



Simulation of the CSC Track Finder

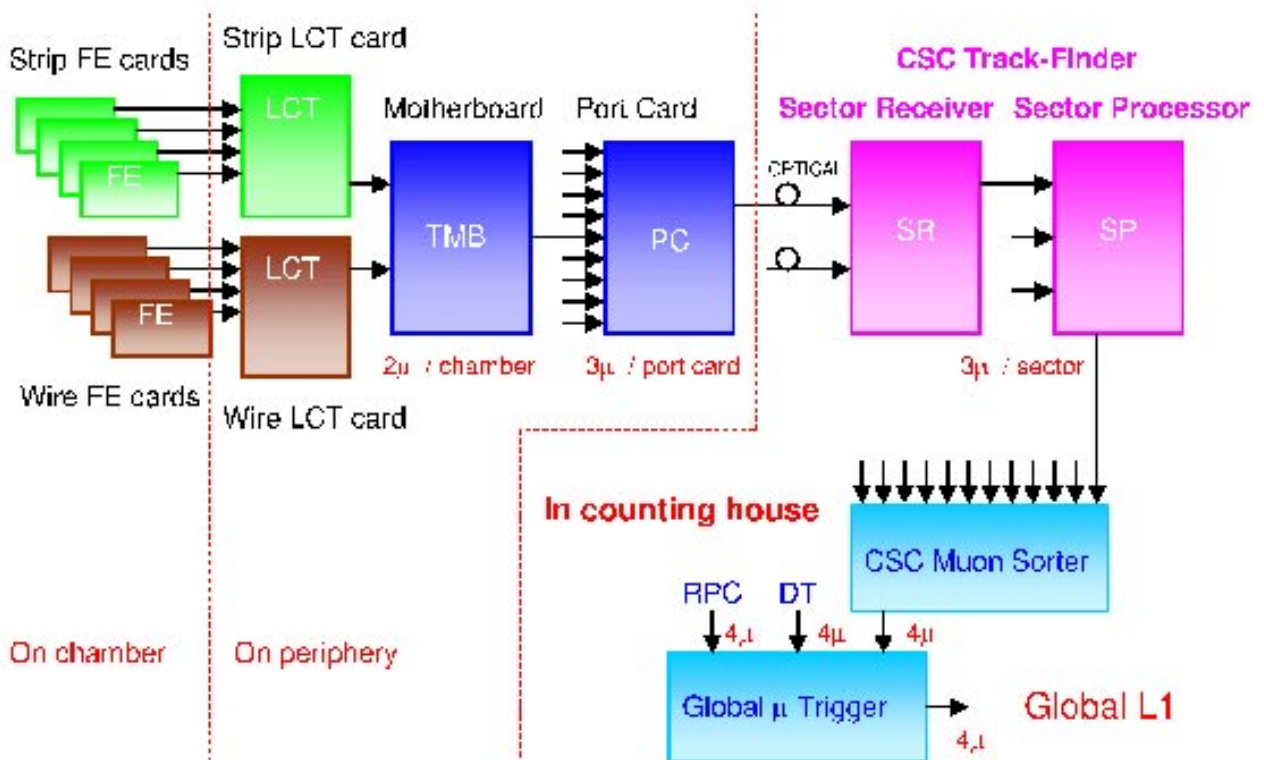
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CMS Week
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- A standalone version of the CSC Track Finder simulation (Endcap region only) is almost ready
- Written in Fortran
- Interface with the ntuple produced by CMSIM
- Emulate as close as possible to the design of the hardware

CSC Muon Trigger Scheme



Sector Processor / Muon Track Finder

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

Sector Processor Block Diagram

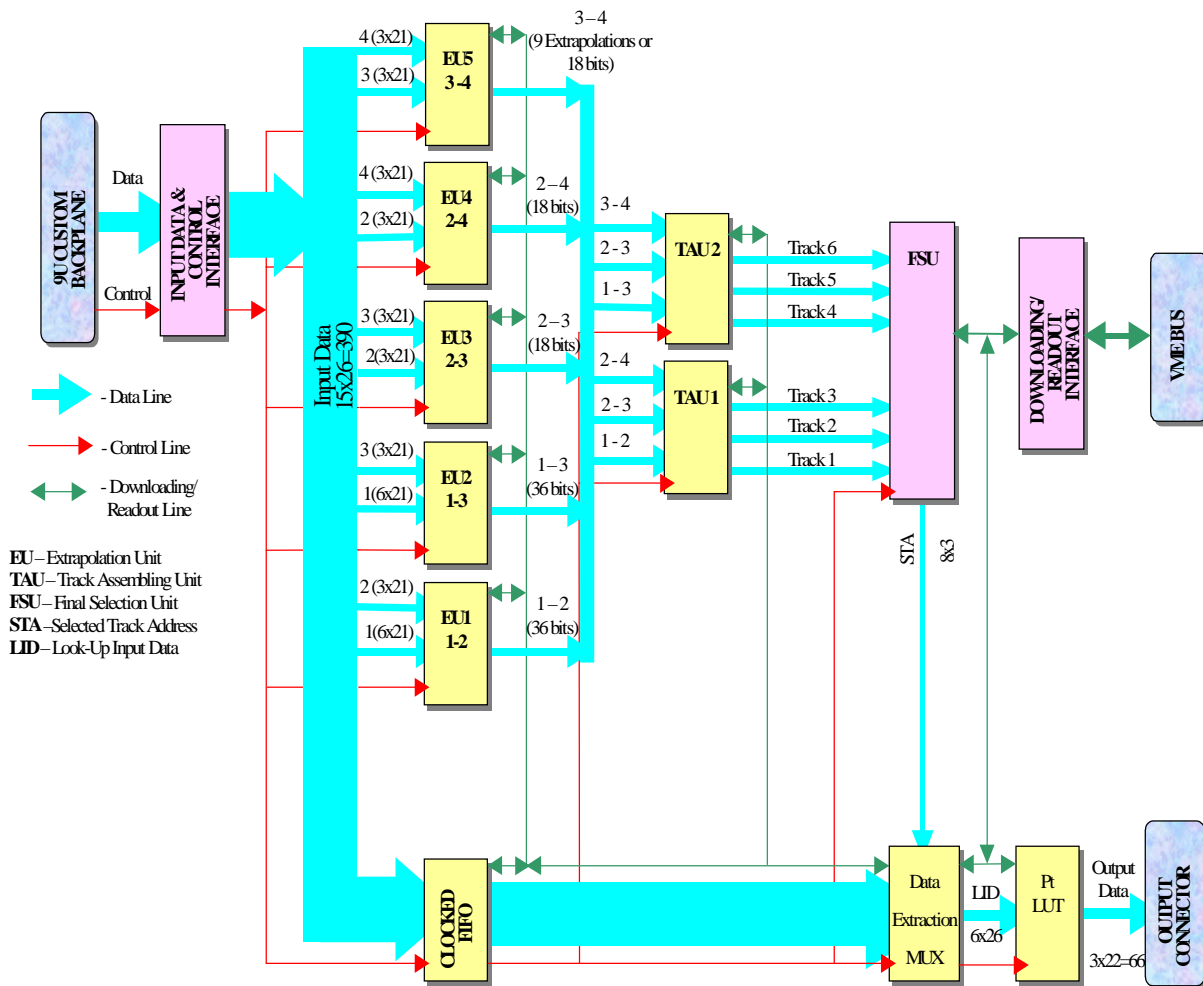
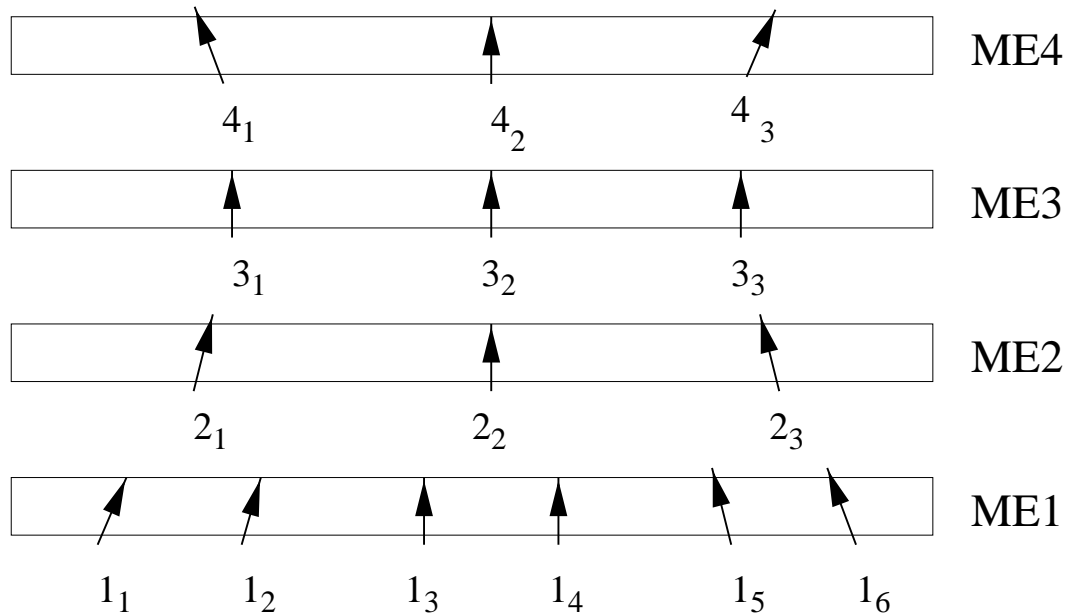


Fig.1. Track Finding Processor. Block Diagram

- **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



- Perform all combinations of extrapolations :

$$1_i \leftrightarrow 2_k, 1_i \leftrightarrow 3_k, 2_i \leftrightarrow 3_k,$$

$$2_i \leftrightarrow 4_k, 3_i \leftrightarrow 4_k,$$

$$\text{no } 1_i \leftrightarrow 4_k$$

Extrapolation Unit in Detail

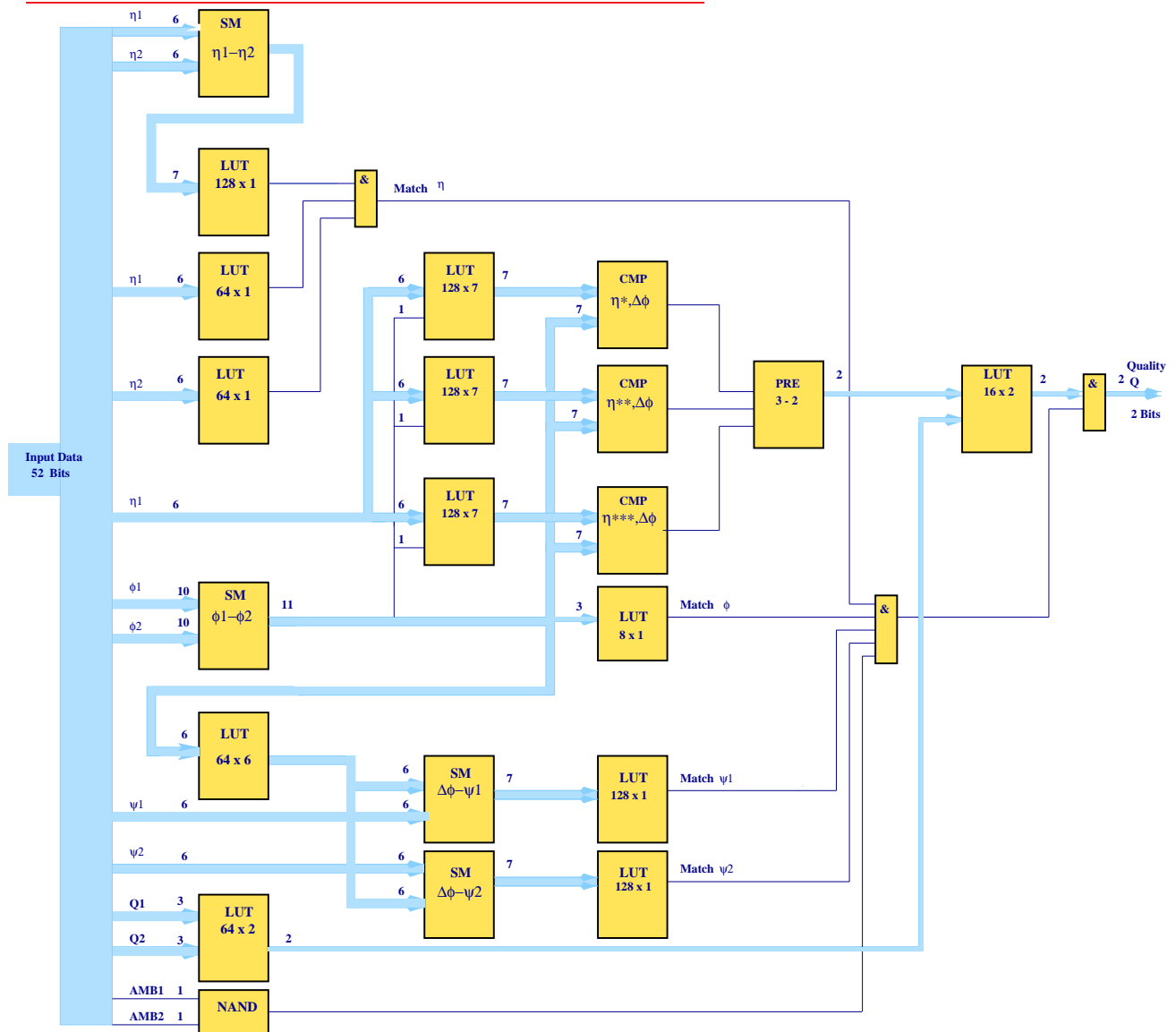
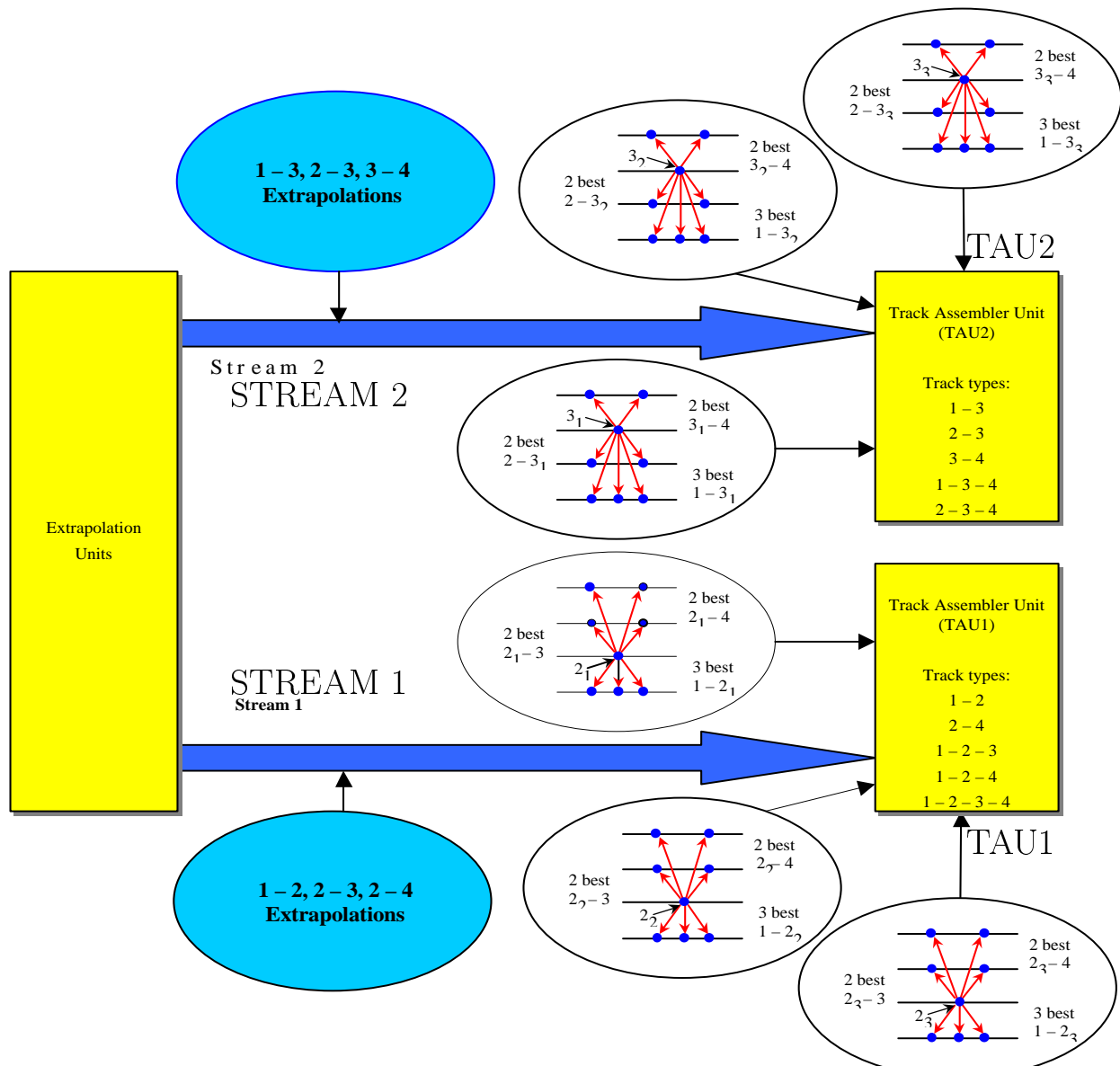


FIG.2. EXTRAPOLATION UNIT. BLOCK DIAGRAM.

- 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)
- 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

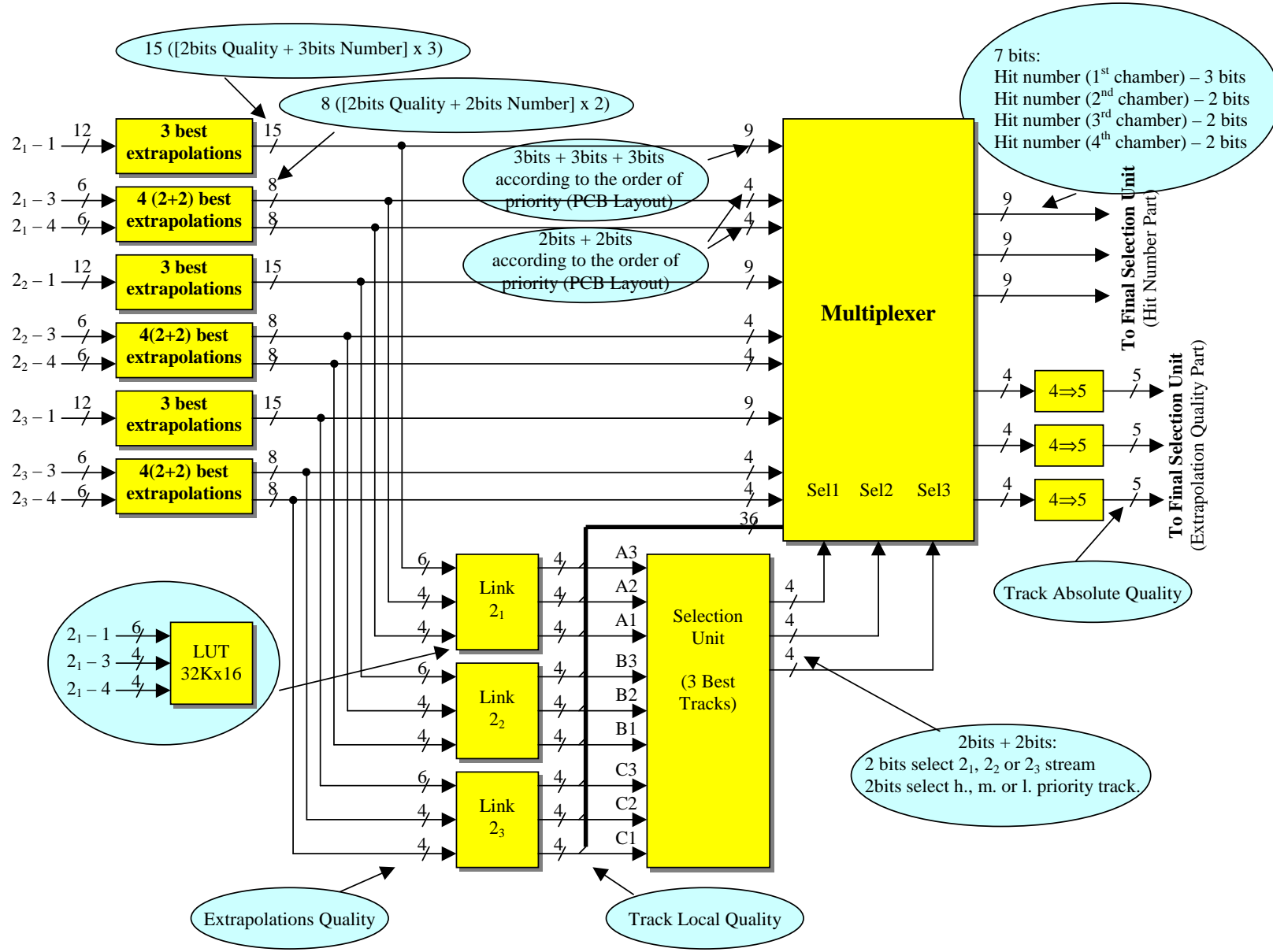


- Results from extrapolations are sent to TAUs in 2 Streams

- 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

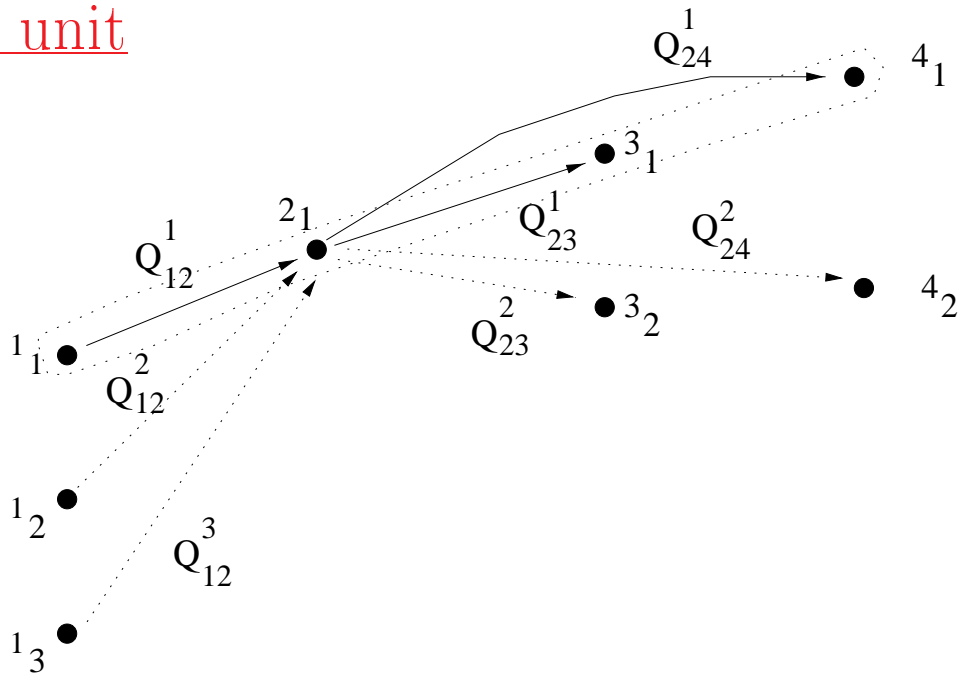
Track Assembler Unit (TAU 1)



Track Assembler Unit (TAU1)

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

LINK unit



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

$$Q_{12}^1 > Q_{12}^2, Q_{12}^3$$

$$Q_{23}^1 > Q_{23}^2$$

$$Q_{24}^1 > Q_{24}^2$$

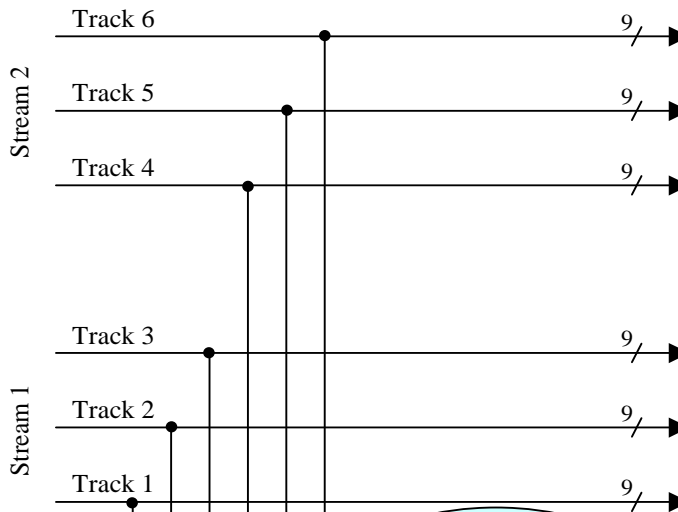
\Rightarrow form a track using LCTs $1_1, 2_1, 3_1$ and 4_1

- In this simulation each LINK unit will form one track

Final Selection Unit (FSU)

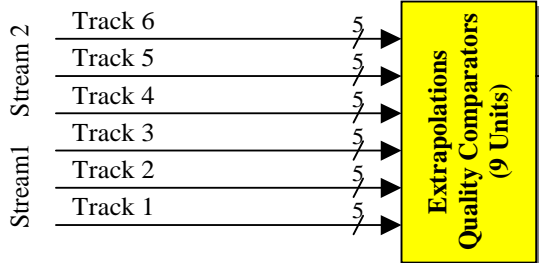
STREAM 2

From Track Assembling Unit
(Hit Number Part)



STREAM 1

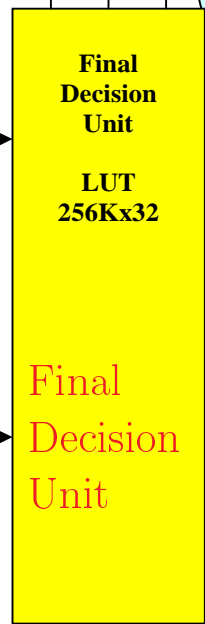
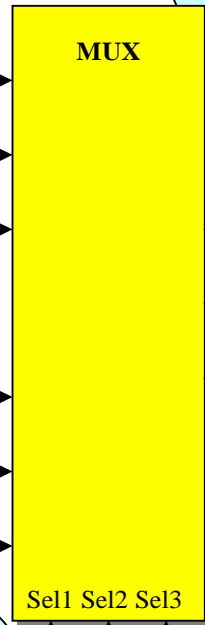
From Track Assembling Unit
(Extrapolations Quality Part)



We should compare:
Track1-Track4; Track1-Track5;
Track1-Track6; Track2-Track4;
Track2-Track5; Track2-Track6;
Track3-Track4; Track3-Track5;
Track3-Track6 (9 bits as total)

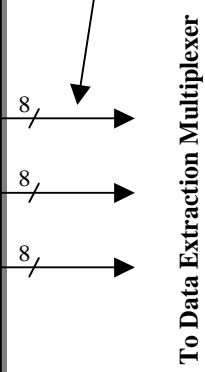
LCT ID Comparator

LCT Quality Comparator



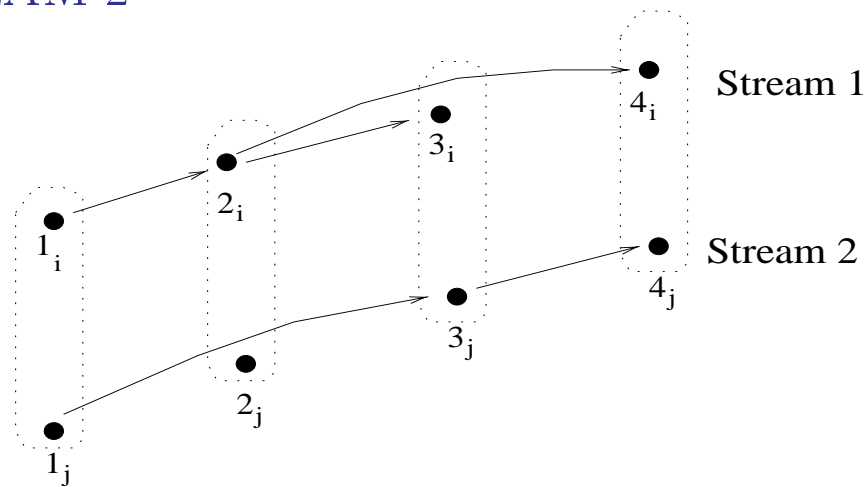
8 bits:
1st track segment number – 4 bits;
2nd track segment number – 4 bits.
(if we need only 2 track segments for Pt calculation)

Each track consists of 4 track segments as maximum
↓
6 Tracks has 24 track segments
↓
We need 10 (5+5)bits to describe all possible combinations



Final Selection Unit

- **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

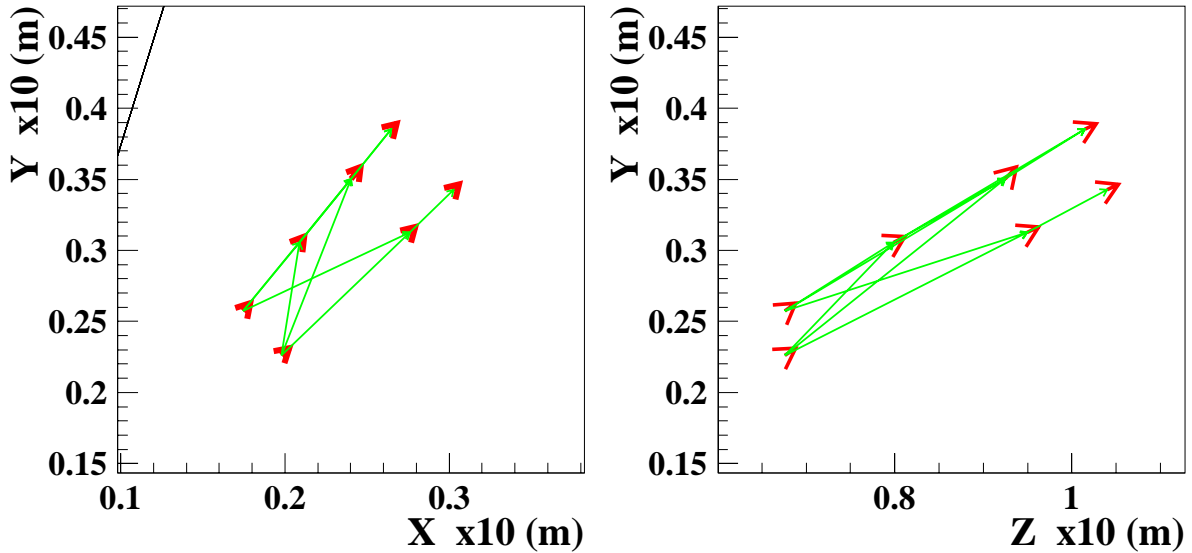


ID Comparator is programmed to consider two tracks are “identical” if both tracks share at least one common LCT

- 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)

Results from the Simulation

Extrapolation Units



(Example: Two muons which are relatively close together. Light green line show the successful extrapolations)

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

%

ME1-ME2 ME1-ME3

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

%

ME1-ME2 ME1-ME3

successful extrapolation	=	99.4	99.4
Low Pt	=	0.02	0.01
Medium Pt	=	0.9	1.1
High Pt	=	98.4	98.2

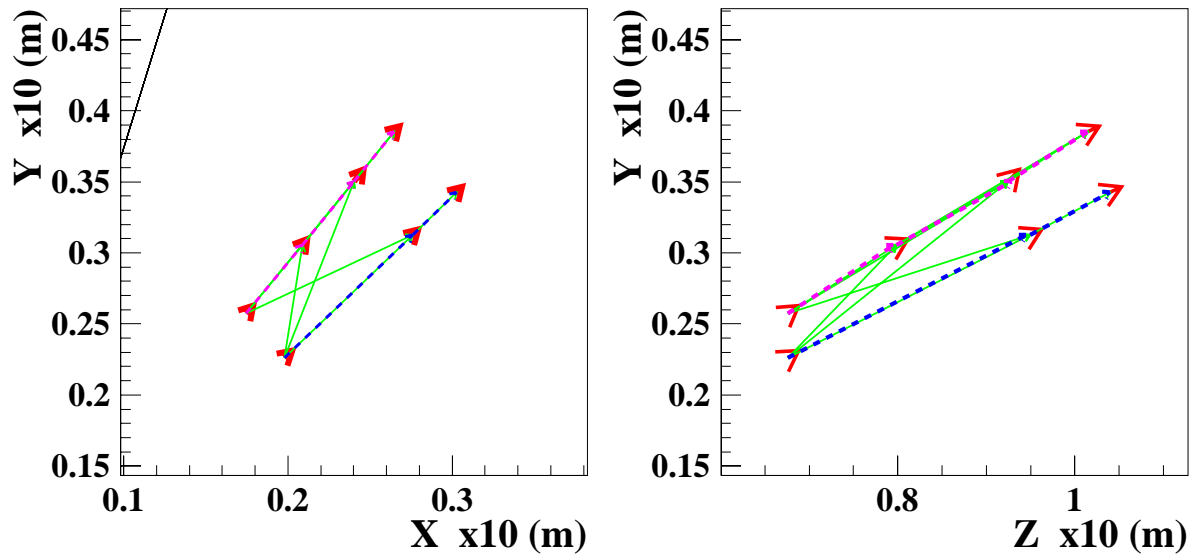
Extrapolation Efficiency of Single halo- μ events :

P = 100 GeV (Total # Evts = 9142)

%

successful extrapolation	=	0.01
Low Pt	=	0.00
Medium Pt	=	0.00
High Pt	=	0.01

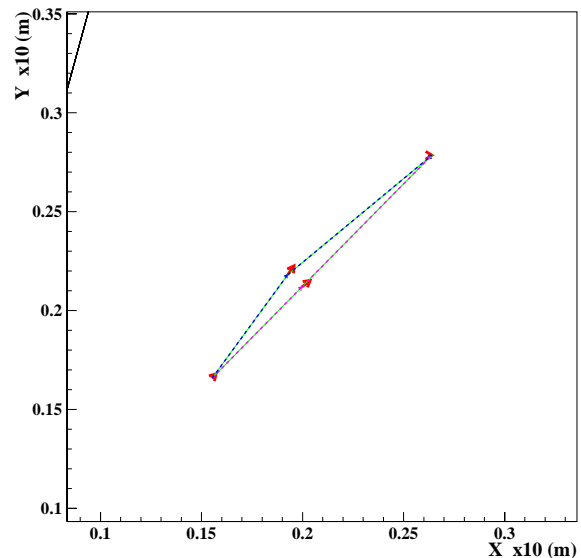
Final Selection Unit



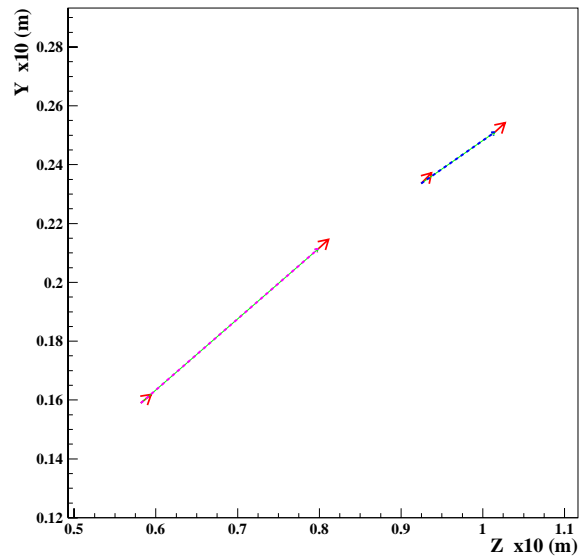
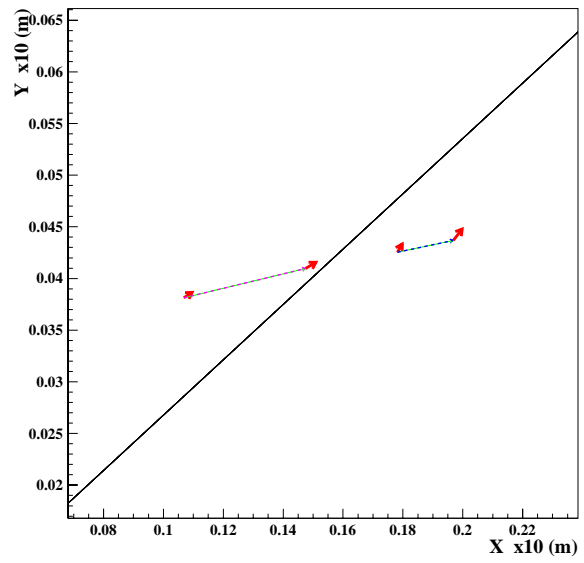
(The dashed line are the tracks found by FSU)

Efficiency of FSU on single muon events

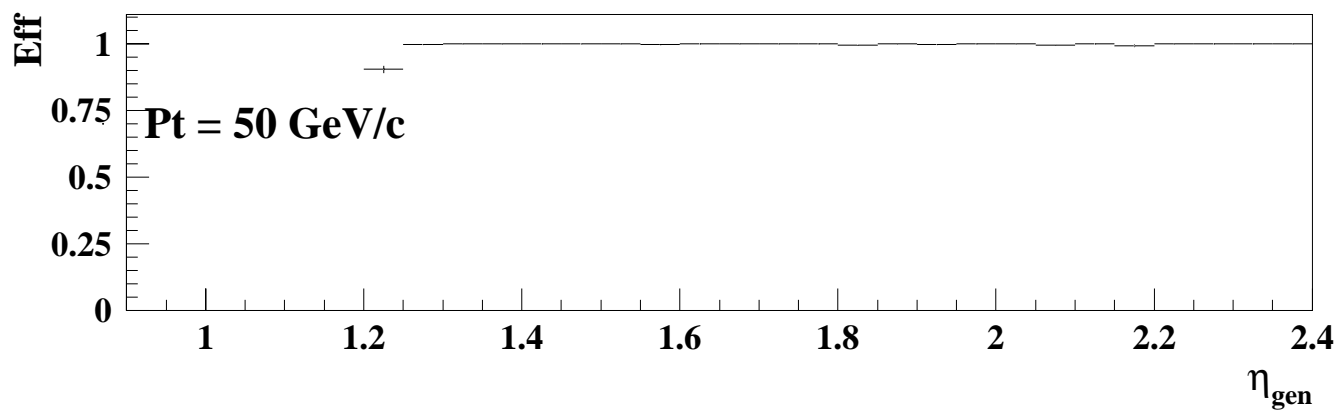
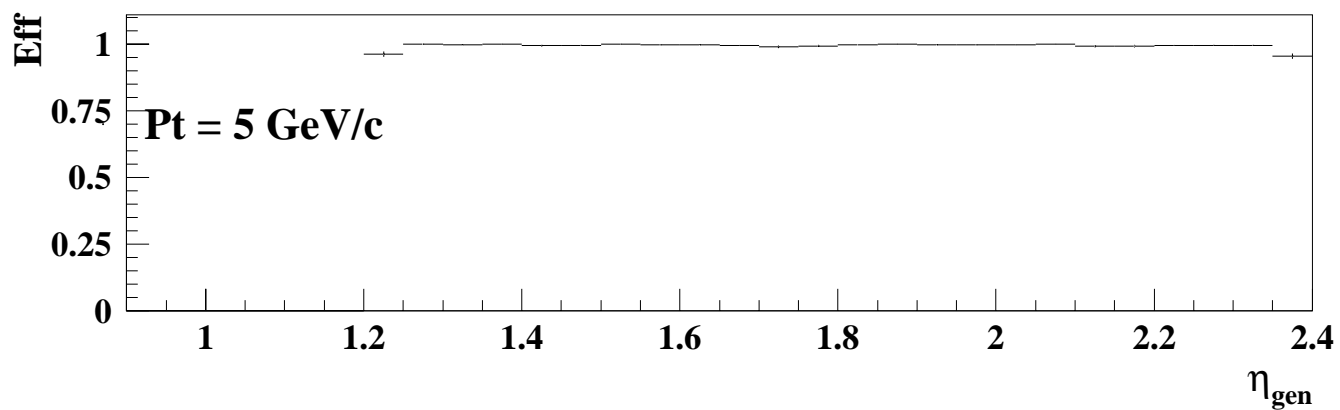
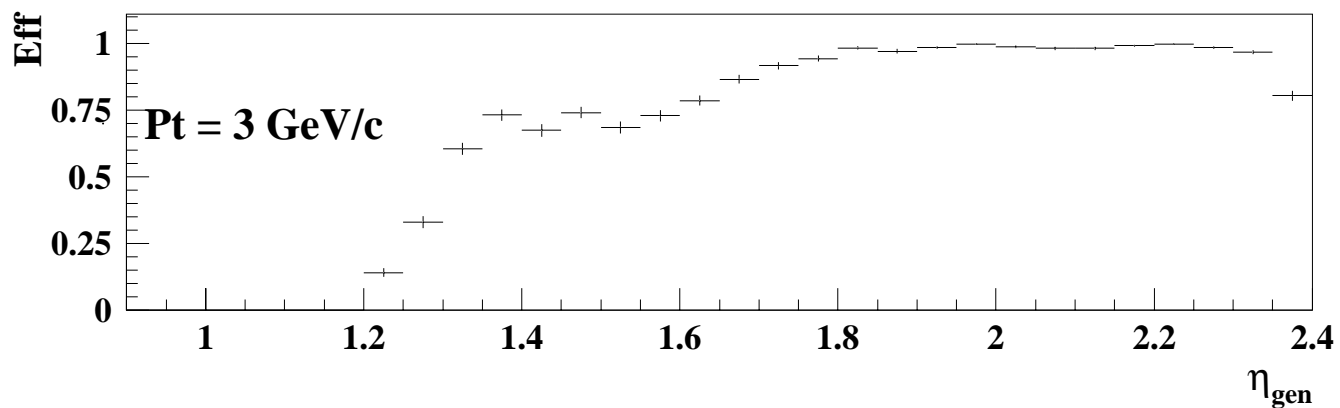
- High efficiency for high Pt muons ($\sim 100\%$)
- $\lesssim 1\%$ of events FSU found > 1 track.
 - Extra LCTs due to bremsstrahlung, delta rays



- Broken track due to sector boundary, failed extrapolation



Single Muon Track Finding Efficiency



Test Track Finder on Physics Events

- Physics process :
 $H^0 \rightarrow ZZ^* \rightarrow 2\mu^+2\mu^-$, $M_H = 300 \text{ GeV}$
- Pre-select events that have at least one muon in the endcap region ($1.2 < |\eta| < 2.4$), and $Pt > 3 \text{ GeV}/c$

<u>Generated</u>		<u>FSU found</u>	
<u># Muons</u>	<u># Evts</u>	<u># Muons</u>	<u># Evts</u>
0	0	0	12
1	672	1	654
2	478	2	477
3	185	3	184
4	21	4	29

(Total number of events = 1356)

- Excess events in the case FSU found 4 tracks are mainly due to :
 - Extra LCTs (bremsstrahlung, delta rays)
 - broken tracks
 - punch throughs

Summary/Plans

- A preliminary version of the Endcap muon Track Finder is almost finished
- The Pt assignment unit will be implemented soon
- Different algorithms used in the Track Assembler Unit and Final Selection Unit will be tested so as to reduce the double counting due to fake tracks
- Apply the Track Finder on Minimum Bias events to estimate trigger rates, and to study issues on ghost/fake tracks
- Move to C++