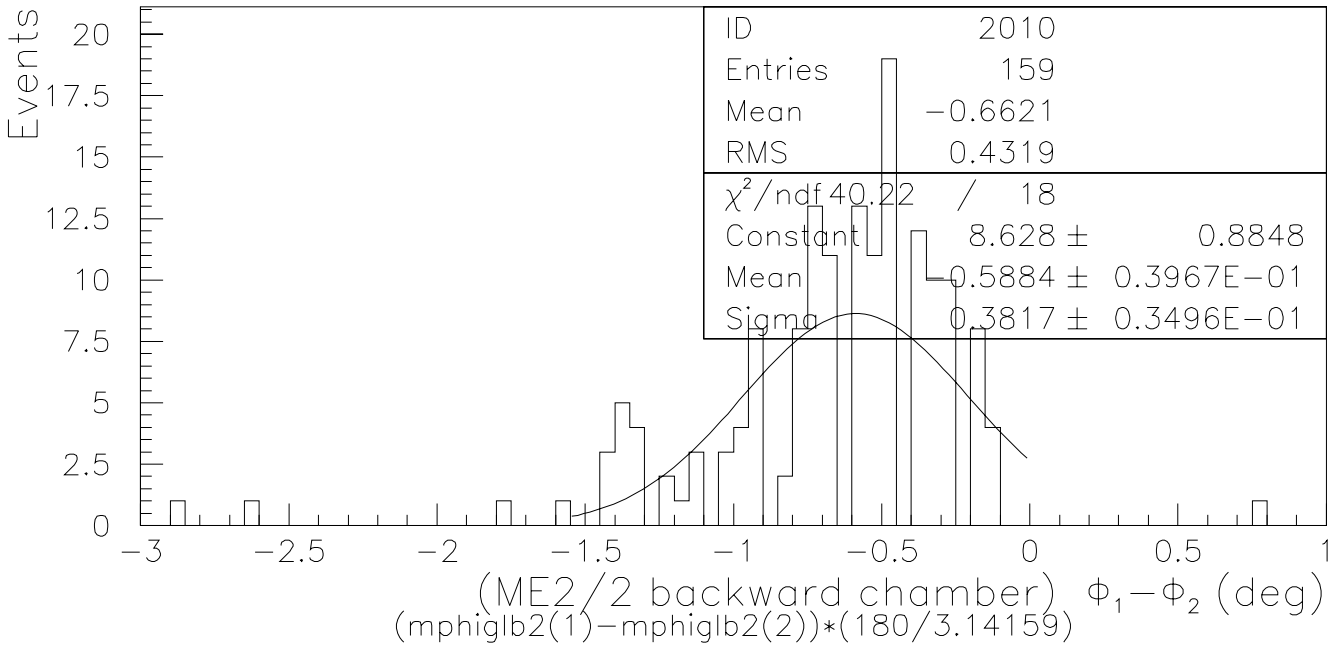

Eff
1
0.8
0.6
0.4
0.2
0
Pt = 50 GeV/c
0
50
100
150
200
250
300
350
Φgen (deg)
(Pt 50 GeV η gt 1.2) FSU track (Phi Gen)

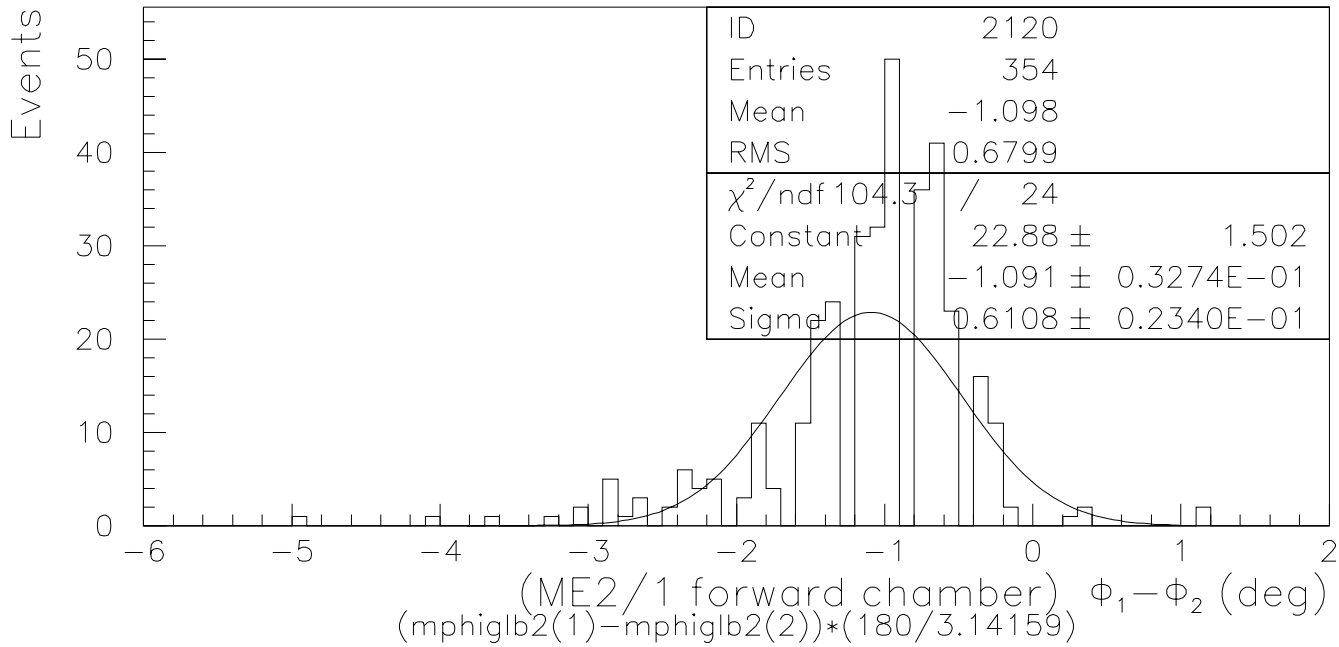
- Contribution to fake tracks due to bremsstrahlung or delta rays may be lesser than expected :
  Old LCT simulation (Jeff/Darin) allows > 1 LCT within 16 cathode strips or anode wires
- Look at the difference in ϕ of two LCTs in a single station
- For 10° chambers with 80 cathode strips,
  $\Rightarrow$ 16 strips $= 2^\circ$ in ϕ
  For 20° chambers with 80 cathode strips,
  $\Rightarrow$ 16 strips $= 4^\circ$ in ϕ
- Only a small fractions of single muon events have two LCTS that are separated by more than 16 cathode strips
- Preliminary studies using new LCT simulation (Benn) indicates only $\sim 0.04\%$ single muon events have > 1 reconstructed tracks in the FSU

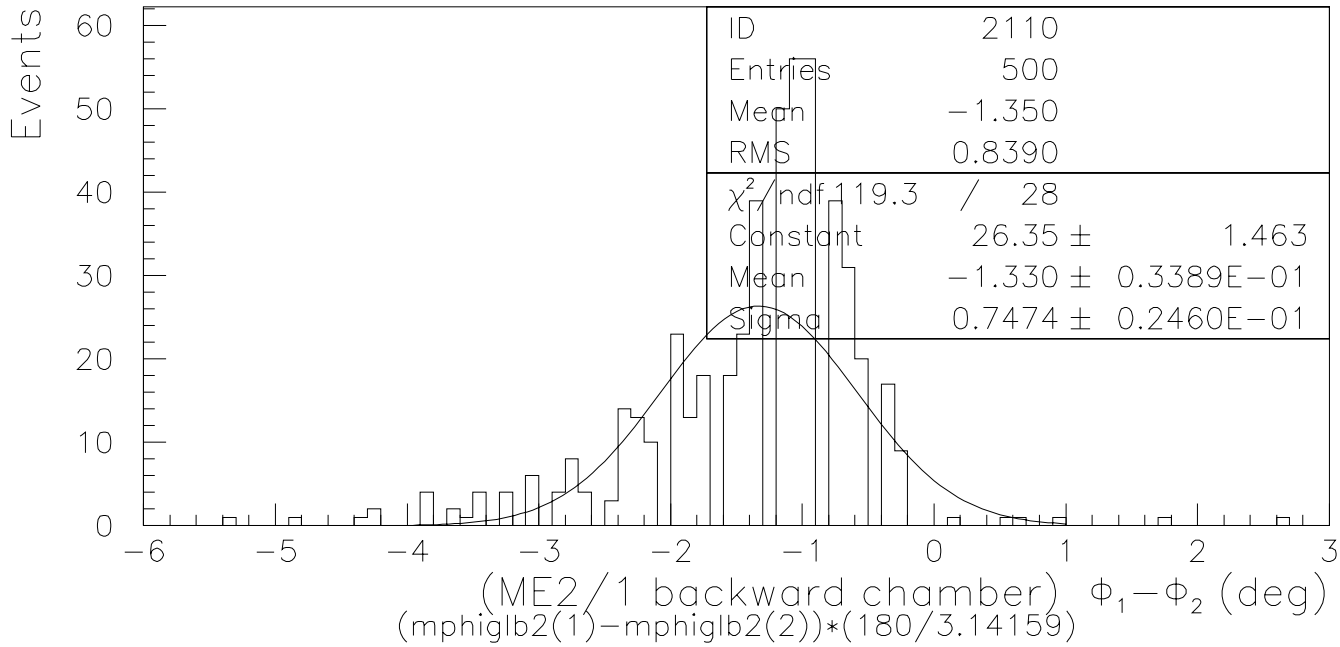

Events
ID 1010
Entries 343
Mean −0.8188
RMS 0.6400
χ²/ndf 63.27 / 35
Constant 28.29 ± 2.522
Mean −0.7519 ± 0.2545E−01
Sigma 0.3962 ± 0.2591E−01
(ME1 forward chamber) Φ1−Φ2 (deg)
(mphiglb1(1)−mphiglb1(2))*(180/3.14159)


Events
ID 1020
Entries 461
Mean −1.167
RMS 0.8502
χ²/ndf 115.1 / 46
Constant 25.31 ± 2.142
Mean −1.048 ± 0.3770E−01
Sigma 0.5532 ± 0.3567E−01
(ME1 backward chamber) Φ1−Φ2 (deg)
(mphiglb1(1)−mphiglb1(2))*(180/3.14159)

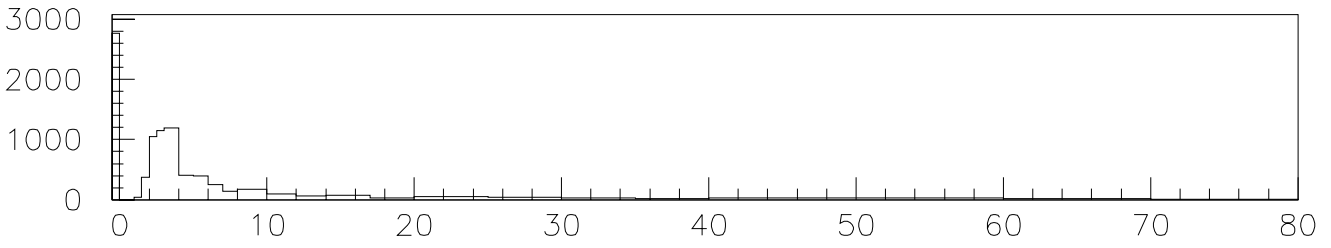

Events
ID 2020
Entries 96
Mean −0.5401
RMS 0.4596
χ²/ndf 18.21 / 18
Constant 5.189 ± 0.6413
Mean −0.3851 ± 0.9334E−01
Sigma 0.4390 ± 0.6739E−01
(ME2/2 forward chamber) Φ1−Φ2 (deg)
(mphiglb2(1)−mphiglb2(2))*(180/3.14159)


Events
ID 2010
Entries 159
Mean −0.6621
RMS 0.4319
χ²/ndf 40.22 / 18
Constant 8.628 ± 0.8848
Mean −0.5884 ± 0.3967E−01
Sigma 0.3817 ± 0.3496E−01
(ME2/2 backward chamber) Φ1−Φ2 (deg)
(mphiglb2(1)−mphiglb2(2))*(180/3.14159)

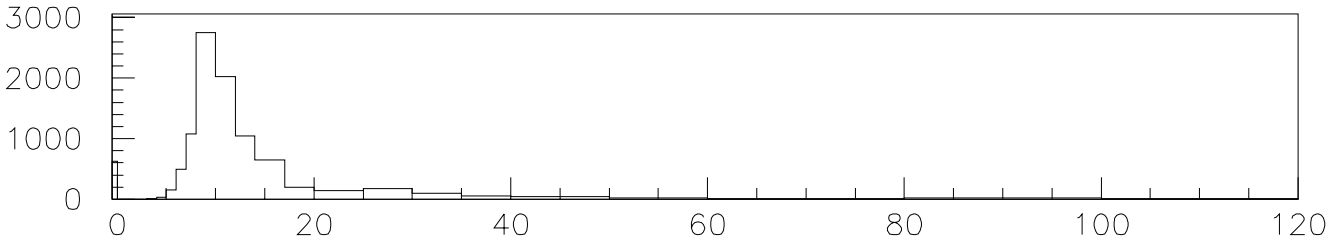

Events
ID 2120
Entries 354
Mean −1.098
RMS 0.6799
χ²/ndf 104.3 / 24
Constant 22.88 ± 1.502
Mean −1.091 ± 0.3274E−01
Sigma 0.6108 ± 0.2340E−01
(ME2/1 forward chamber) Φ1−Φ2 (deg)
(mphiglb2(1)−mphiglb2(2))*(180/3.14159)


Events
ID 2110
Entries 500
Mean −1.350
RMS 0.8390
χ²/ndf 119.3 / 28
Constant 26.35 ± 1.463
Mean −1.330 ± 0.3389E−01
Sigma 0.7474 ± 0.2460E−01
(ME2/1 backward chamber) Φ1−Φ2 (deg)
(mphiglb2(1)−mphiglb2(2))*(180/3.14159)

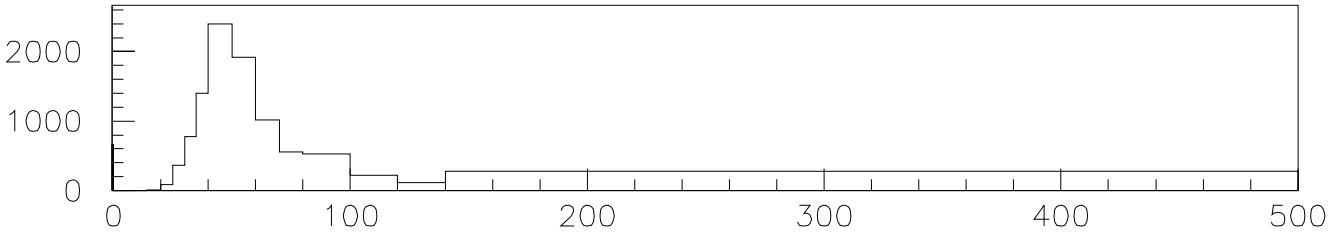
Pt from Pt Assignment Unit



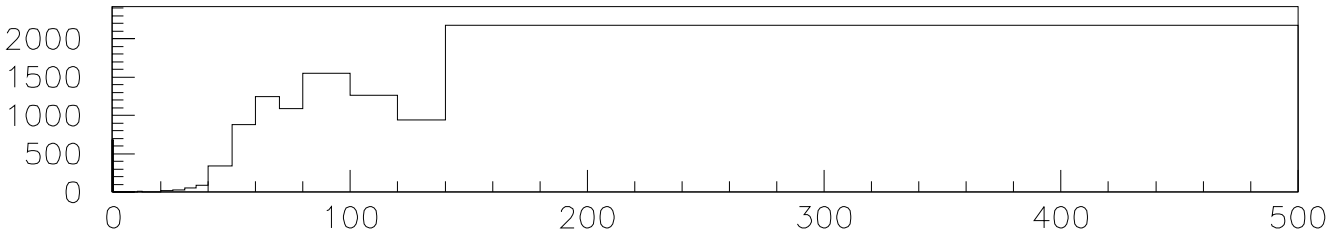
(Pt=3 GeV) Pt Assign



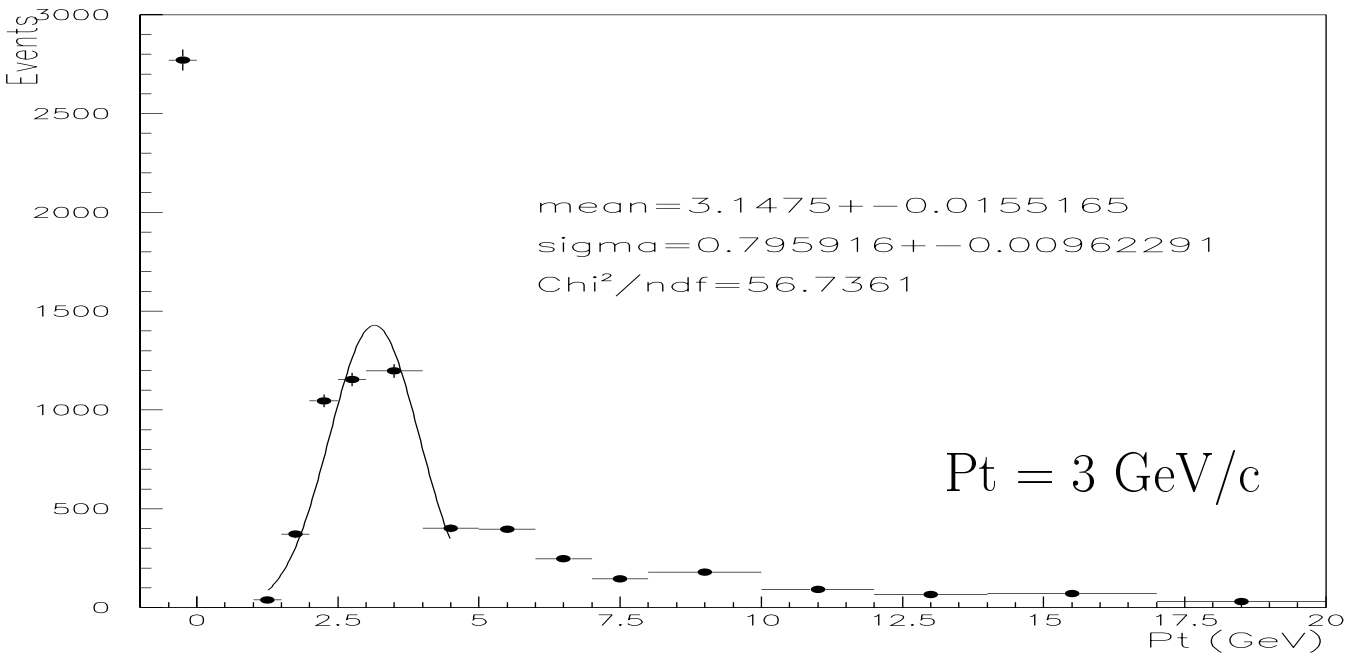
(Pt=10 GeV) Pt Assign

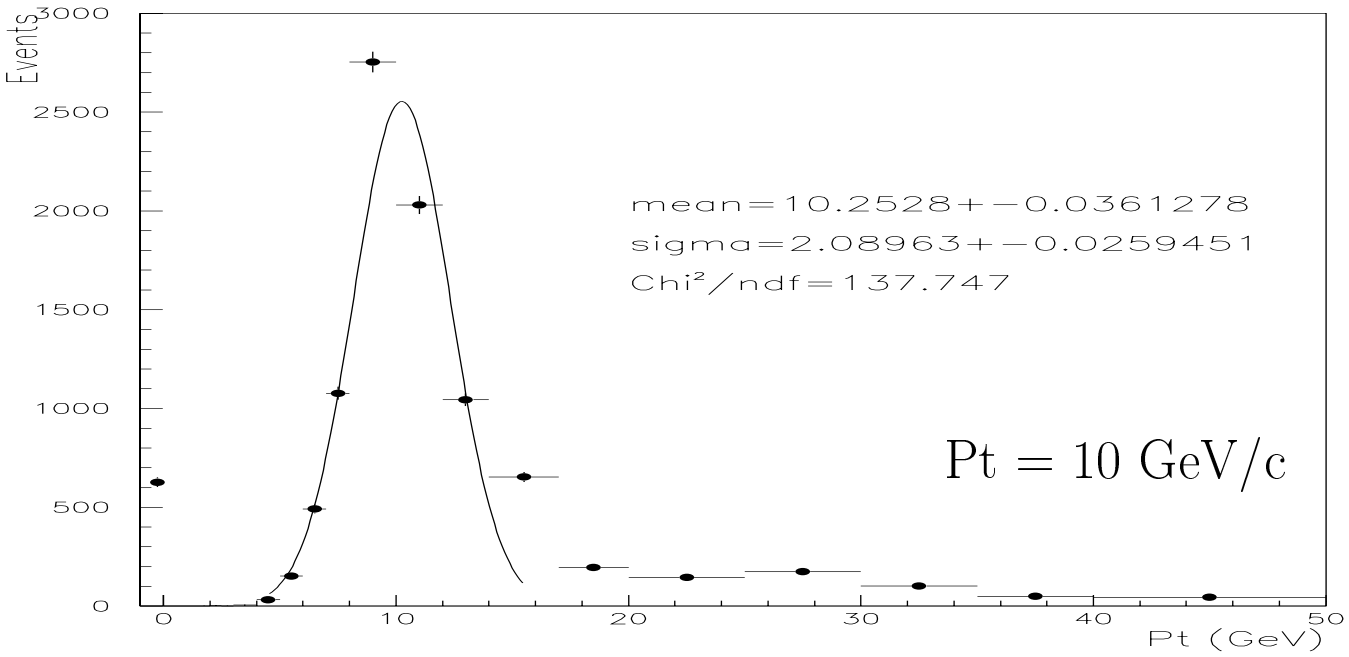


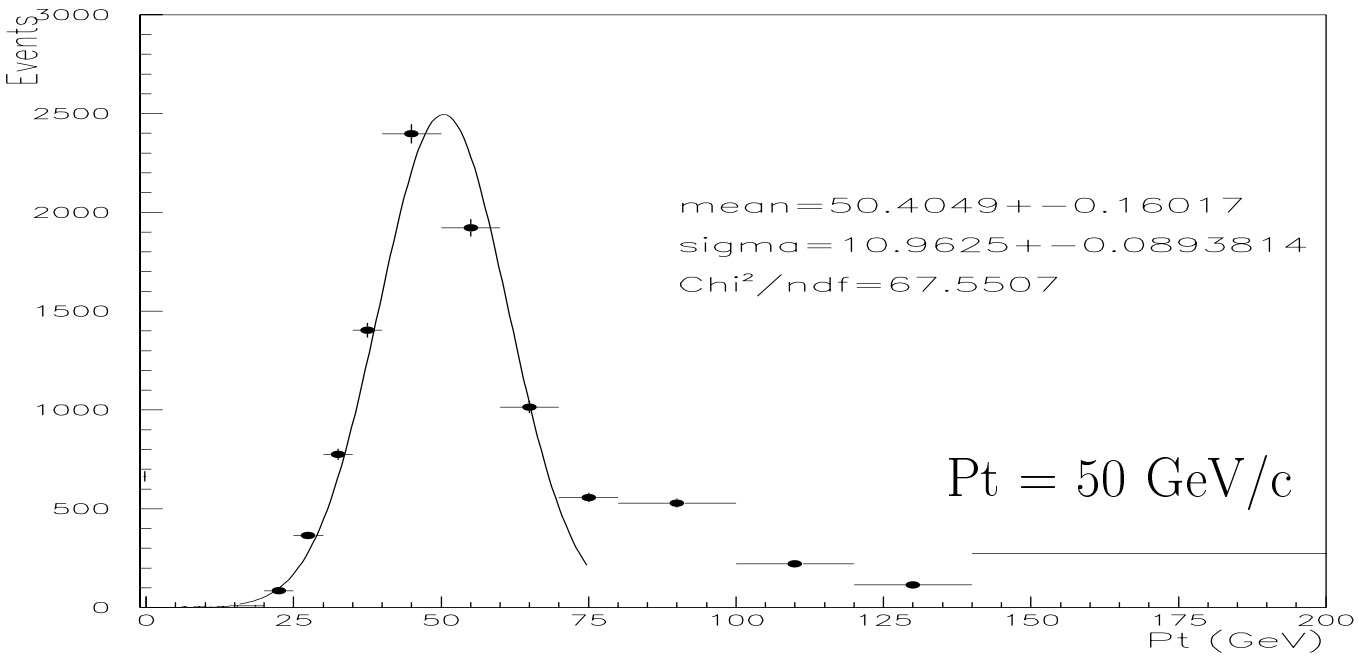
(Pt=50 GeV) Pt Assign

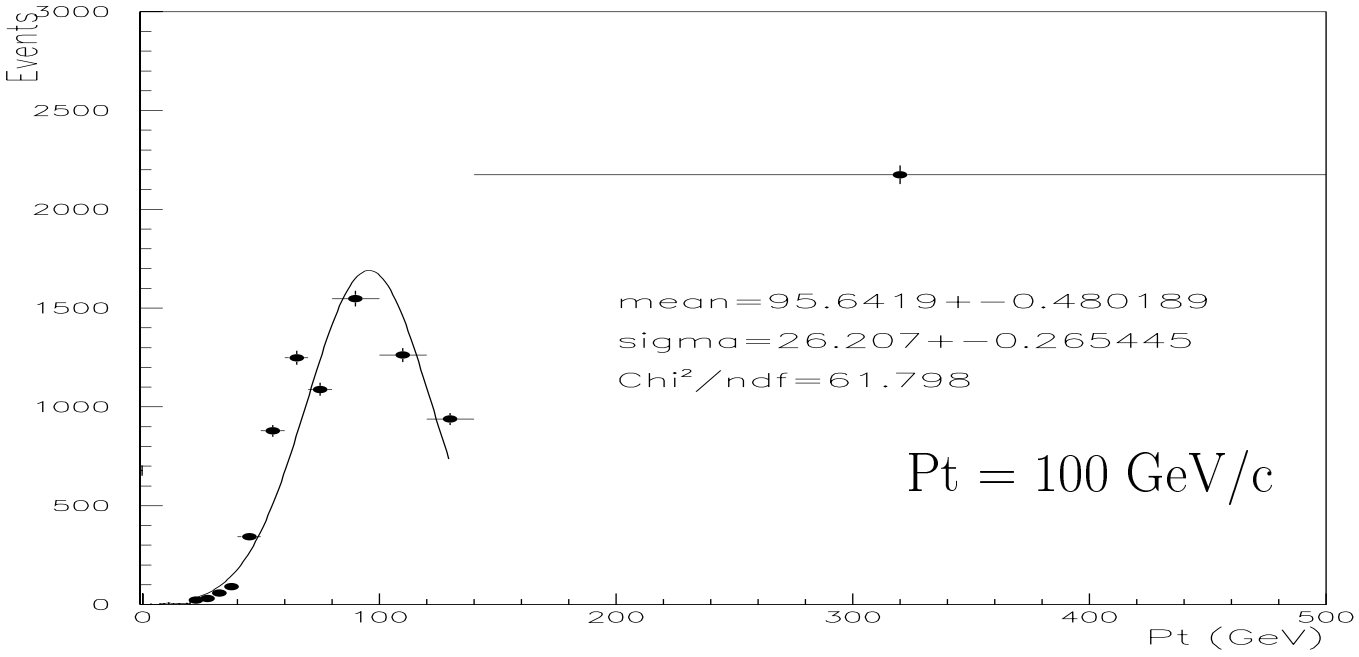


(Pt=100 GeV) Pt Assign


Events
3000
2500
2000
1500
1000
500
0
mean=3.1475+−0.0155165
sigma=0.795916+−0.00962291
Chi²/ndf=56.7361
Pt = 3 GeV/c
0
2.5
5
7.5
10
12.5
15
17.5
20
Pt (GeV)


Events
3000
2500
2000
1500
1000
500
0
mean=10.2528+−0.0361278
sigma=2.08963+−0.0259451
Chi²/ndf=137.747
Pt = 10 GeV/c
0
10
20
30
40
50
Pt (GeV)


Events
3000
2500
2000
1500
1000
500
0
0
25
50
75
100
125
150
175
200
Pt (GeV)
mean=50.4049+−0.16017
sigma=10.9625+−0.0893814
Chi²/ndf=67.5507
Pt = 50 GeV/c


Events
3000
2500
2000
1500
1000
500
0
0
100
200
300
400
500
Pt (GeV)
mean=95.6419+−0.480189
sigma=26.207+−0.265445
Chi²/ndf=61.798
Pt = 100 GeV/c

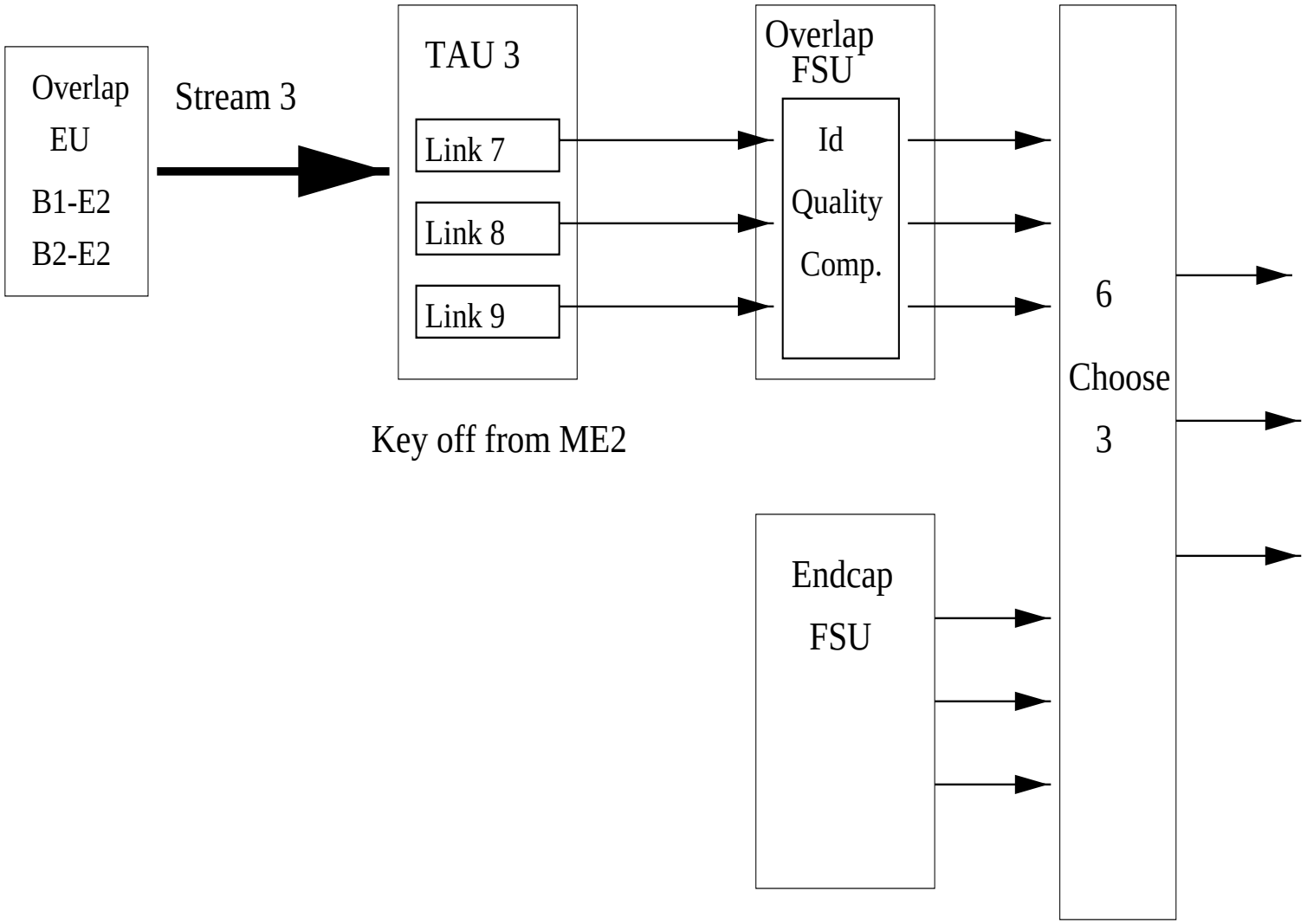
Overlap + Endcap Track Finder

- Include extrapolations MB1-ME2, MB2-ME2

  $\leq$ 4 LCTs in MB1, MB2

  $\leq$ 3 LCTs in ME2 ($\eta_{LCT} < 1.2$)

- Add in the third data stream, STREAM 3

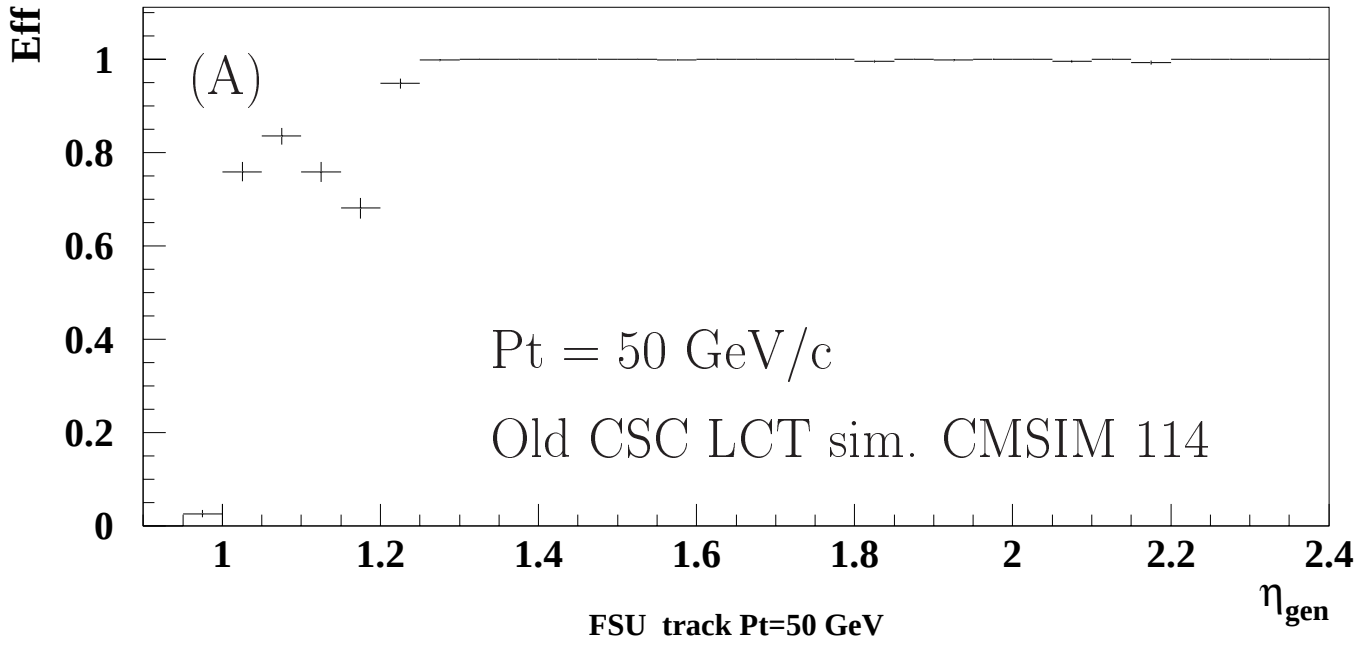


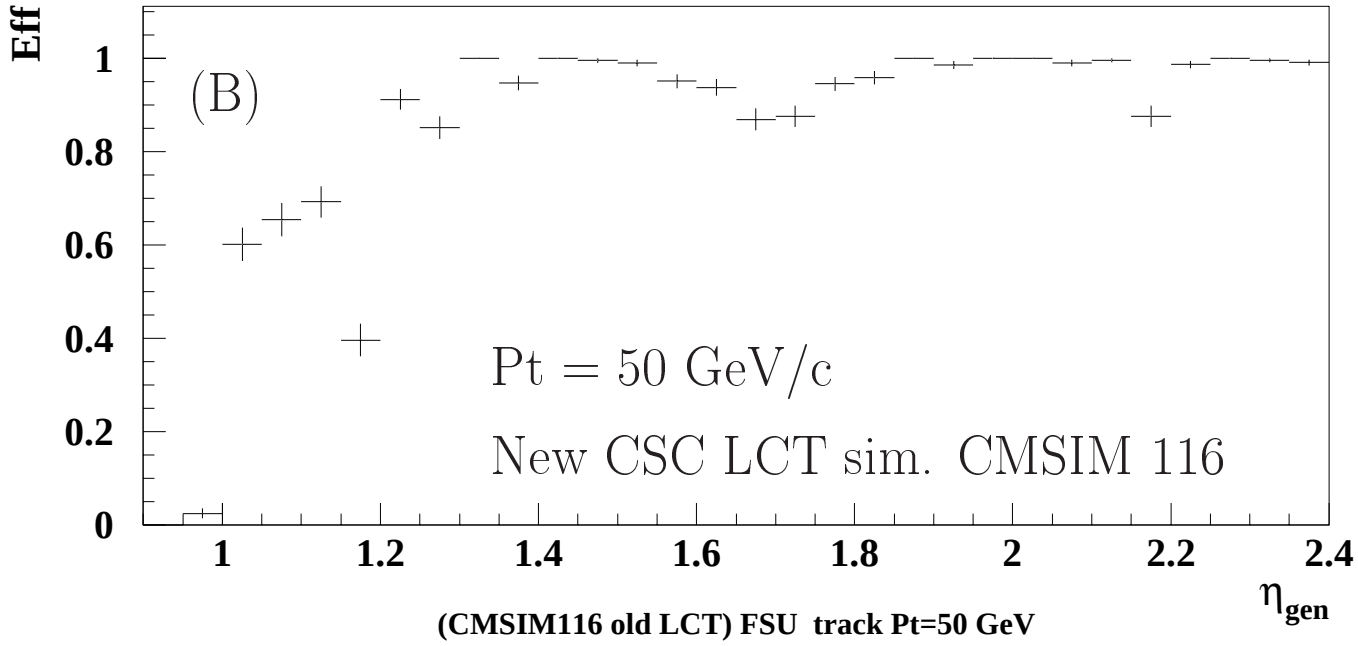
Extrapolation Eff. for Single Muon Events in Overlap

		%	
Pt = 5 GeV		MB1-ME2	MB2-ME2
successful extrapolation	=	100	100
Low Pt	=	48.9	70.9
Medium Pt	=	39.9	3.1
High Pt	=	11.2	26.0
Pt = 50 GeV			
successful extrapolation	=	99.8	100
Low Pt	=	0.3	1.8
Medium Pt	=	0.6	0.8
High Pt	=	98.9	97.5

(Note :The chamber efficiency was not taken into account)

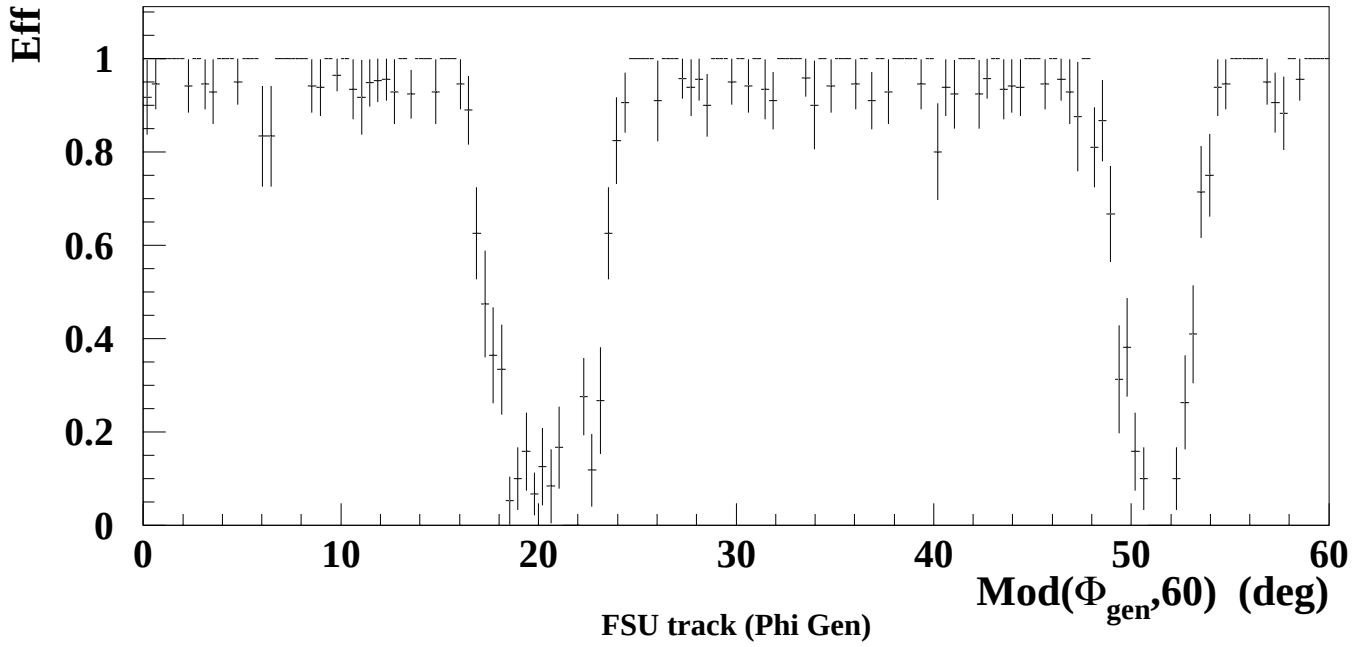
Efficiency in the Overlap + Endcap regions





- Lower efficiency for (B) compare to (A), due to more realistic simulation of the magnetic field effect on the charged particles in the Barrel muon chambers in CMSIM 116 (the overlap region), and lower efficiency for the new CSC LCT finder.

Efficiency vs ϕ $(1.05 < \eta < 1.15)$



- MC sample, single muon at Pt = 50 GeV/c, Old CSC LCT sim. CMSIM 114
- The two dips at about 30° apart are due to the gaps between the Barrel muon chambers

Summary/Plans

- Modify the Track Finder simulation so that it is much closer to the real hardware design
- Implement the 3-stations Pt assignment