4D track reconstruction in the CBM experiment

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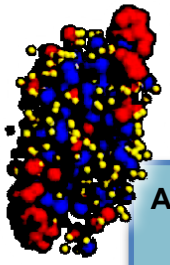
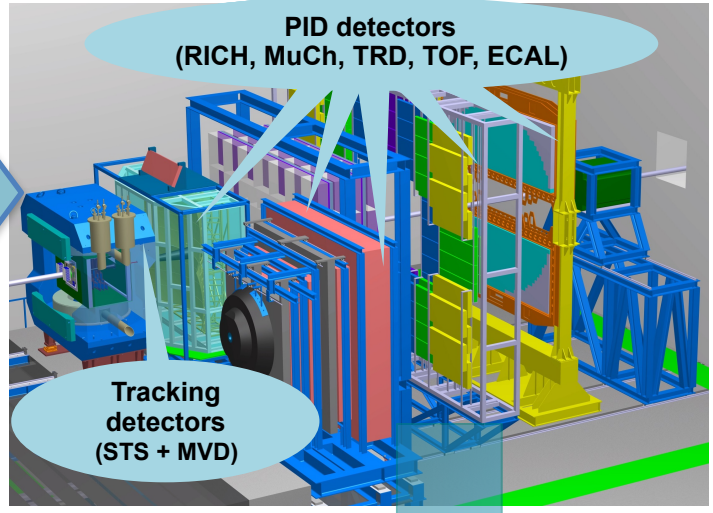
Online Reconstruction in CBM

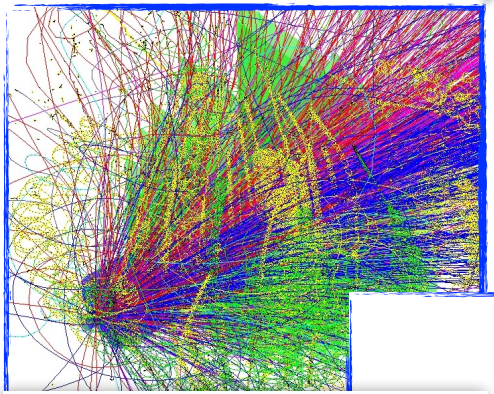


A+A collisions at 10MHz

CBM Detector Setup



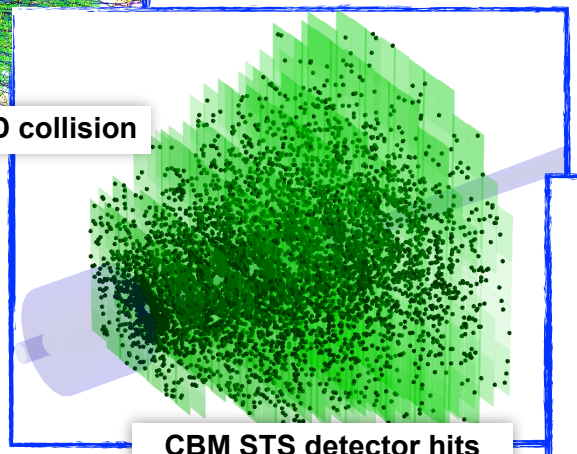
- Interaction rate up to 10 MHz
- free-streaming data
- self-triggered front-end electronics
- no hardware trigger



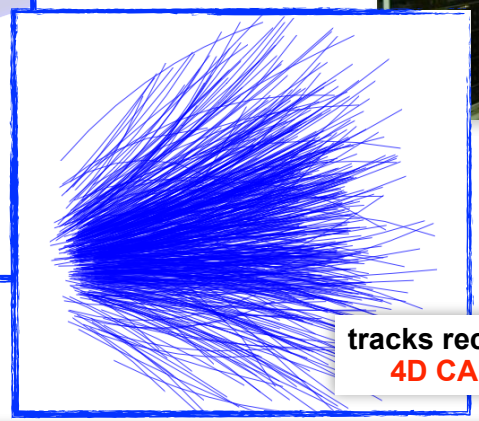
simulated AuAu UrQMD collision

~ 1 TB/s dataflow

FLES prototype: Loewe CSC Frankfurt



CBM STS detector hits



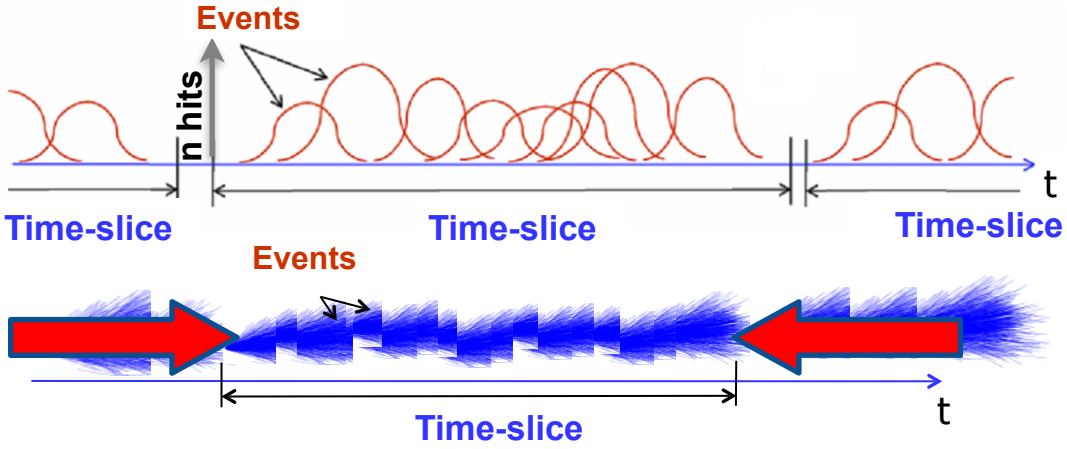
tracks reconstructed with 4D CA Track Finder

~ 1 GB/s dataflow

Mass storage

Limited bandwidth of data storing leads to
online event reconstruction and selection on a dedicated computer farm.

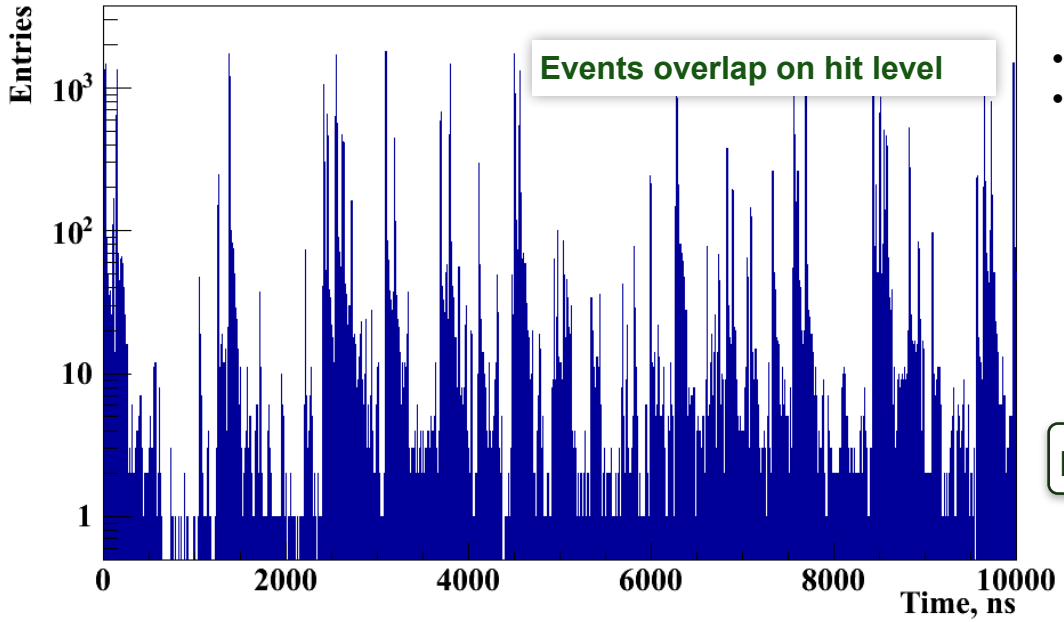
Time-based 4D Reconstruction



- Interaction rate up to 10 MHz
- free-streaming data
- self-triggered front-end electronics
- no hardware trigger

Events overlap

Hit time measurement in STS at interaction rate 10 MHz



- Time-slices instead of event-based reconstruction
- Time-based tracking: 4D measurements (x, y, z, t)

4D track reconstruction

Track state vector:
$(x, y, t_x, t_y, q/p) \rightarrow (x, y, t_x, t_y, q/p, t)$

position | slope | momentum | +time

No a-priori association of signals to physical events!
Correct procedure of event building from time-slices is crucial for correct physics interpretation.

4D Cellular Automaton (CA) Track Finder

100 AuAu minimum bias events at 10 AGeV

Efficiency, %	3D	4D 0.1MHz	4D 1MHz	4D 10MHz
All tracks	92.5 %	93.8 %	93.5 %	91.7 %
Primary high-p	98.3 %	98.1 %	97.9 %	96.2 %
Primary low-p	93.9 %	95.4 %	95.5 %	94.3 %
Secondary high-p	90.8 %	94.6 %	93.5 %	90.2 %
Secondary low-p	62.2 %	68.5 %	67.6 %	64.3 %
Clone level	0.6 %	0.6 %	0.6 %	0.6 %
Ghost level	1.8 %	0.6 %	0.6 %	0.6 %
True hits per track	92%	93 %	93 %	93%
Hits per MC track	7.0	7.0	6.97	6.70

Timeslices from CBMROOT, time-based digitisation, cluster and hit finder in STS

Reconstructable track:≥ 4 consecutive mcPoints

All set: p ≥ 0.1 GeV/c

Ghost: purity < 70%

Clone: tracks reconstructed more than once

* Algorithm version without search for short 3-hit tracks

Time-based tracking performance comparable with event-by-event.

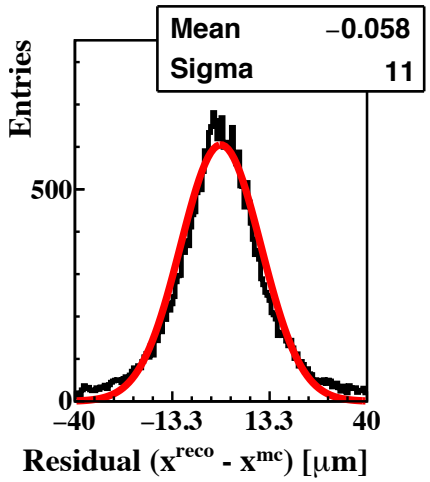
4D Kalman Filter Track Fitter

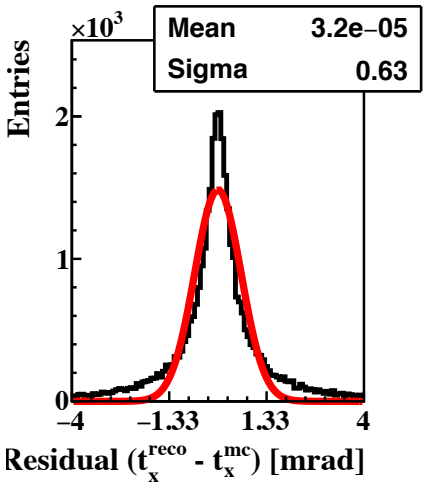
100 AuAu UrQMD minimum bias events at 10 AGeV, 8 STS stations

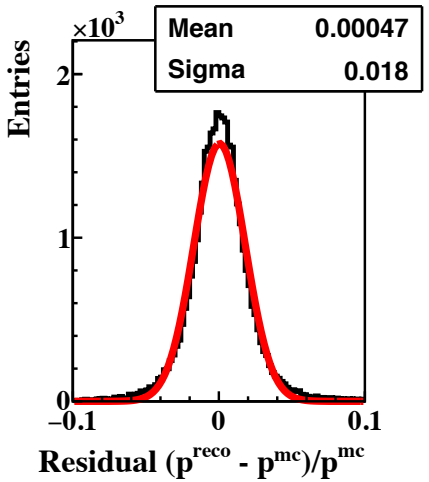
Residual - difference between simulated and reconstructed parameter
Pull - residual normalised by fitting error

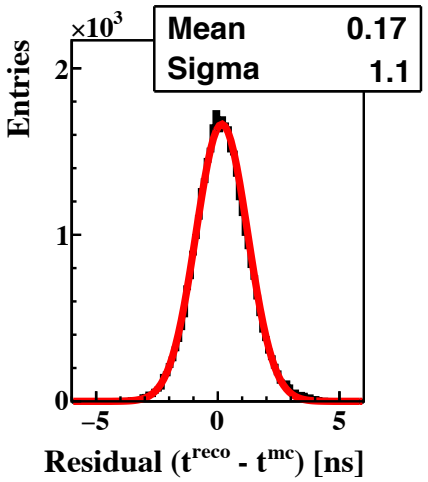
Track state vector:
$(x, y, t_x, t_y, q/p, t)$

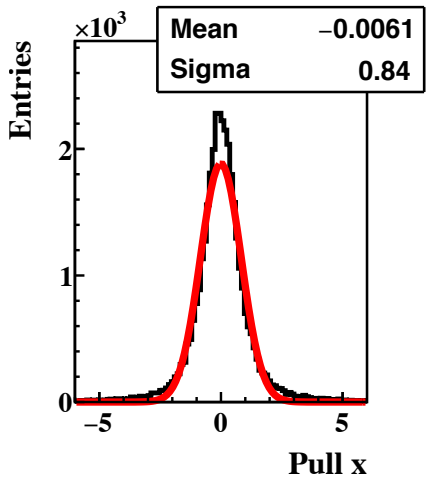
position | slope | momentum | +time

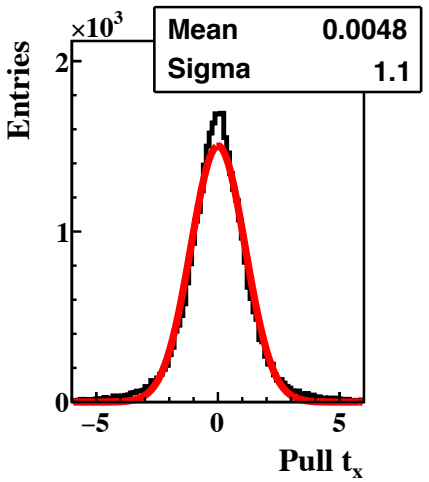


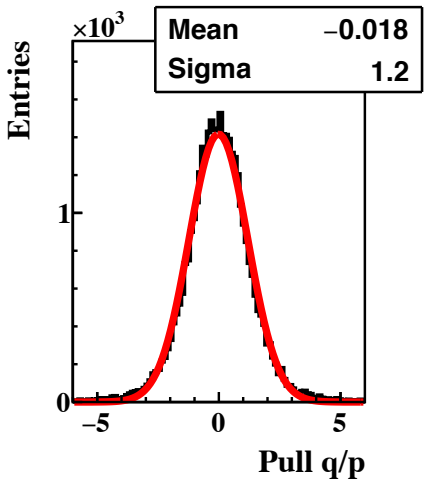


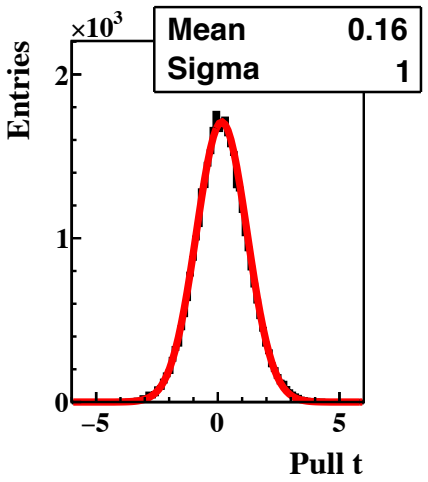






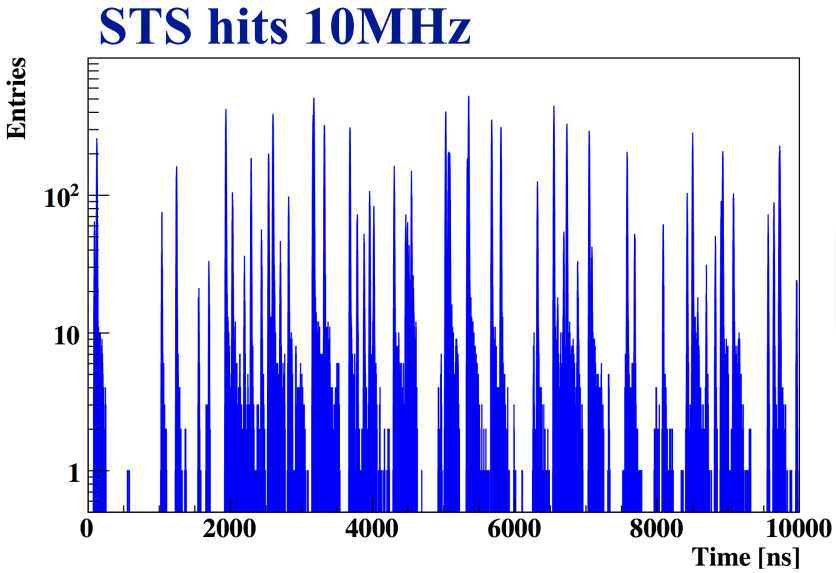




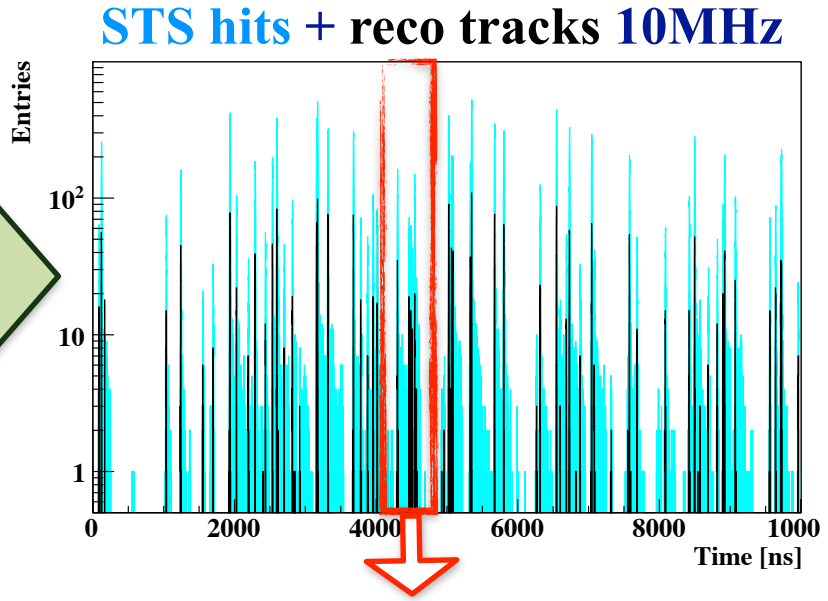


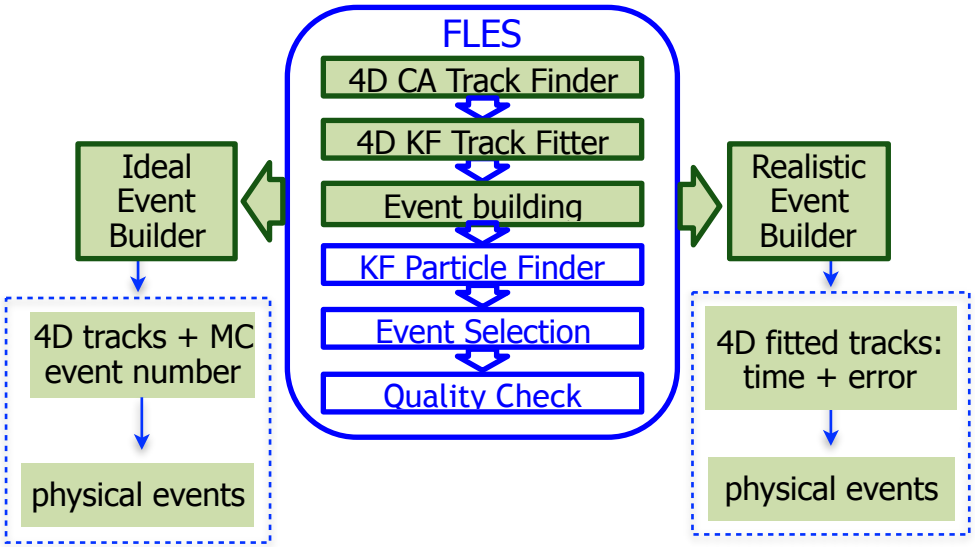
Track fit quality is high: parameters are unbiased, errors are correctly estimated.

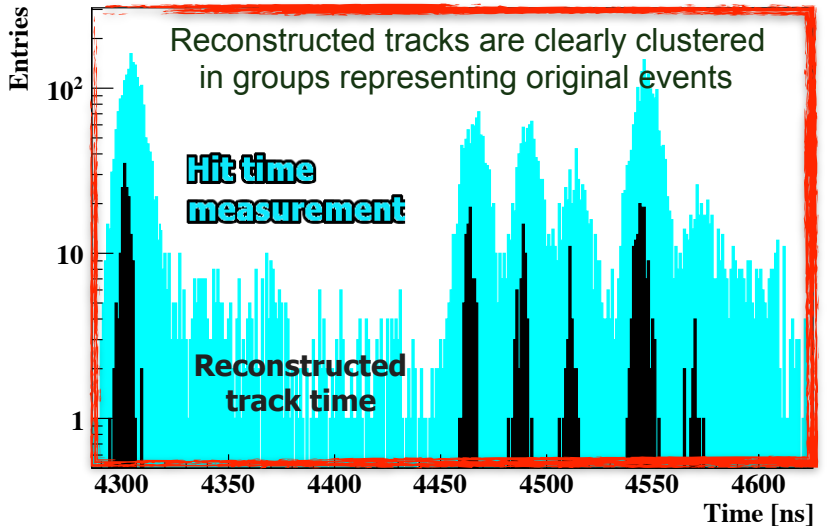
4D Reconstruction Chain



Track Finder

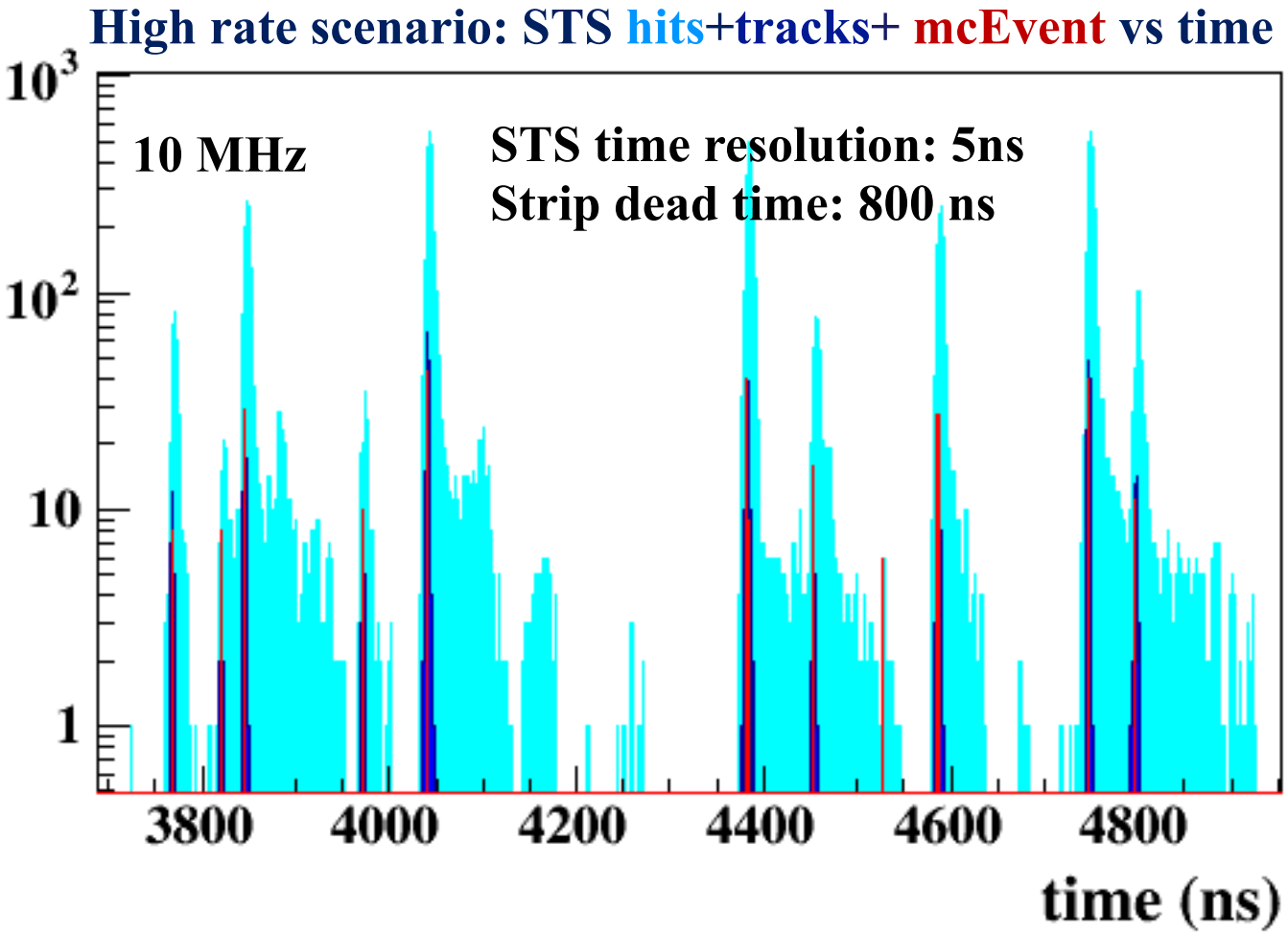






Event building as a part of the CBM reconstruction chain.

Track based Event Builder



Further analysis

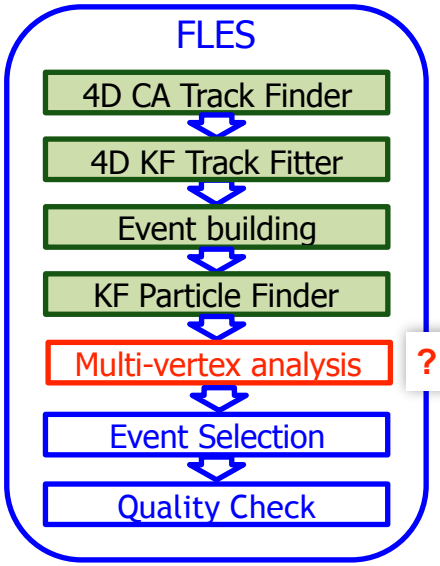
- Multi-vertex analysis
- Global tracking (ToF)

Track-based EB with STS allows to resolve ~ 80% of collisions at 10 MHz IR

~ 99% of collisions at <= 1 MHz IR

Build events with isolated collisions from continuous time-stamped data.

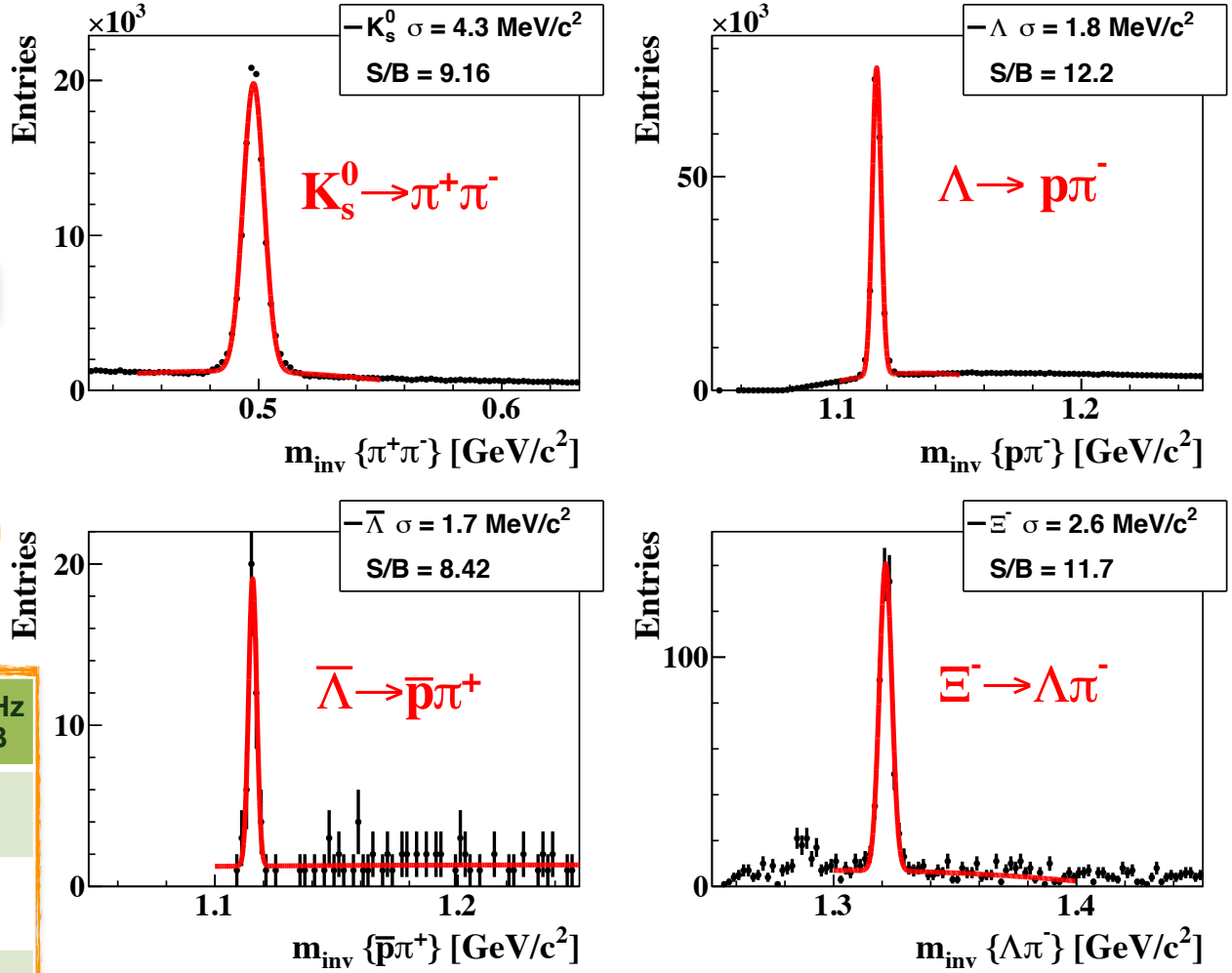
Short-lived Particle Reconstruction



Extreme case of 10 MHz interaction rate requires further input from fast detectors (**ToF**) and **multi-primary vertex analysis**

Particle /Case	3D	4D 10 MHz Ideal EB	4D 10 MHz Real EB
K^0_s	22.9%	21.2%	21.2%
Λ	21.9%	19.8%	19.6%
Ξ^-	7.8%	6.3%	6.3%

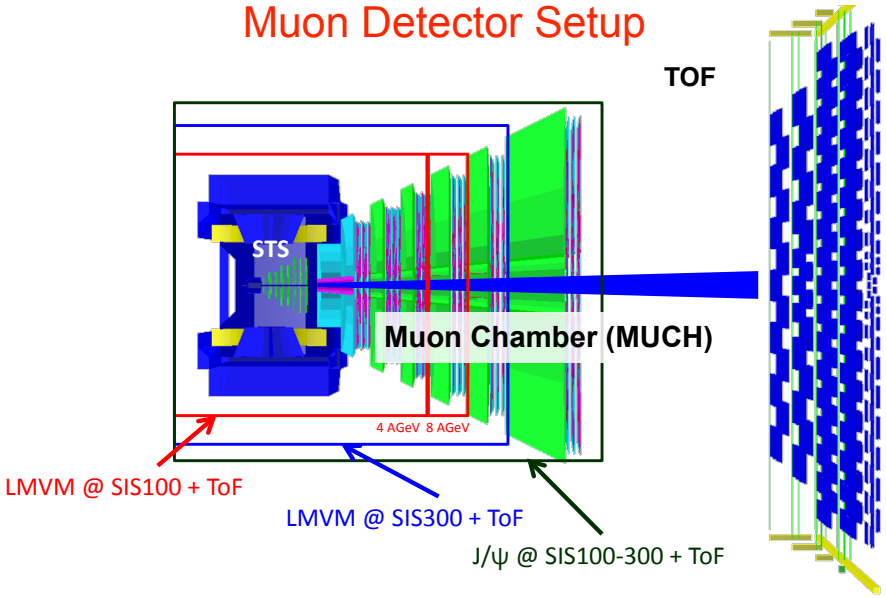
300k mbias AuAu 10 AGeV events at 10 MHz, KF Particle Finder, ideal PID, realistic event builder



Full reconstruction chain from time-slices to physics analysis.

Towards Global CA Track Reconstruction

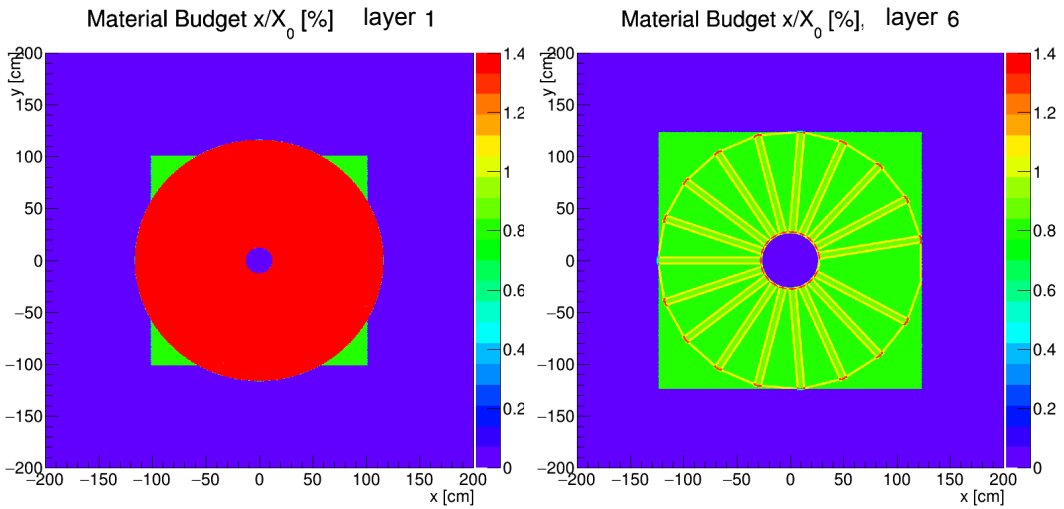
Muon Detector Setup



Motivation

- Extend existing fast and parallel CA track finder to other detector systems for online reconstruction
- mCBM needs tracking algorithm for complete mCBM detector system
- Easier alignment procedure due to independent reconstruction in detector sub-systems

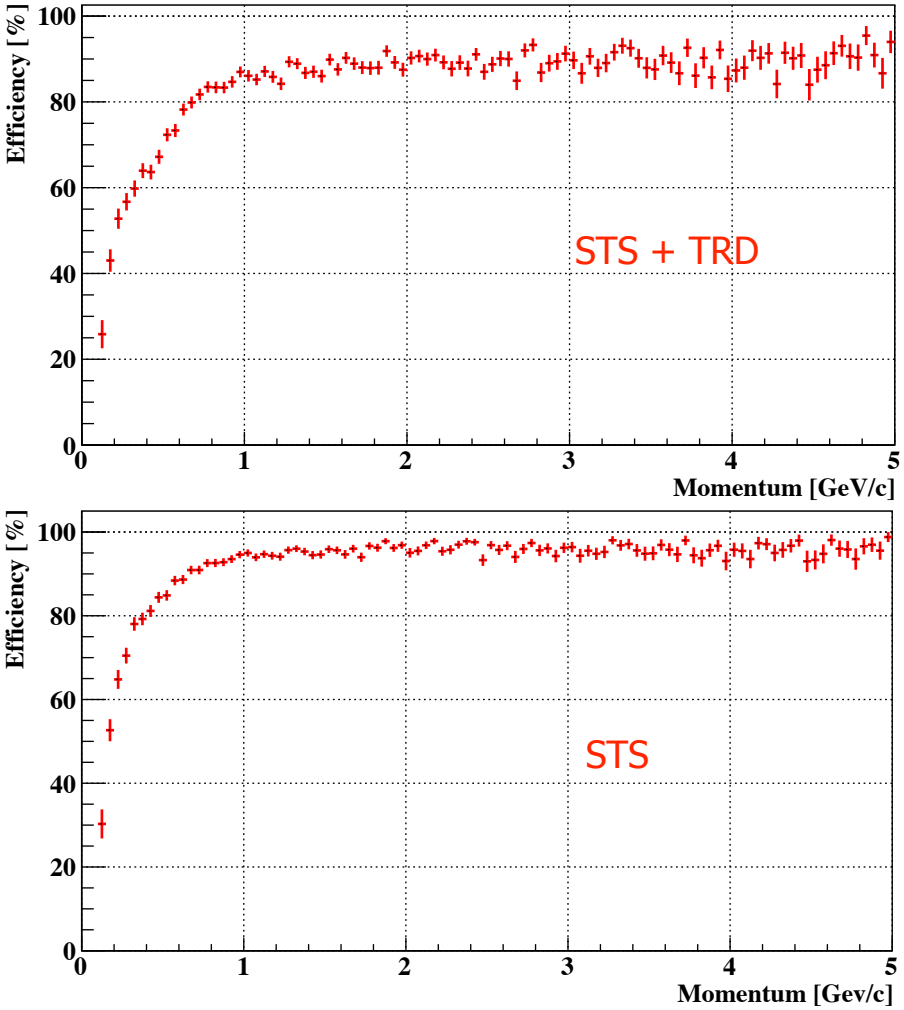
MUCH Material Budget Map



Algorithm adaptation

- Straight line track propagation
- Thick absorber material
- No straightforward momentum estimate

CA Global Track reconstruction: STS+TRD



Reconstructable track:≥ 4 consecutive mcPoints

All set: p ≥ 0.1 GeV/c

Ghost: purity < 70%

Clone: tracks reconstructed more than once

CA Global Track Finder Performance Preliminary:

mbias UrQMD AuAu 10 AGeV events

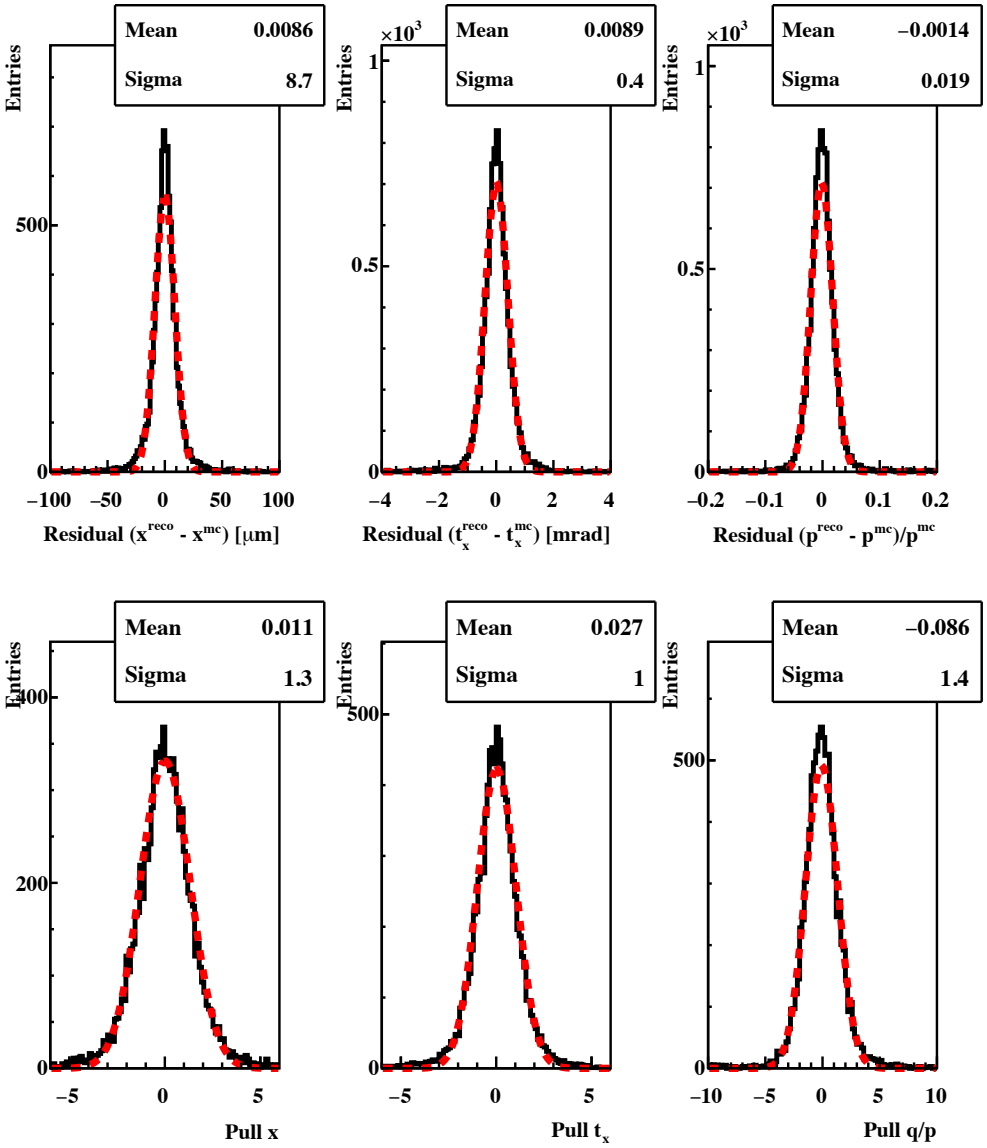
	STS + TRD	STS
All tracks efficiency	83.4 %	91.9 %
Clone level	2.3 %	2.8 %
Ghost level	8.5 %	6.0 %
True hits per track	70.5 %	85.5 %
mcPoints per mcTrack	9.50	6.93
Hits per mcTrack	9.23	7.10
Tracks per event	383.5	374.6

- MC momentum is used in the area of no magnetic field
- to be replaced with realistic estimate from the deflection angle in the magnetic field

On the way to include TRD and ToF detectors to 4D track reconstruction

CA Global Track Reconstruction: STS+MuCh

Kalman Filter Track fit quality at the 1st hit position (STS + MuCh)



On the way to include MuCh and ToF detectors to 4D track reconstruction

Summary and Outlook

- Time-based reconstruction chain for CBM has been developed
- It includes CA track finder, KF track fit, event builder and KF Particle Finder
- The CA and KF track reconstruction is being extended to all detector sub-systems for global track reconstruction
- Adding of time information from other detector systems to 4D analysis is in progress

Outlook:

- Switch to realistic momentum estimate for global track reconstruction in zero magnetic field area
- Add ToF detector to the global track reconstruction and event building
- Include ToF information and switch to realistic PID
- Multi-vertex analysis

Momentum Estimate in MUCH

Momentum based on
the slope of a straight track:

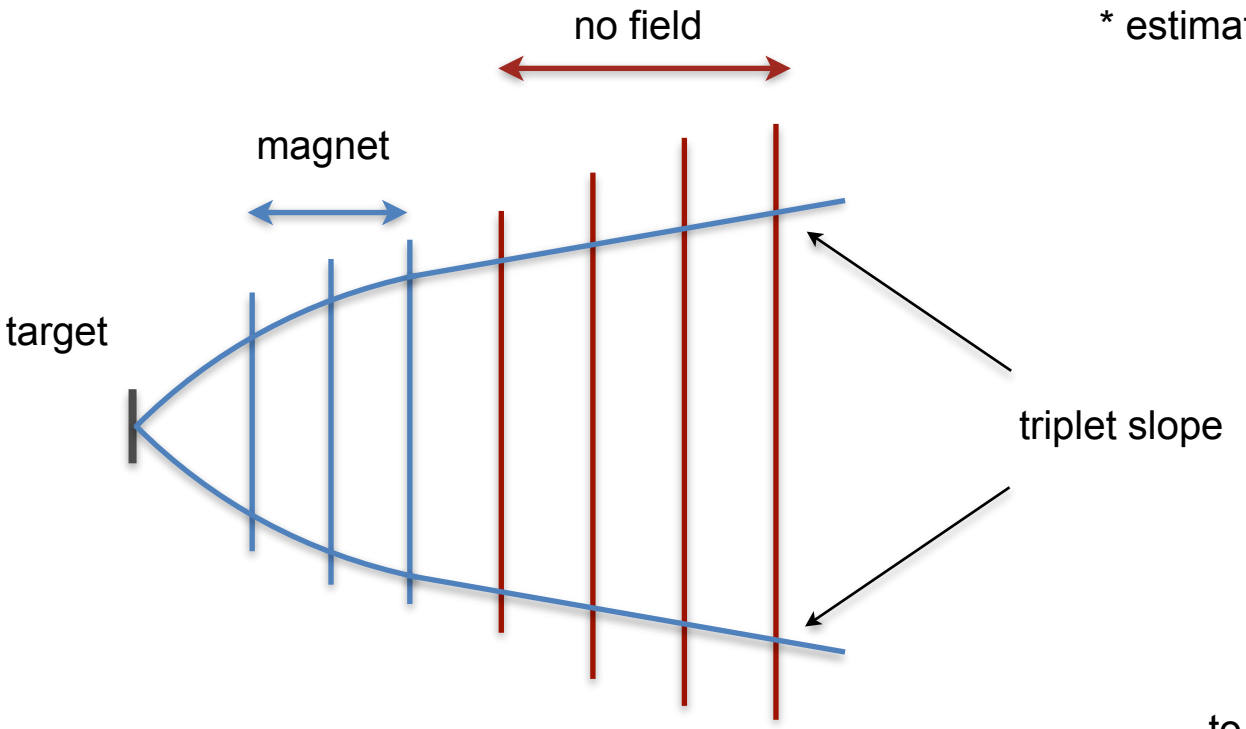
(assuming primary track)

$$\frac{Q}{p} = \frac{[x - (z - z_{target})t_x]\ \sqrt{1 + t_x^2}}{\int B_y d\ell \cdot (z_{magnet} - z_{target})\sqrt{1 + t_x^2 + t_y^2}} \quad *$$

field integral

track slopes

* estimate used in HERA-B



to be implemented…

triplets in MUCH can be binned based on the momentum estimate