Simulations of a DT-Tracker muon trigger for Phase 2

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SCOPE

INCREASE PT RESOLUTION BY ASSOCIATION OF MUON AND TRACKER TRIGGER DATA

STEPS

- ☐ BACKWARD EXTRAPOLATION OF MUON TRIGGER TOWARDS TRACKER
- ☐ MATCH BETWEEN EXTRAPOLATED MUON AND TRACKER INFORMATION
- ☐ PT EVALUATION

ASSUMPTIONS

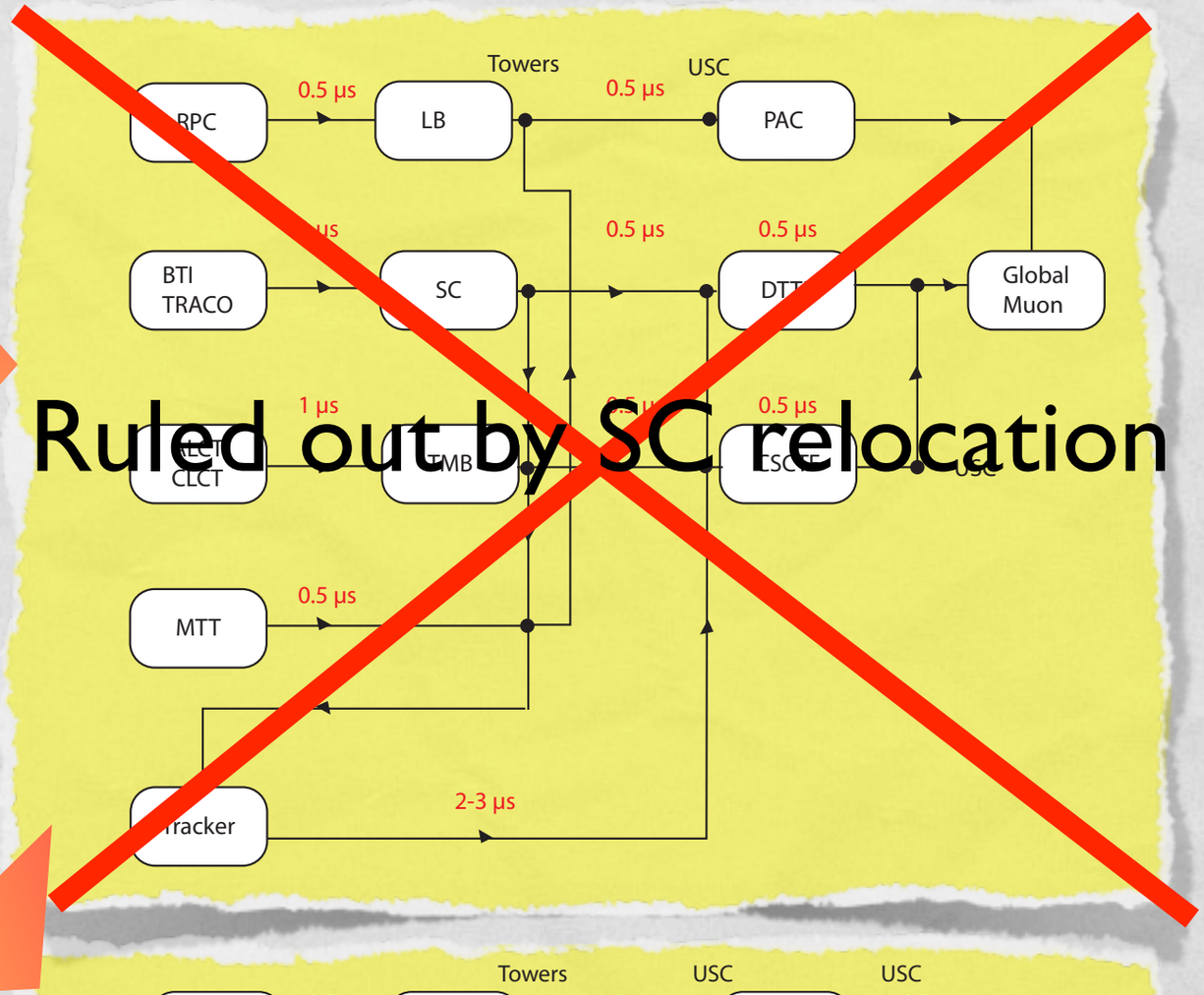
- ☐ 100 KILOHERTZ BANDWIDTH
- ☐ 6.4 MICROSECONDS LATENCY

Nov 2008 FNAL Architectures

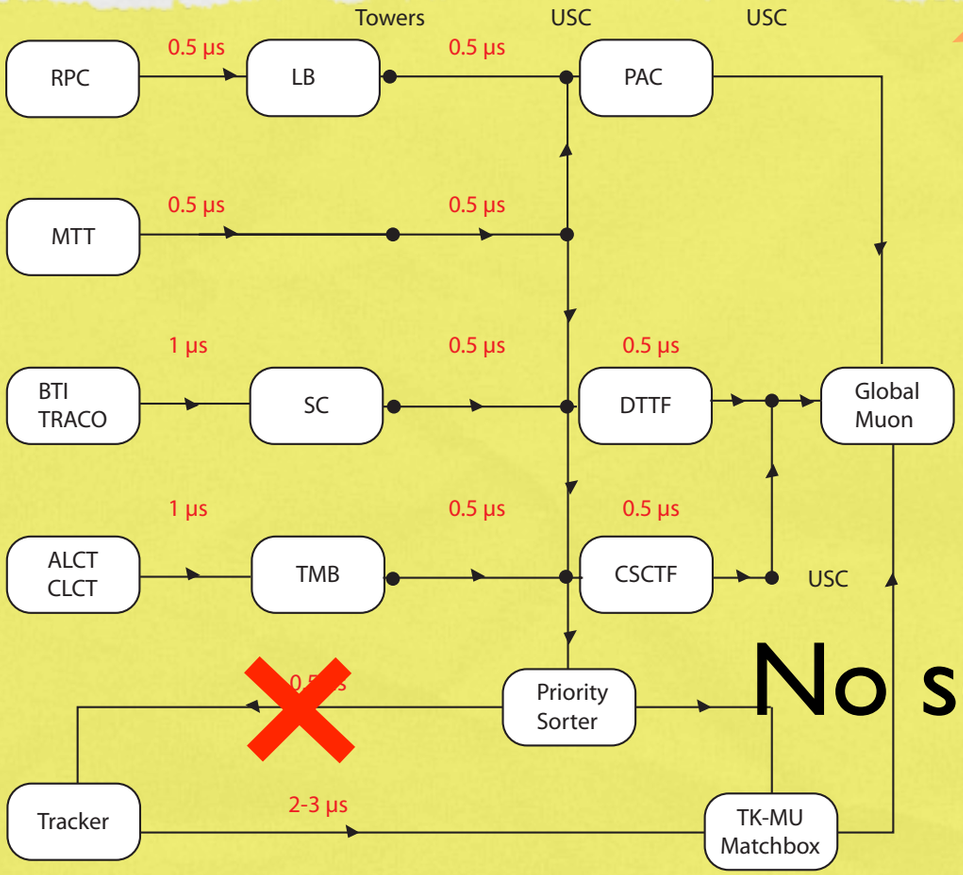
Tracker addressing from towers

Tracker addressing from USC before the TFs

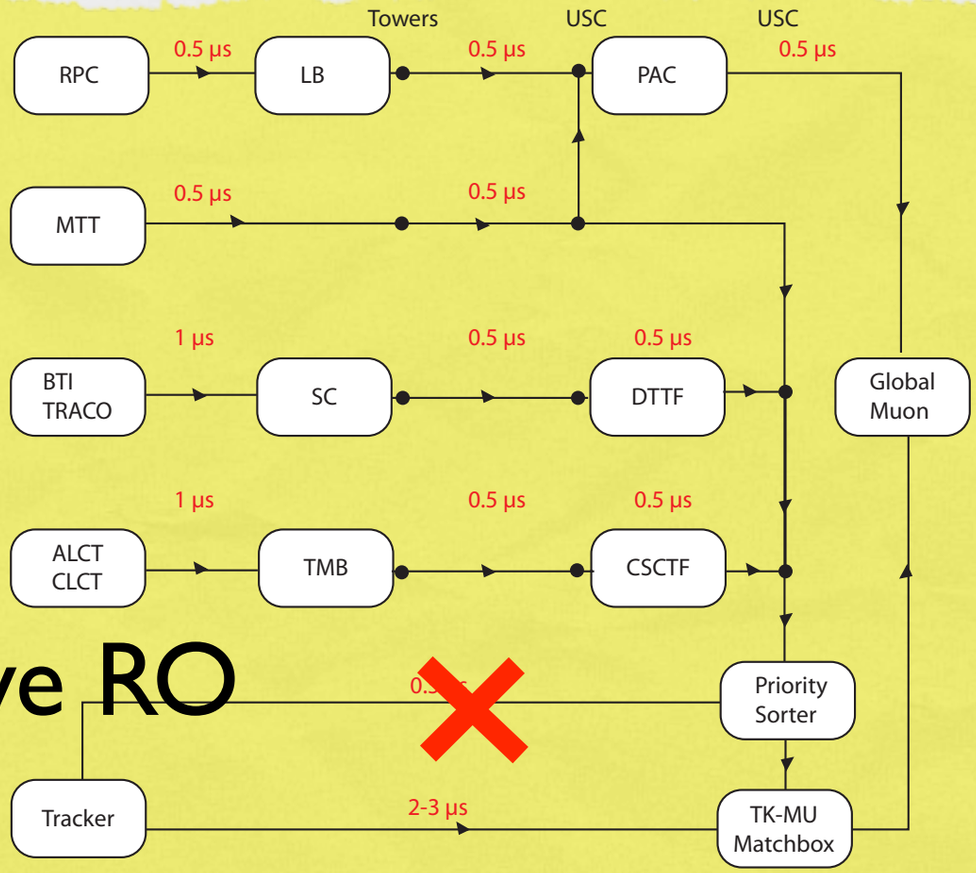
Tracker addressing from USC after the TFs



Ruled out by SC relocation



No selective RO



DT OPTIONS

☐ INPUT FROM DTTF → NEEDS HW AND SW MODIFICATIONS

- INSUFFICIENT INFORMATION
- LOW RESOLUTION (PHI, PT,ETA INSTEAD OF PHI, BENDING ANGLE,THETA)
- FAKE REJECTION AND QUALITY SORTING ALREADY DONE

☑ INPUT FROM PRIMITIVES → SW AVAILABLE PART OF THE HW ALGORITHM COULD BE INCLUDED IN NEW SC

- FULL RESOLUTION (PHI, BENDING ANGLE,THETA)
- HIGHER EFFICIENCY (ONLY ONE STATION NEEDED)
- PARALLEL WORK ON SECTORS: NEED FAKE REJECTION, MERGING AND SORTING

TRACKING TRIGGER OPTIONS

☑ ALGORITHMIC → SW FULLY AVAILABLE

- COMPUTE TRIGGER PRIMITIVES FROM TRACKER CLUSTERS
- CONNECT PRIMITIVES IN DIFFERENT LAYERS TO BUILD UP TRACKS
- INTERMEDIATE TRIGGER OBJECTS AVAILABLE (STUBS, TRACKLETS)

☐ PATTERN → SW PARTIALLY AVAILABLE

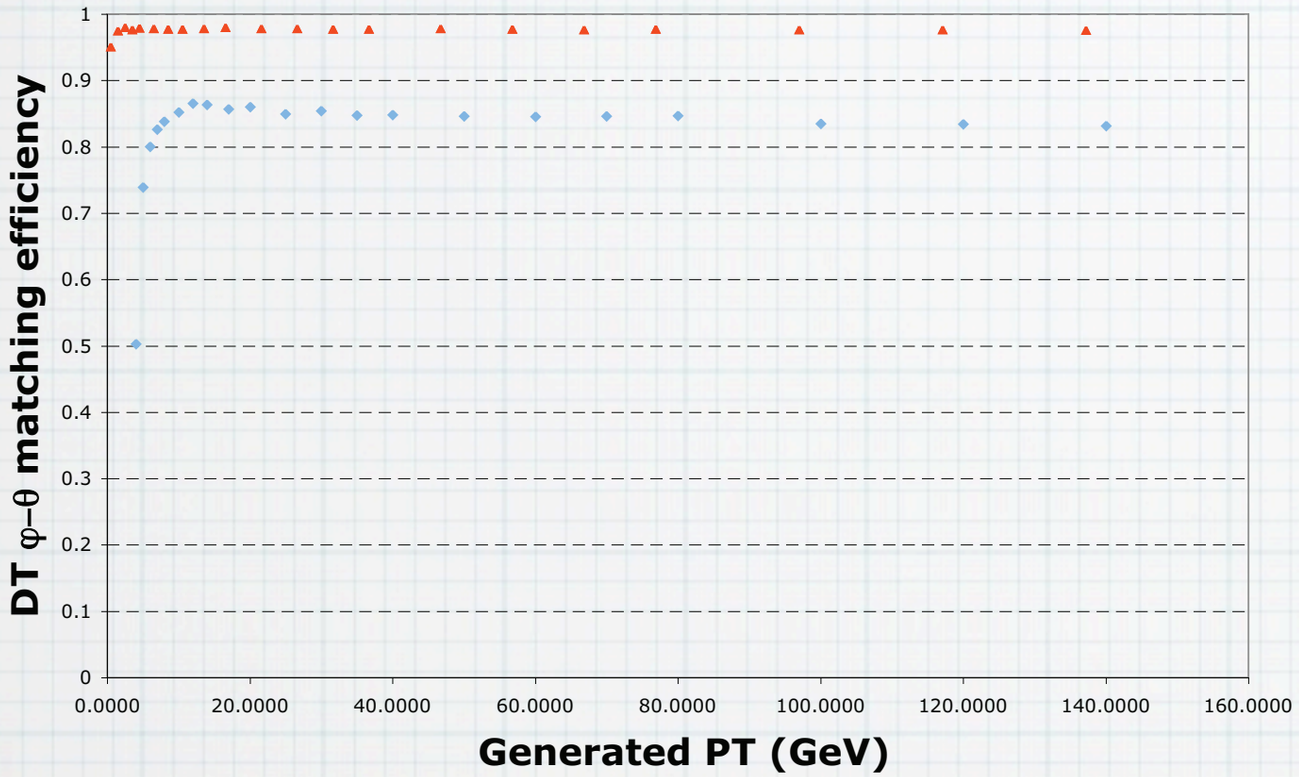
- GET TRACKER CLUSTERS (AFTER SOME DATA REDUCTION)
- CONNECT CLUSTERS IN DIFFERENT LAYERS TO BUILD UP TRACKS WITH ASSOCIATIVE MEMORIES
- ONLY FINAL OBJECT AVAILABLE (?)

ALGORITHM

- associate φ and θ trigger primitives within each muon station
- order by quality rank
- extrapolate to tracker layers
- search for objects in a region around the extrapolated position
- create a list of tracker objects found inside the search region
- estimate transverse momentum combining listed objects

Code available for longbarrel
CMSSW 4.2.8 version in full simulation

Local muon definition



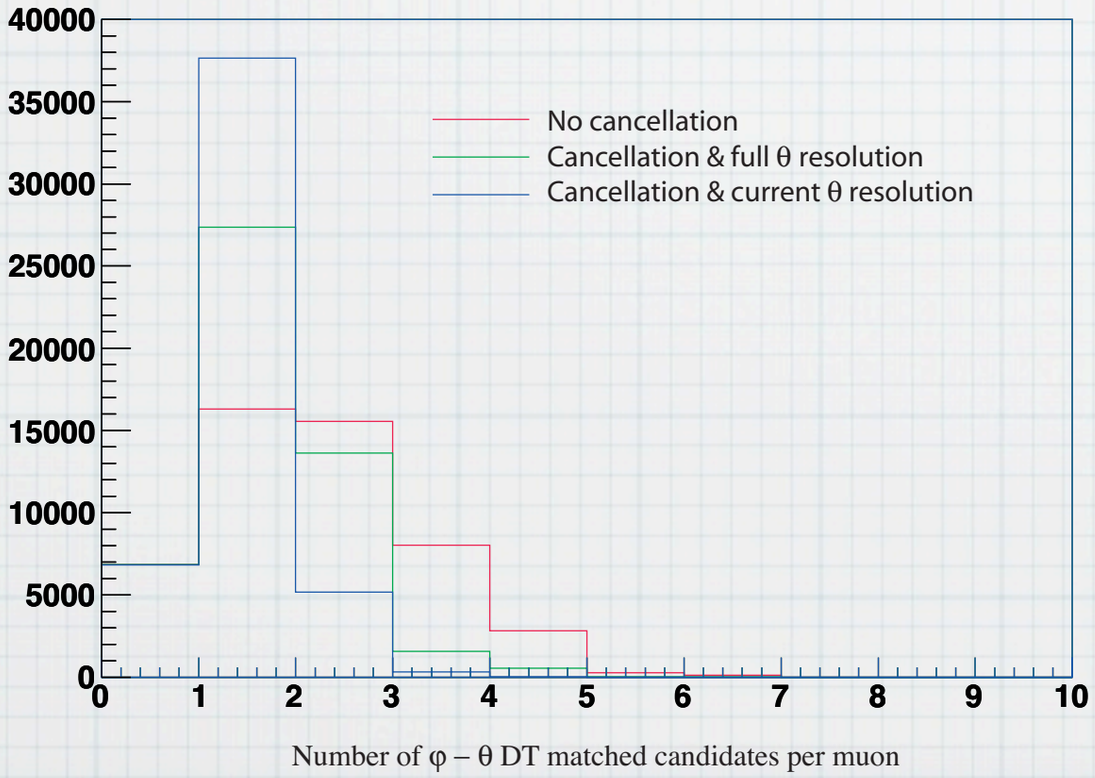
Primitives in the two DT projections are matched and ordered by quality (6 bits)

Only single chamber triggers in Station 1 and Station 2

~85% efficiency if only matched tracks accepted

~96% efficiency if θ missing primitives are accepted (only code better than H)

No extra information required



Origin of fake triggers:

- ghost triggers at wrong bx
- duplicates due to superposition of station 1 & 2
- second triggers due to mismatch or noise
- ambiguities if more than a TP in a station

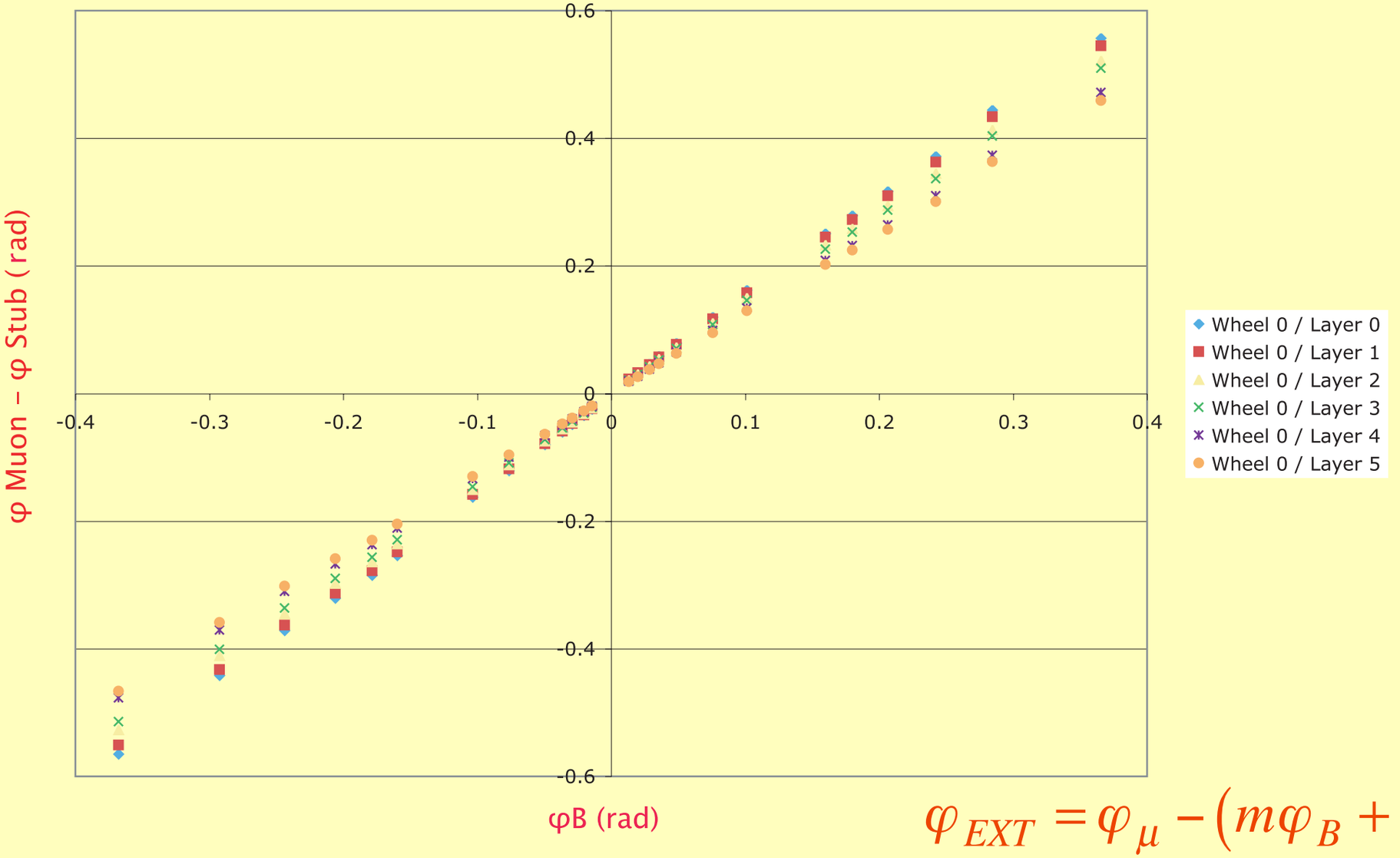
Two possible choices for TPs resolution in θ projection

full resolution: ~1.5 mrad (single BTI)

current resolution: ~ 20 mrad (OR of 8 BTIs)

A 2D detector (25 x 25 cm^2) close to DTs could be very helpful for fake rejection

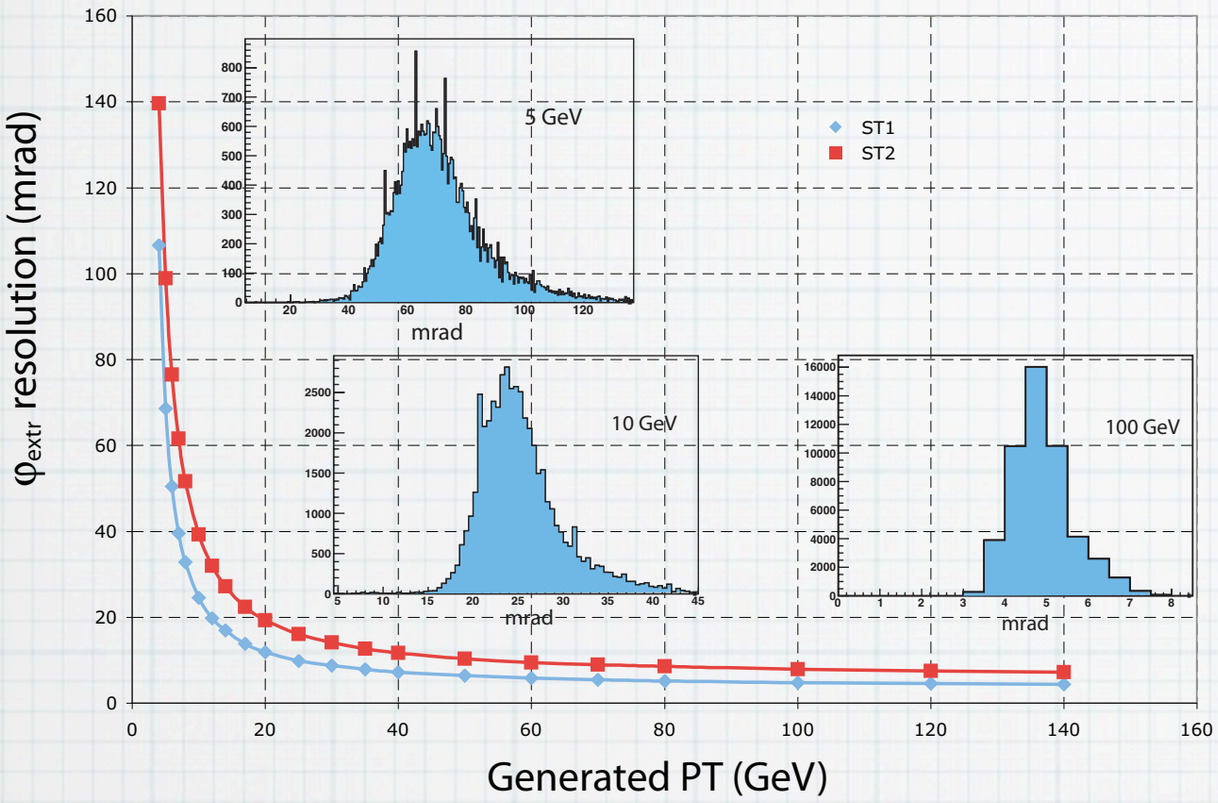
Estimation of muon hit position in the tracker



$$\varphi_{EXT} = \varphi_{\mu} - (m\varphi_B + q)$$

Matched primitives are extrapolated using the linear relationship between the φ deviation (φ_{μ} - φ_{Tk}) and the bending angle of the muon primitive φ_B

φ search windows



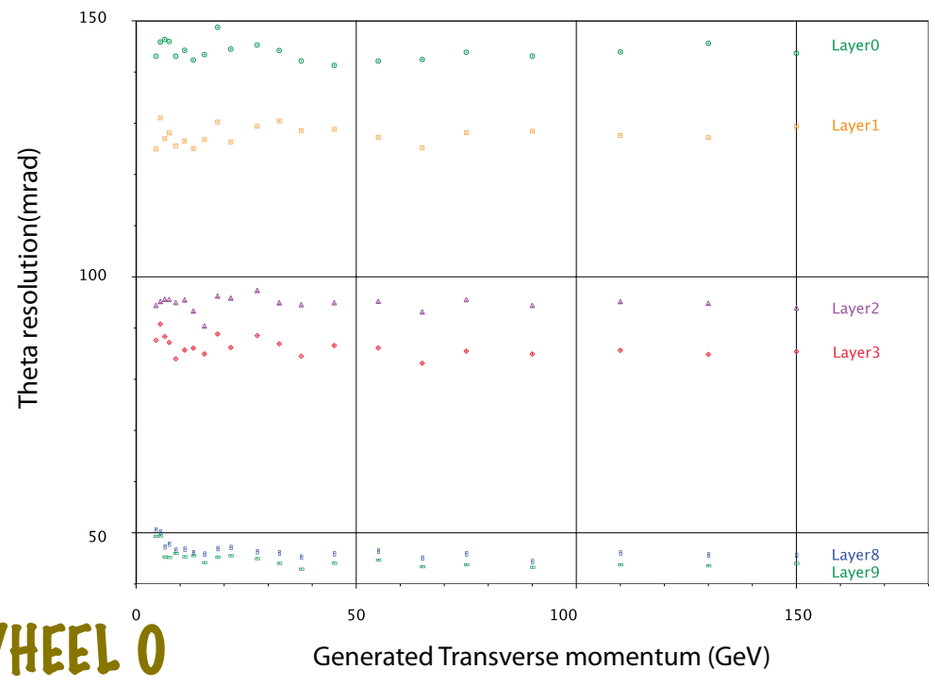
The **resolutions** of DT Trigger Primitives parameters are **dominated by multiple scattering**

The size of the matching window is given by error propagation on the extrapolation function

$$\sigma_{extr} = \sqrt{\sigma_{\varphi}^2 + m^2 \sigma_{\varphi_B}^2}$$

N.B resolution of uncorrelated φ primitives set to 10 GeV values

θ search windows



Resolution dominated by the uncertainty on z-vertex position of the collision

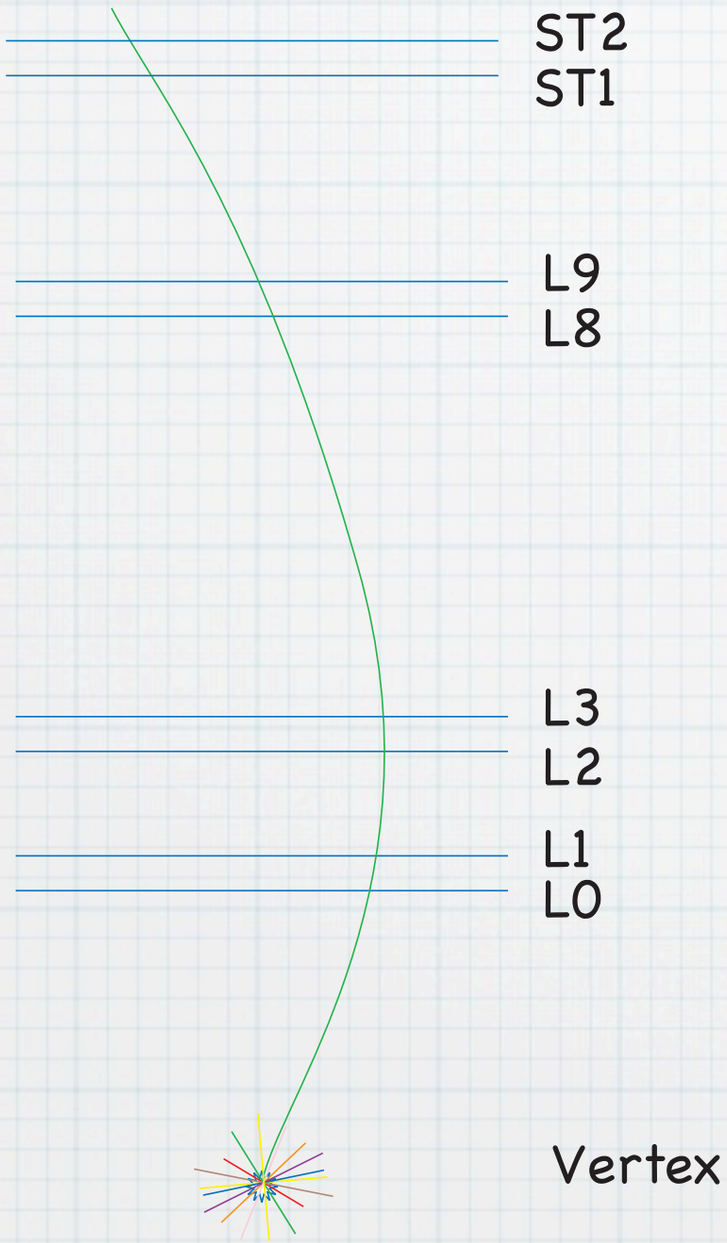
The size of the matching window is

- independent of momentum
- largely dependent on tracker layer
- slightly dependent on barrel wheel

N.B resolution of θ missing primitives set to half chamber

Muon transverse momentum estimation

Circle through three points



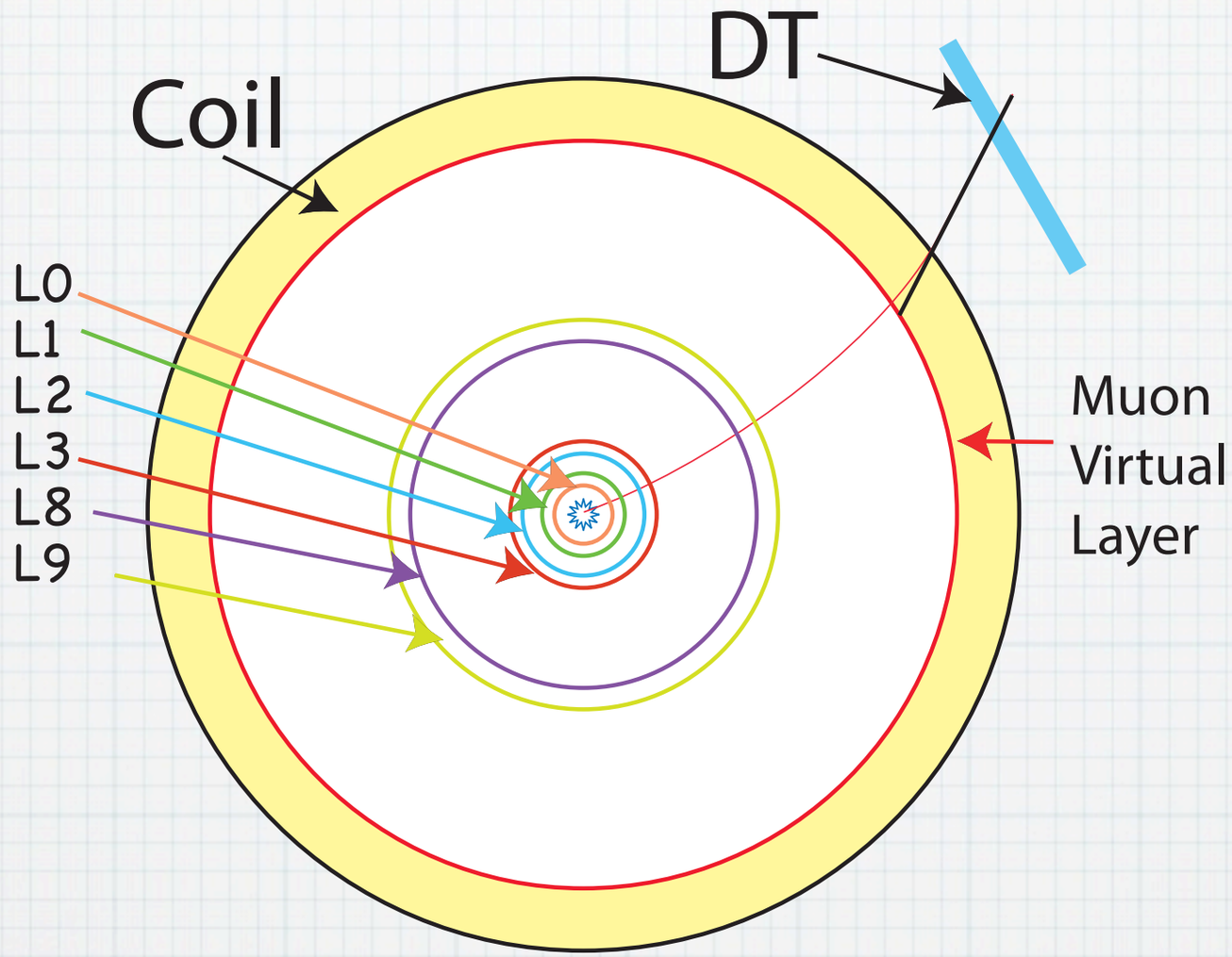
Several possibilities investigated

- Combinations of muon and two stubs in inner layers (L0,L1,L2 or L3) (worst case)
- Combinations of muon and two stubs in any tracker layer
- Combinations of muon and two tracklets in any Superlayer
- Association of a DT muon to a L1_track

Combinations conventionally coded as Mu-x-y

Mu = ST1 or ST2 on Virtual Muon Layer
x = Stub or Tracklet
y = Stub or Tracklet

Momentum estimation using DT primitives



In order to use the muon trigger coordinates to estimate momentum the DT primitive is linearly extrapolated to the virtual layer defined by the coil internal boundary surface

Only way for the circle assumption to be (almost) true

p_T evaluation algorithms

Combinatorics is controlled allowing no multiplicity

- Only the highest rank muon primitive is considered
- In each tracker layer/superlayer only the stub/tracklet/L1_track closest to the extrapolated position is considered

Each extrapolated muon originates several p_T evaluations

e.g. in the case of muon+2 stubs in the inner layers there are 6 combinations (Mu-L3-L2, Mu-L3-L1, Mu-L3-L0, Mu-L2-L1, Mu-L2-L0, Mu-L1-L0) each one providing a p_T

- Different algorithms were tried for final p_T assignment: priority encoding, majority, average

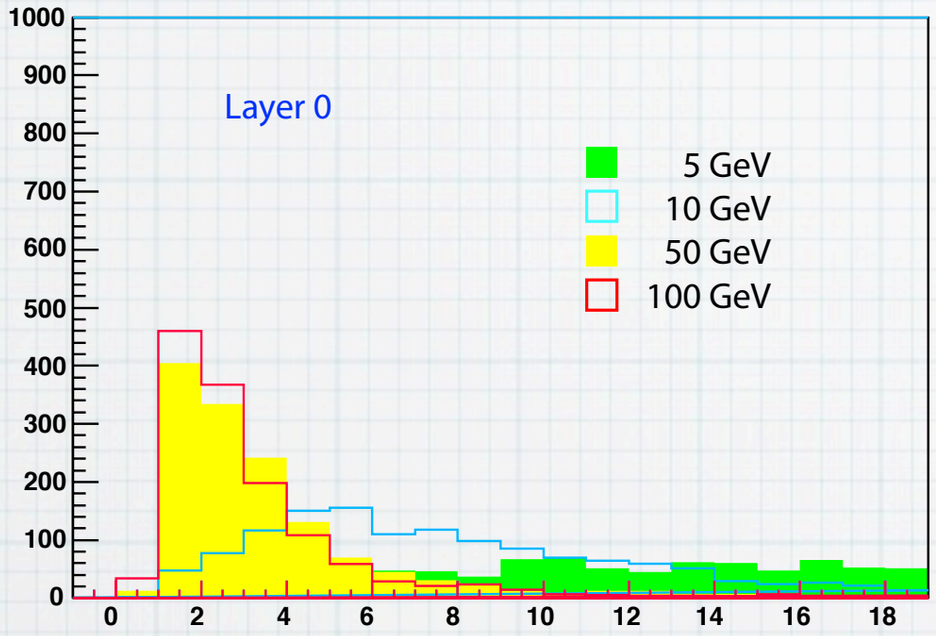
Several thresholds on different objects investigated

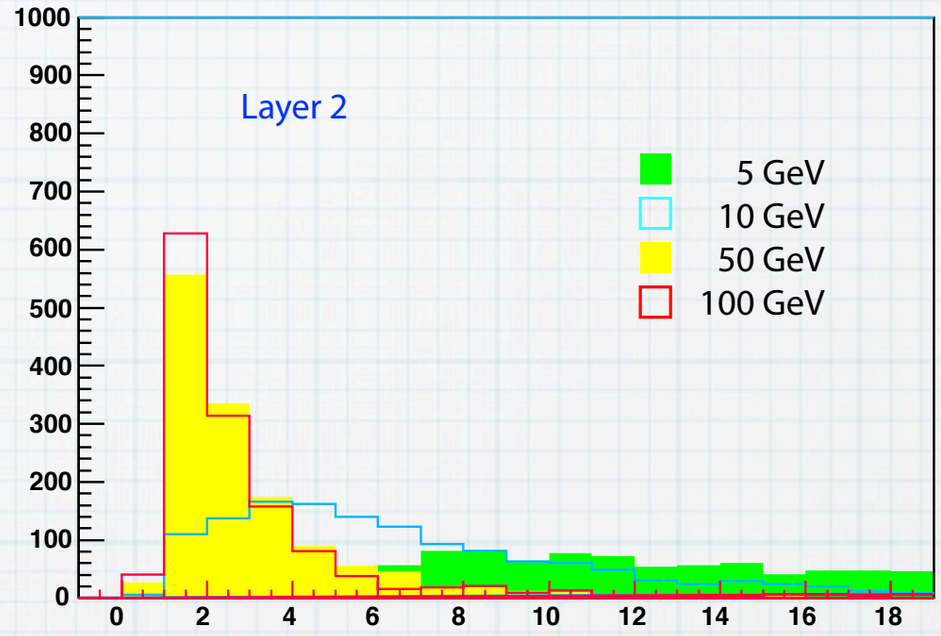
- A combination of muon + 2 stubs (or tracklets) is accepted only if its $p_T > 4$ GeV
- Different stubs threshold: $p_T > 2$ GeV and $p_T > 5$ GeV
- Different tracklets threshold: $p_T > 2$ GeV, $p_T > 5$ GeV and $p_T > 10$ GeV

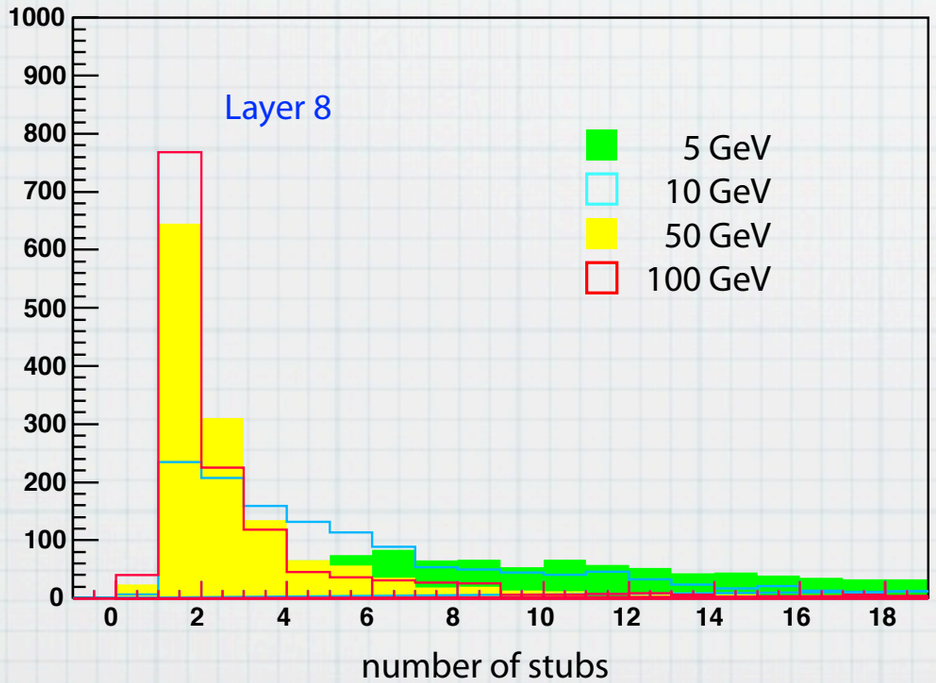
p_T bins are defined like in the current hardware and p_T thresholds are chosen at 95% efficiency for $p_T \geq$ threshold without pile-up

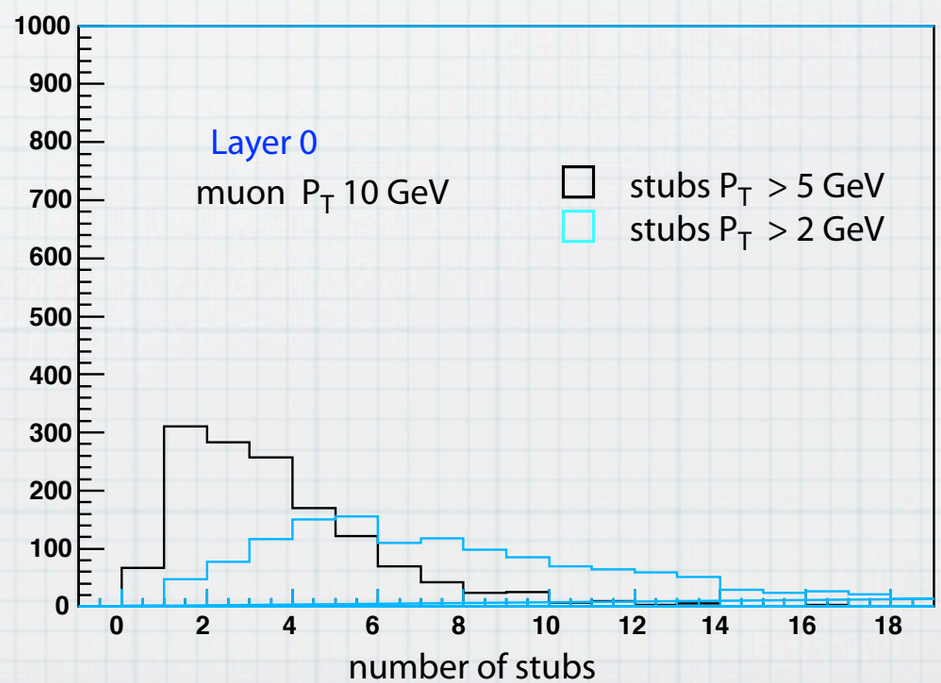
Pile-up 200 Stubs occupancy

Stub multiplicity in the extrapolation window may be very high. Some occupancy reduction is obtained using a tighter cut in stubs p_T



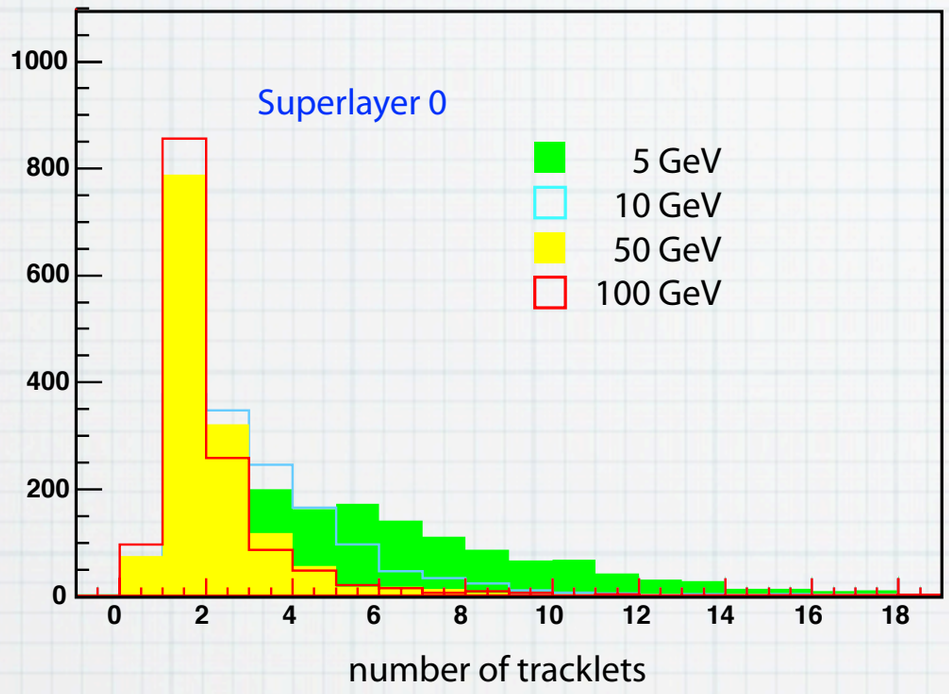


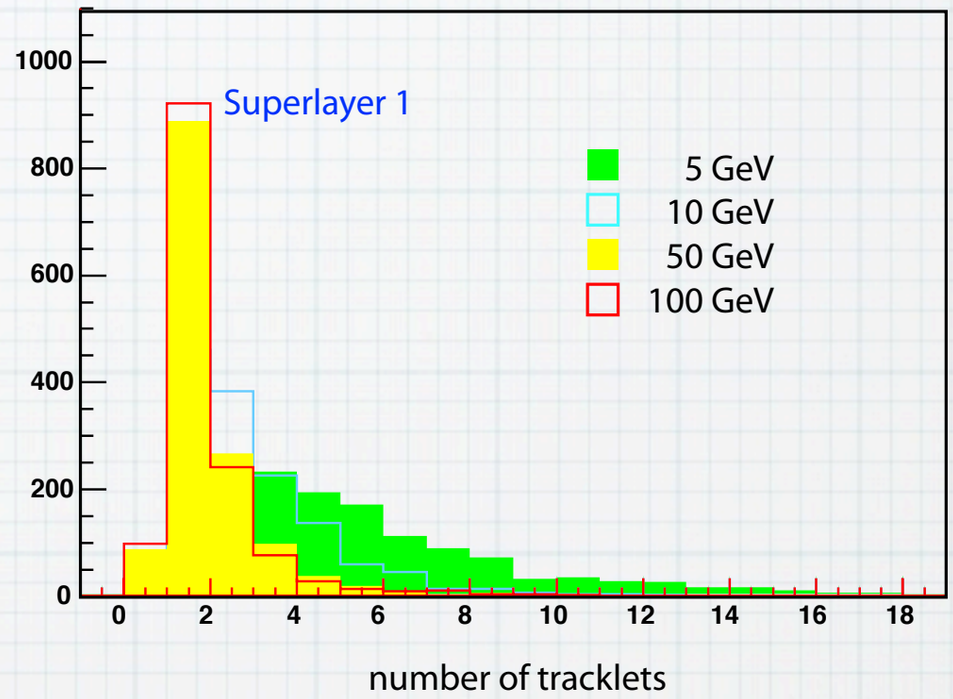


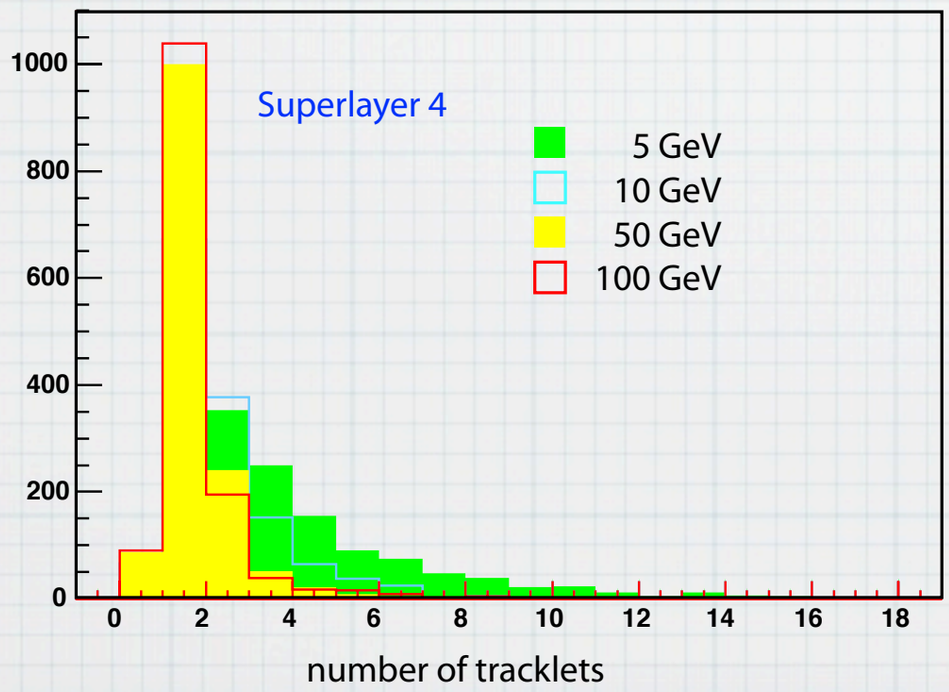


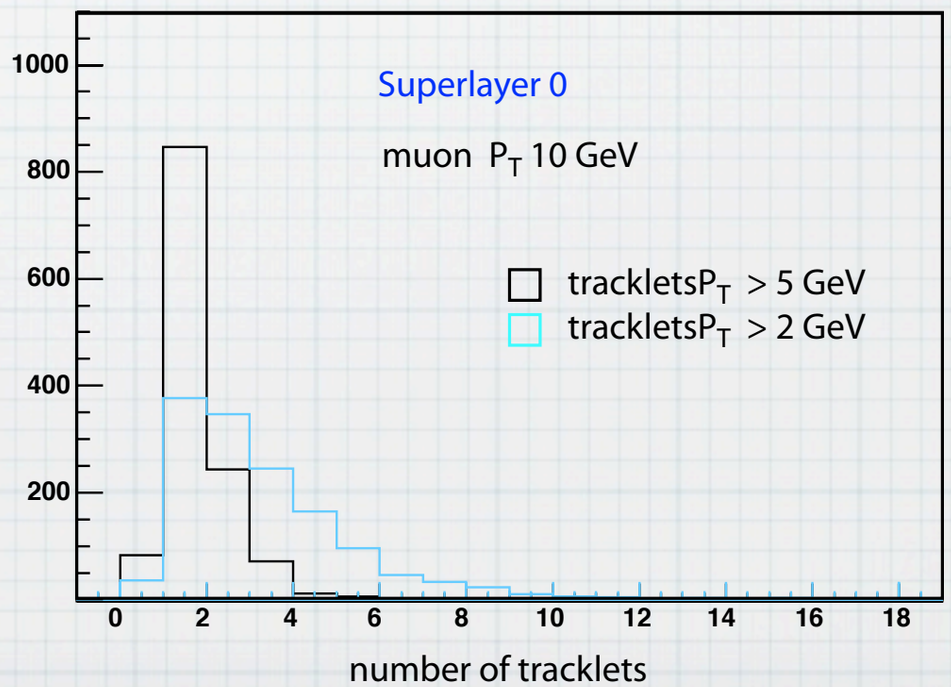
Pile-up 200 Tracklets occupancy

Tracklets multiplicity in the extrapolation window is much lower than stubs multiplicity
Tighter cuts in tracklets p_T improves substantially the occupancy









Algorithms for p_T assignment

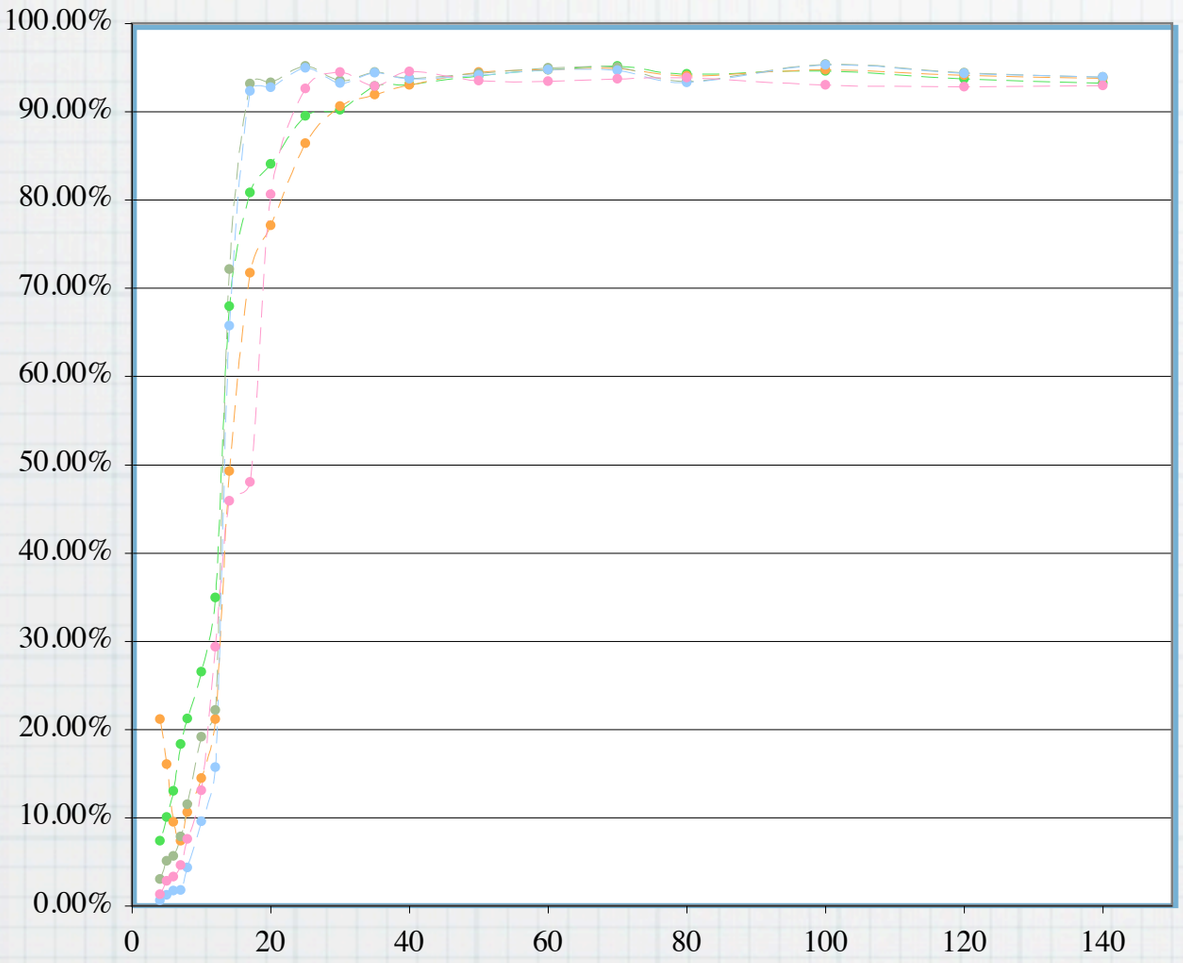
1. Priority encoding
2. Average of available MU-x-y p_T determinations
3. Majority of available MU-x-y p_T determinations
4. Mixedmode: a mixture of Majority and Average with p_T matching

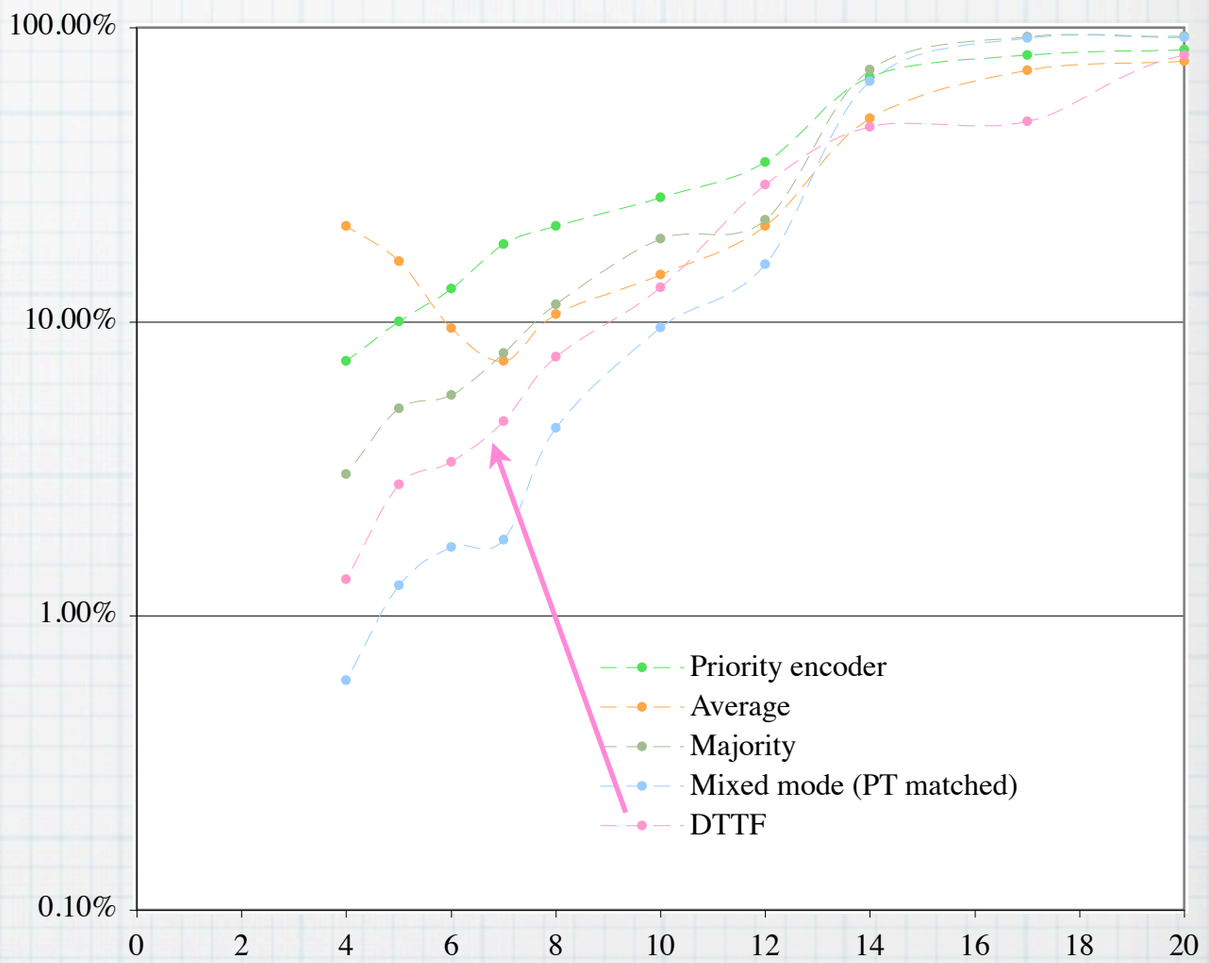
- every Mu-x-y p_T determination is compared to the determination computed from the bending angle inside the DT chamber (low resolution)
- the Mu-x-y determination is kept only if there is a 3 sigma match
- the selected stubs are then checked for majority
- if the majority is weak (currently if it is equal to 1) the average of the matching p_T determinations is taken

Applied to all studied combinations of DT primitives with tracker objects

Turn on curves

Only inner layers with p_T Threshold 14 GeV and p_T stubs > 5GeV

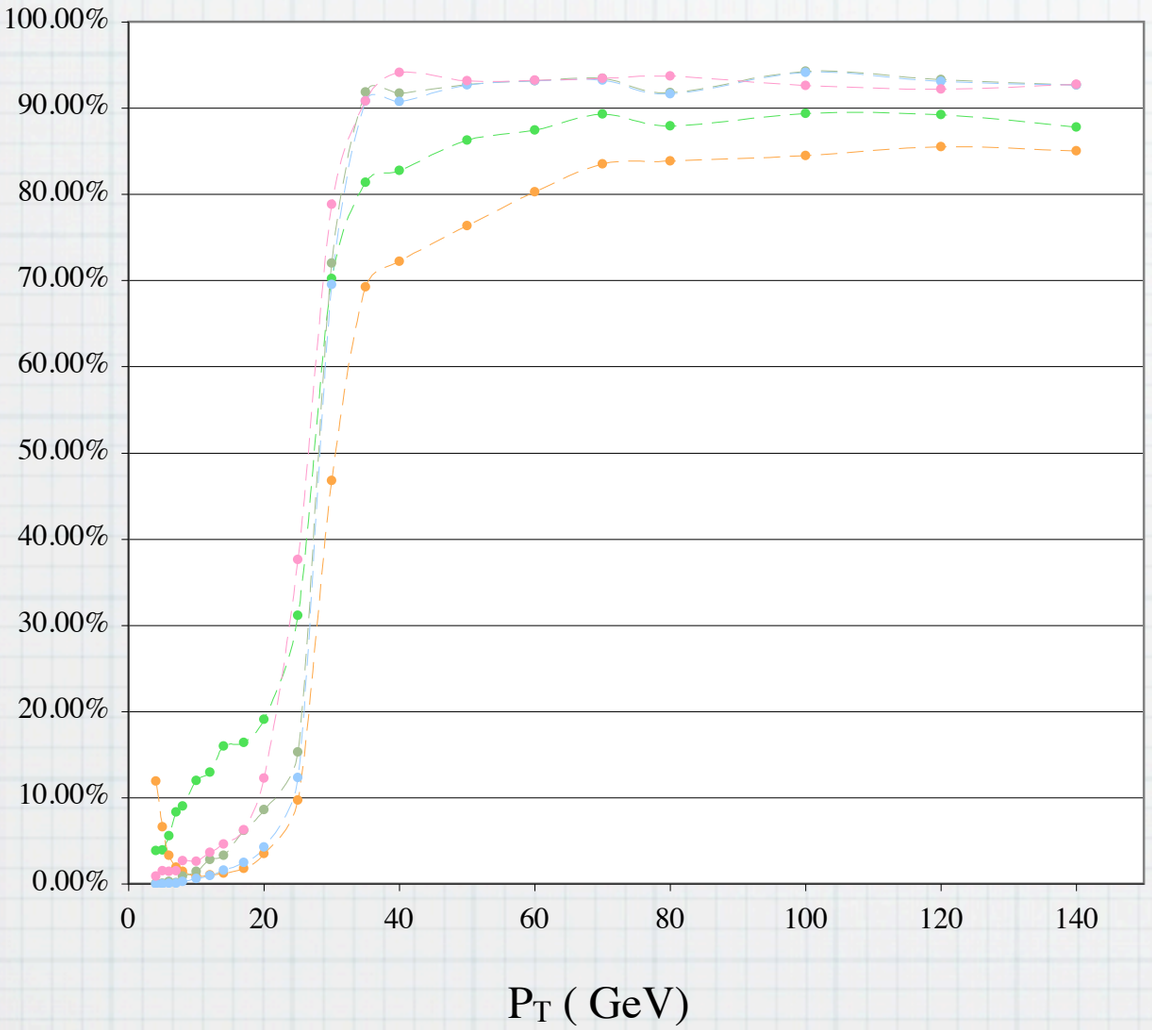


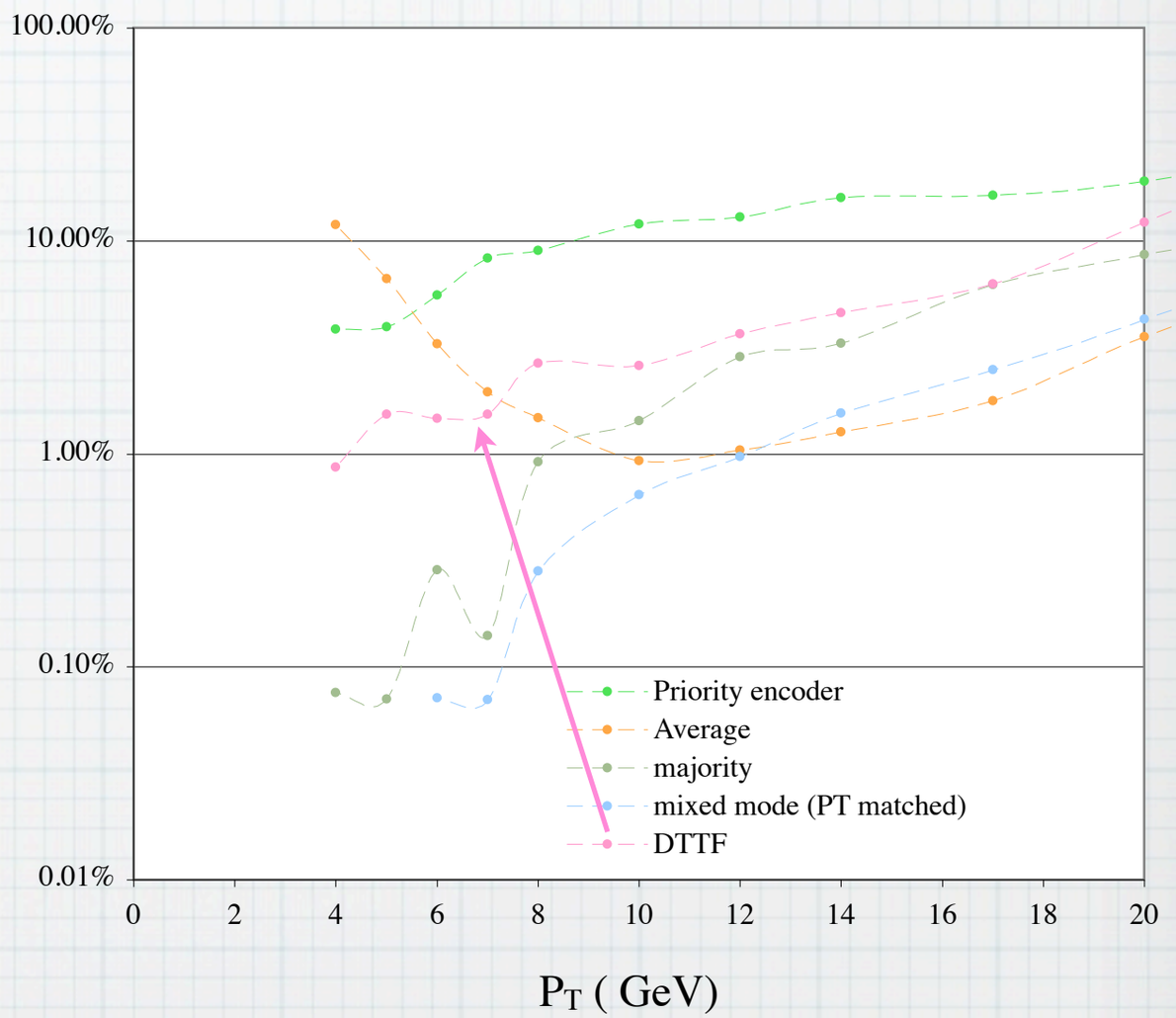


Muon + Tracker choice is better than DTTF only if Mixedmode algorithm is used: it is heavy but not impossible

Turn on curves

Only inner with p_T Threshold 30 GeV and p_T stubs > 5

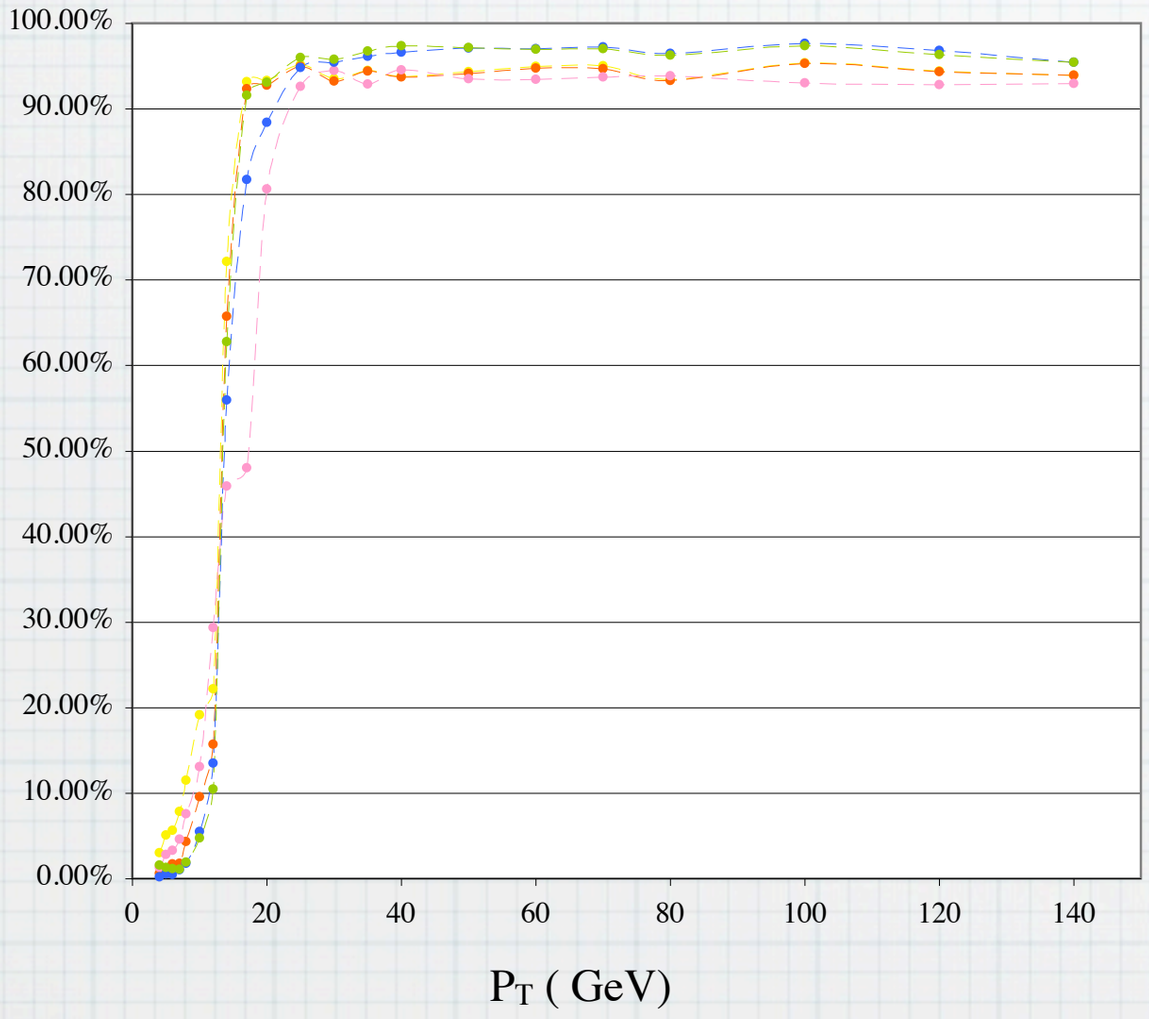


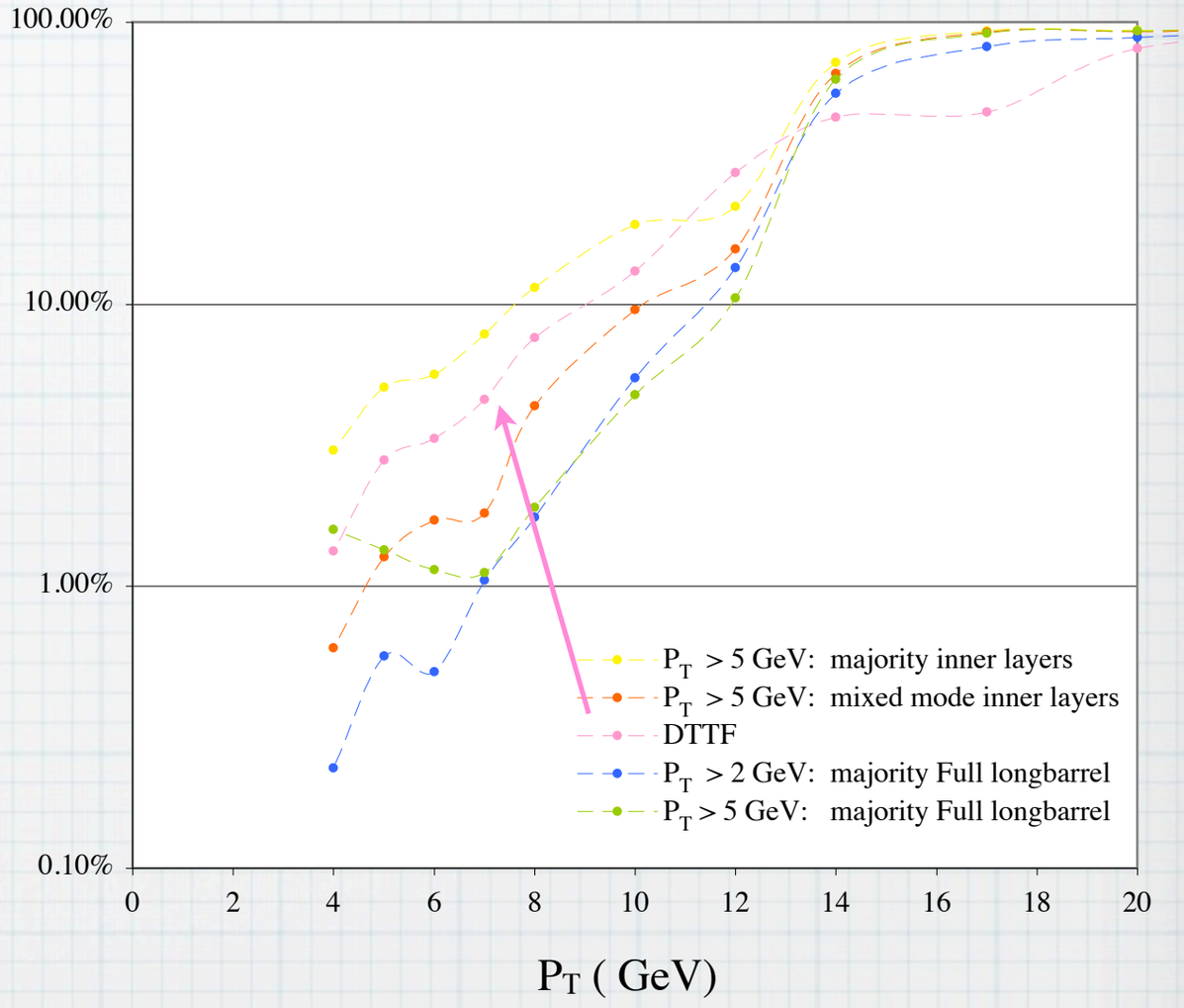


Increasing the p_T threshold the Muon + Tracker choice is better than DTTF also for **Majority** algorithm but efficiency is quite lower

Turn on curves

Full Longbarrel stubs with p_T Threshold 14 GeV



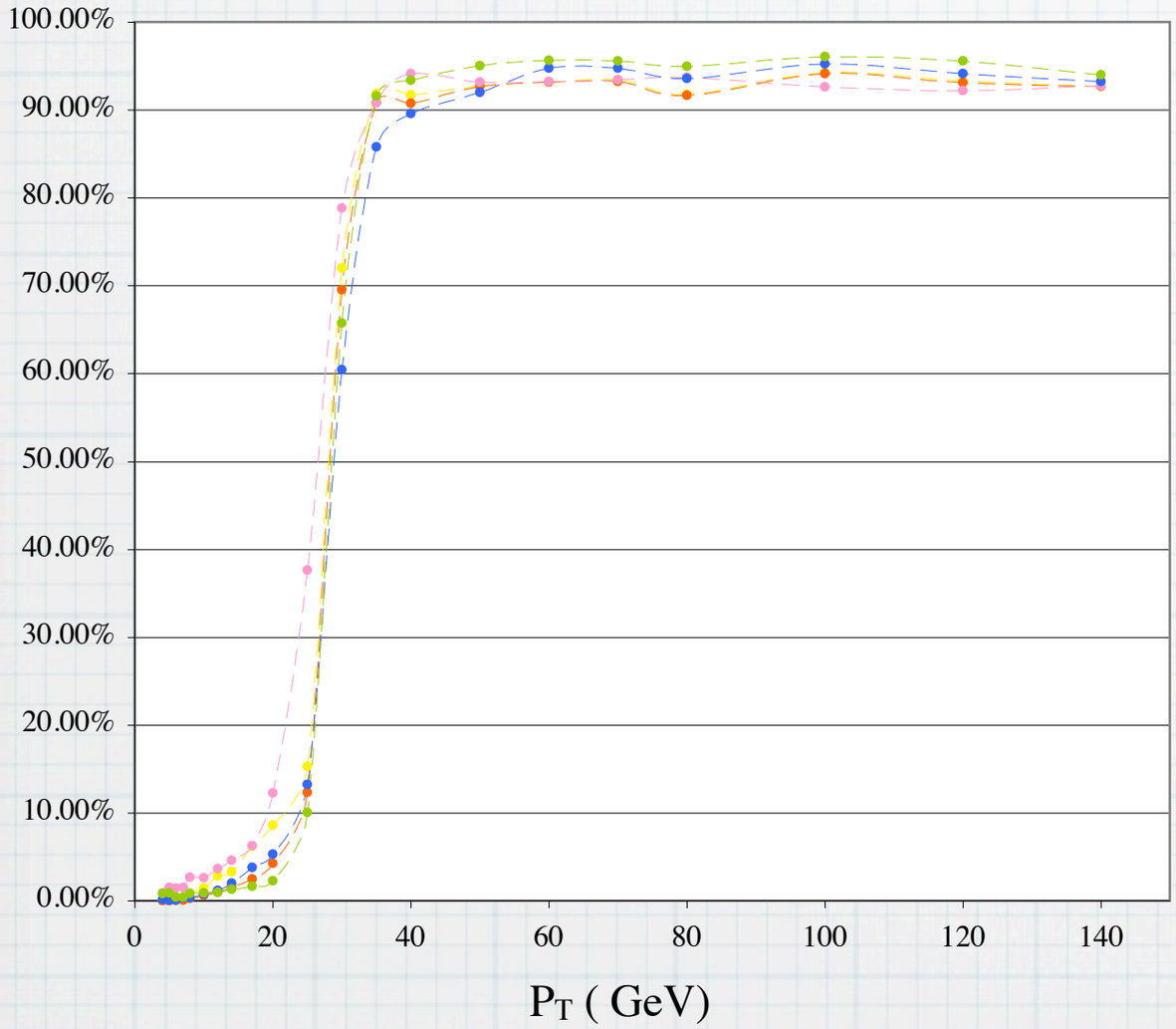


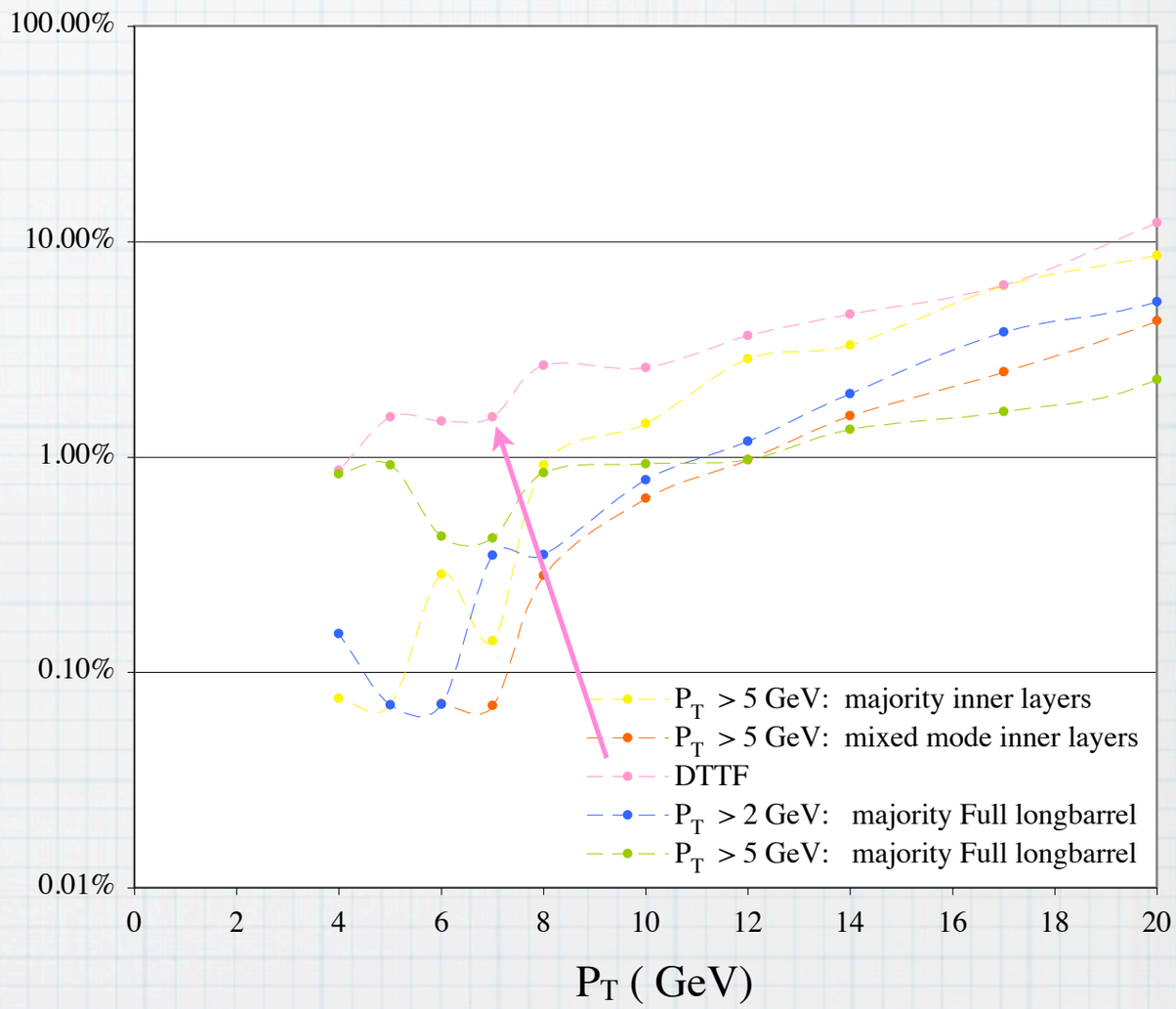
A simple Majority (15 available determinations) is better than DTTF

P_T match could be implemented to improve purity

Turn on curves

Full Longbarrel stubs with p_T Threshold 30 GeV

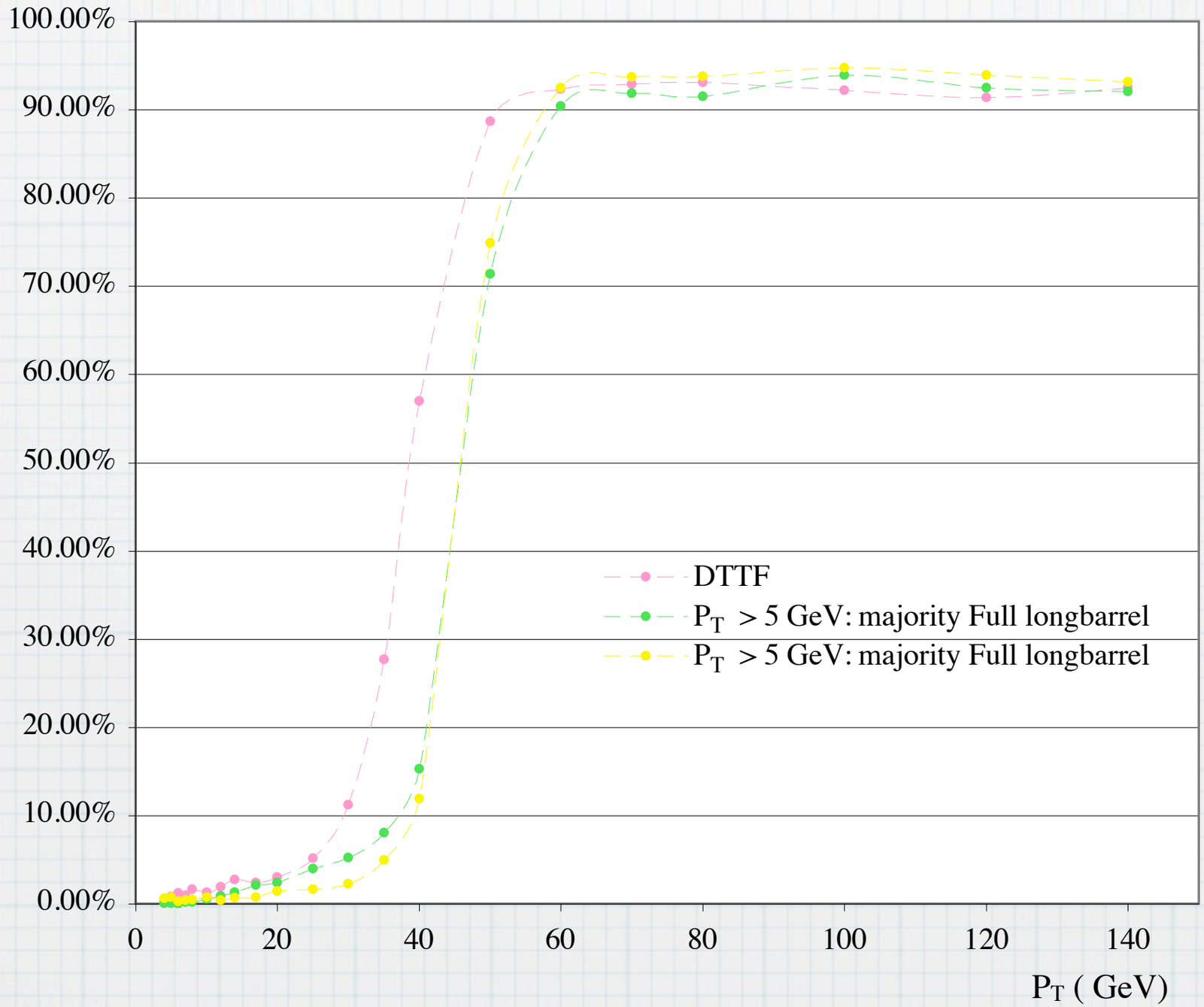




Efficiency, steepness, quality are always better than DTTF
Cut on p_T of stubs is practically not needed (big redundancy)

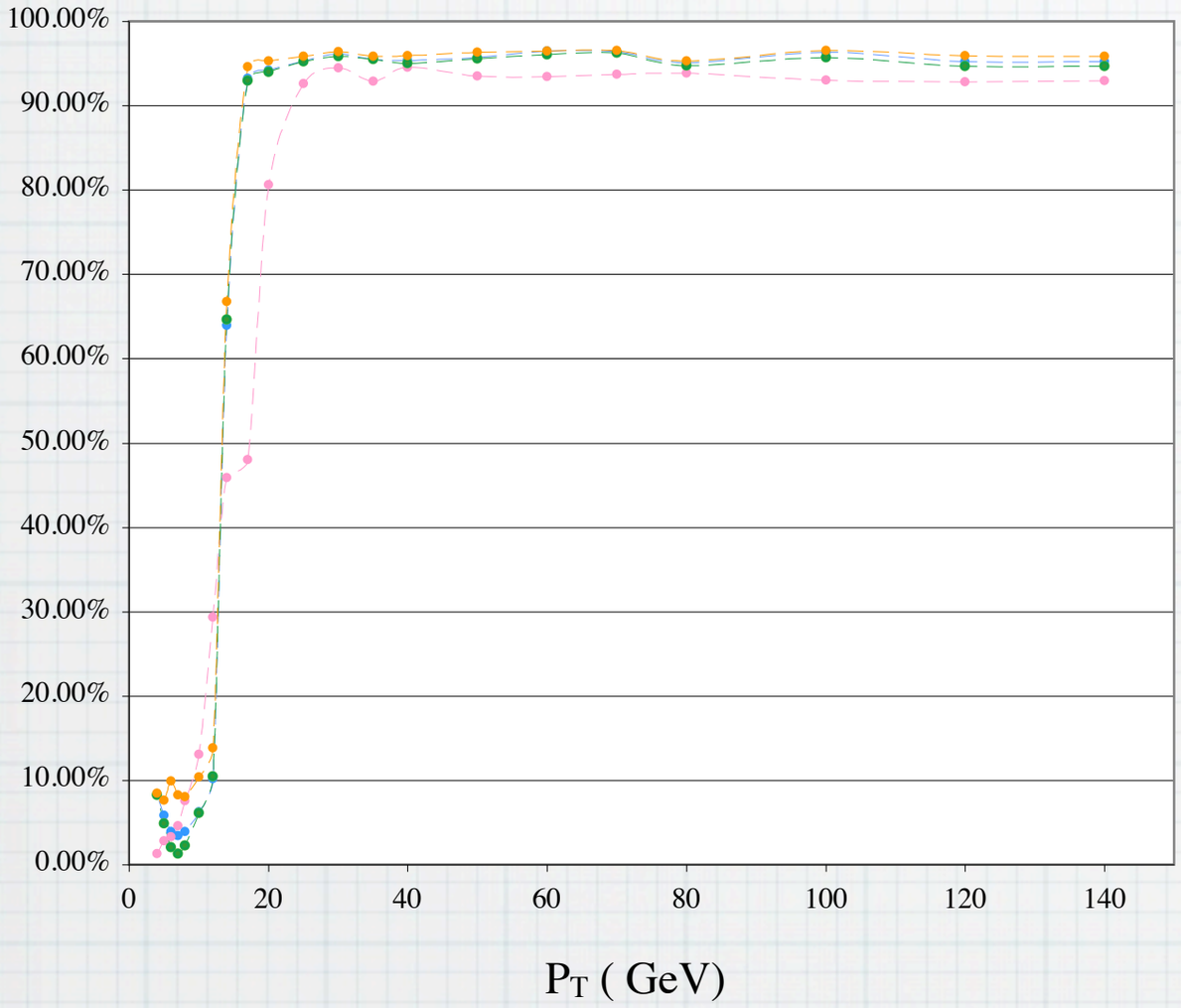
Turn on curves

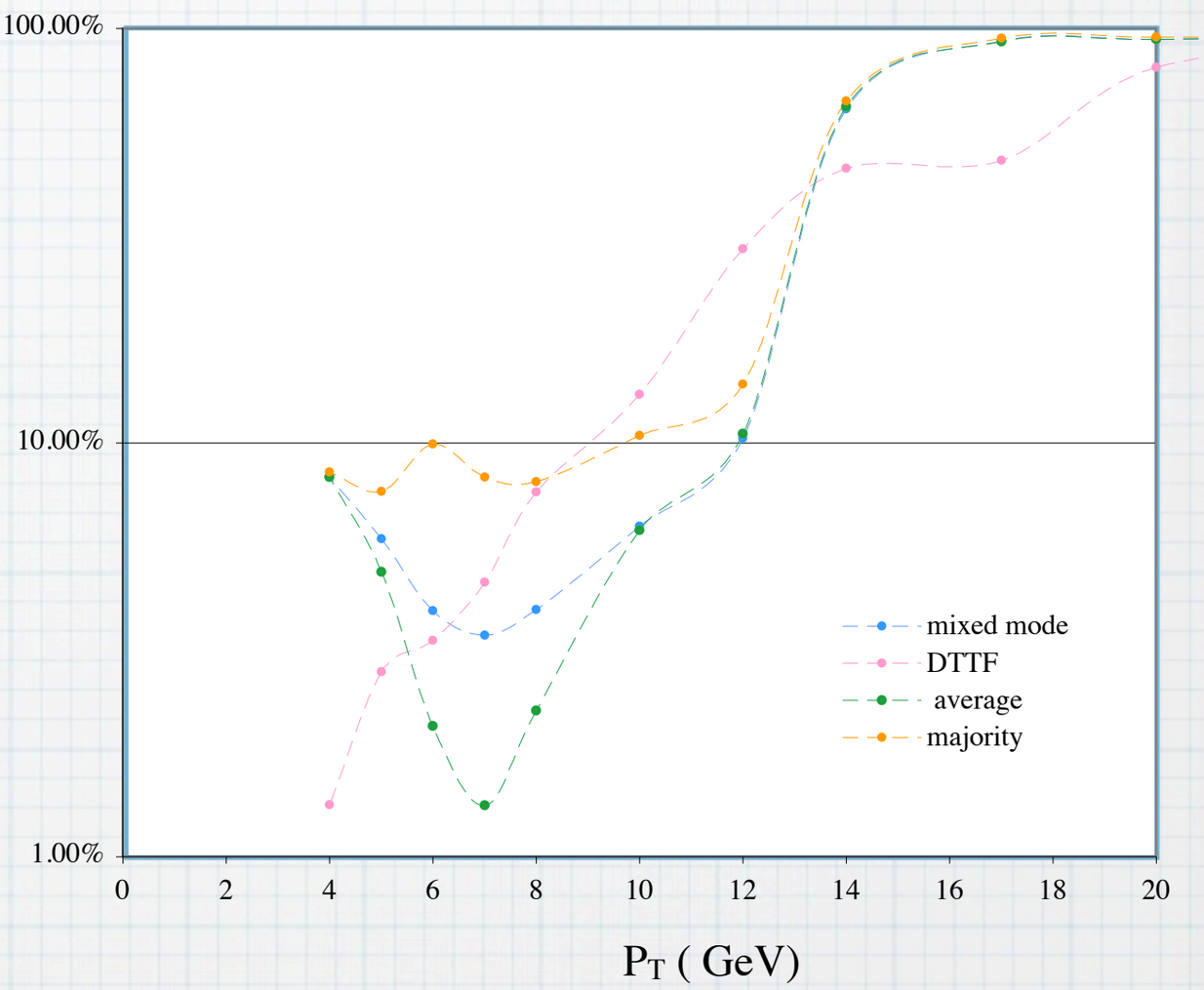
Full Longbarrel stubs with p_T Threshold 50 GeV



Turn on curves

Full Longbarrel with p_T Threshold 14 GeV and Tracklets p_T > 5 GeV

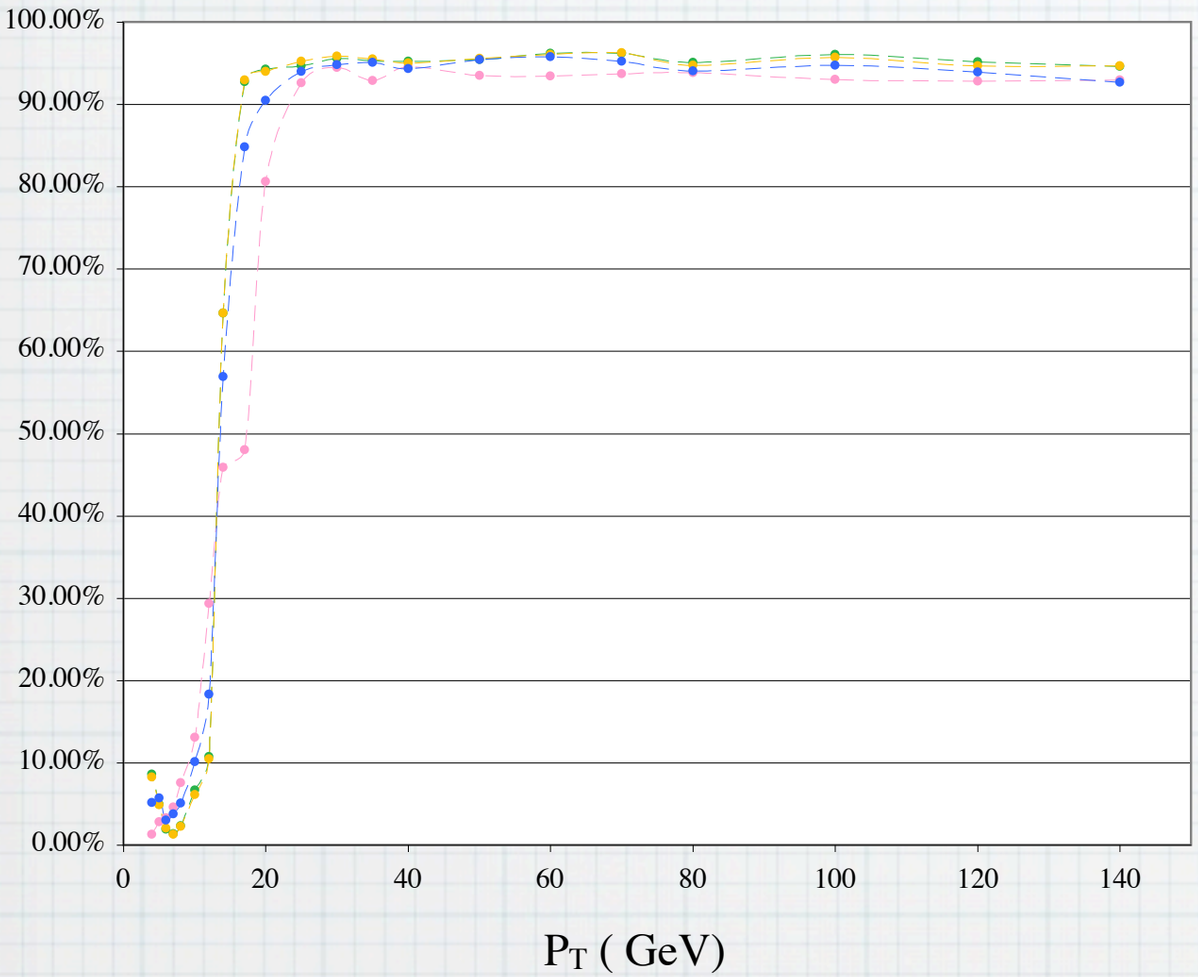


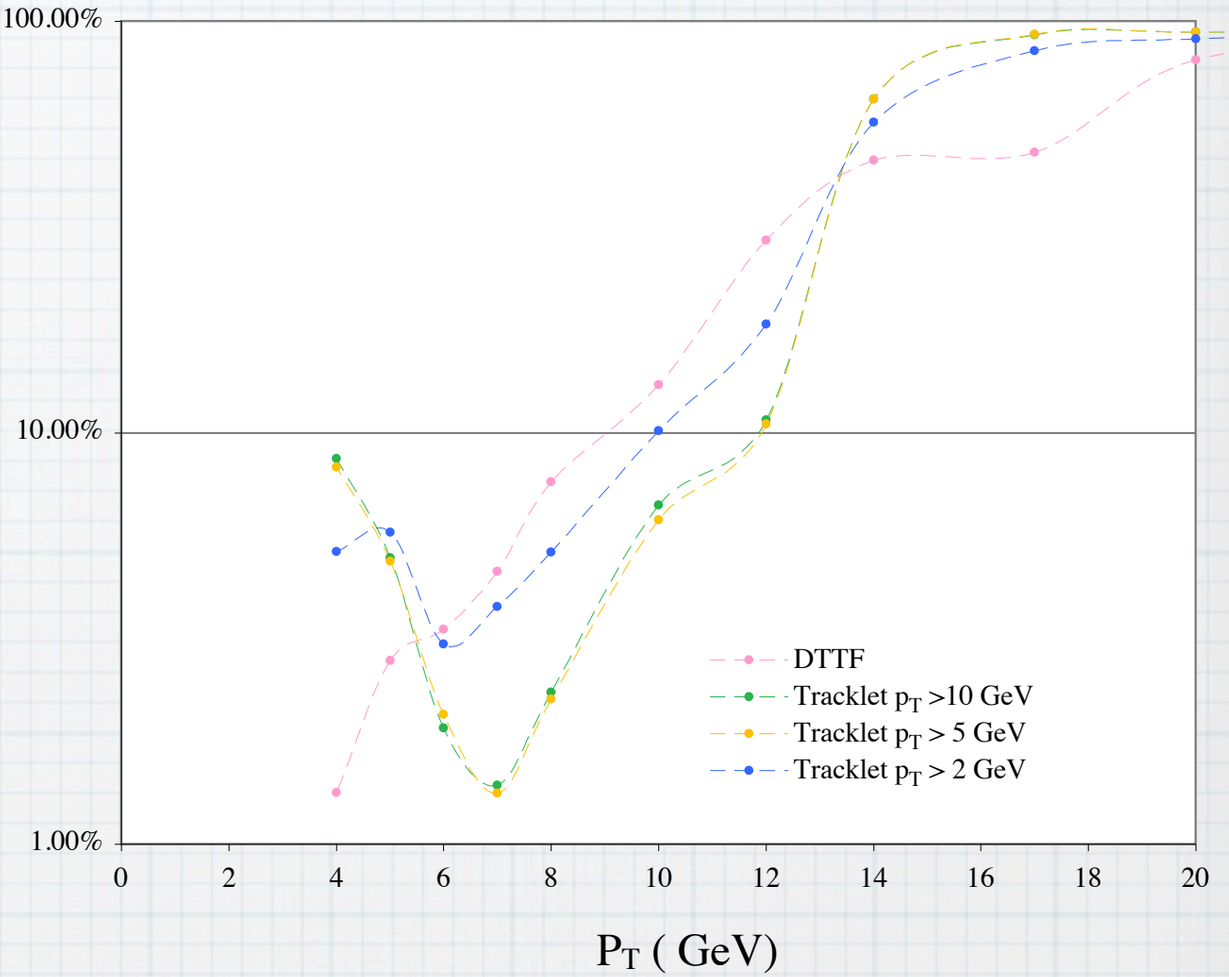


The best expected algorithm is Average since at most 3 p_T evaluations could be available so Majority is weak.

Turn on curves

Full Longbarrel Average with p_T Threshold 14 GeV and Tracklets

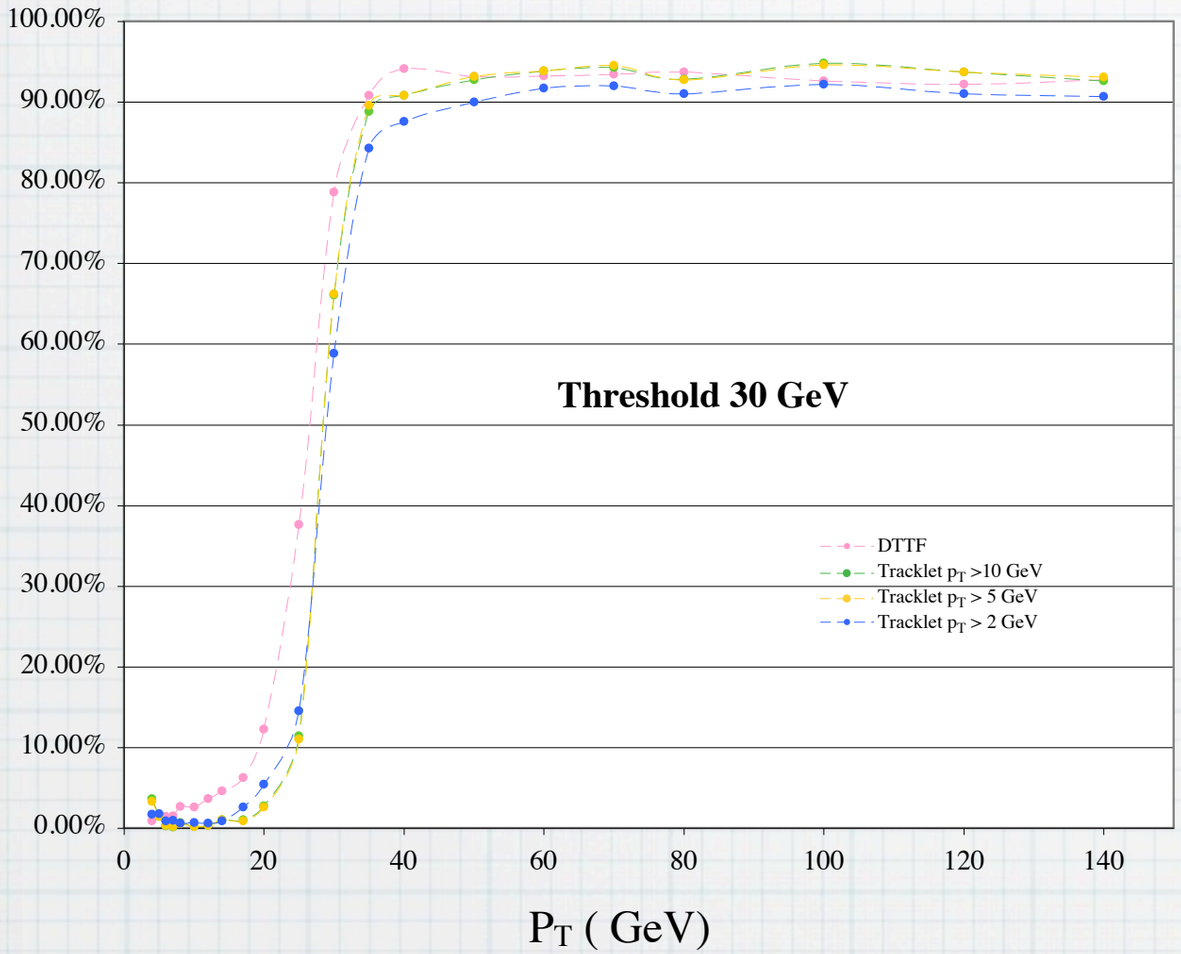


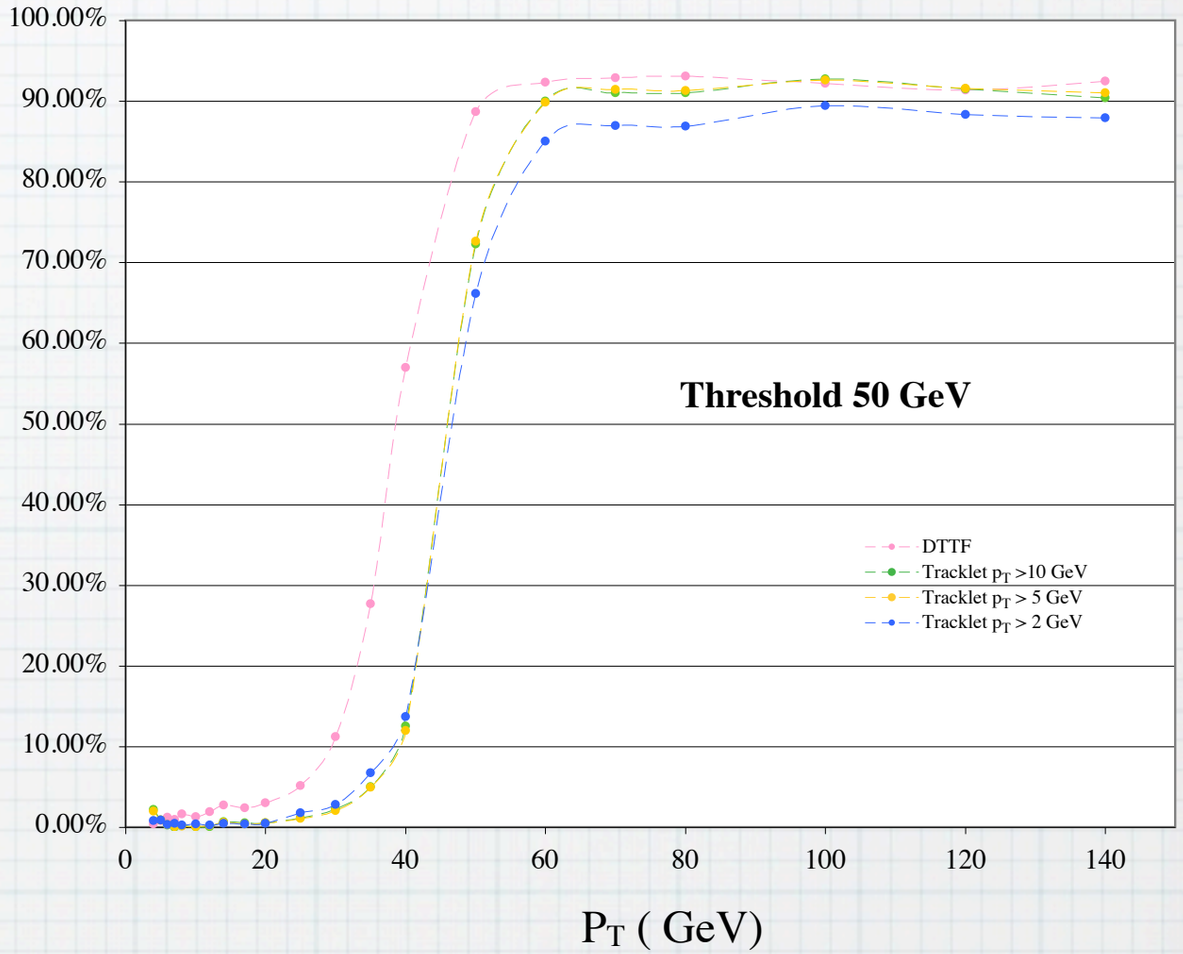


Cuts on tracklets p_T higher than 5 GeV are unuseful
Improvement is expected allowing p_T match.

Turn on curves

Full Longbarrel with p_T Thresholds 30-50 GeV and Tracklets





Curves are steeper than DTTF
Efficiency is lower than DTTF (evident with tracklet p_T > 2 GeV cut) and worsening while threshold increases (poor redundancy)

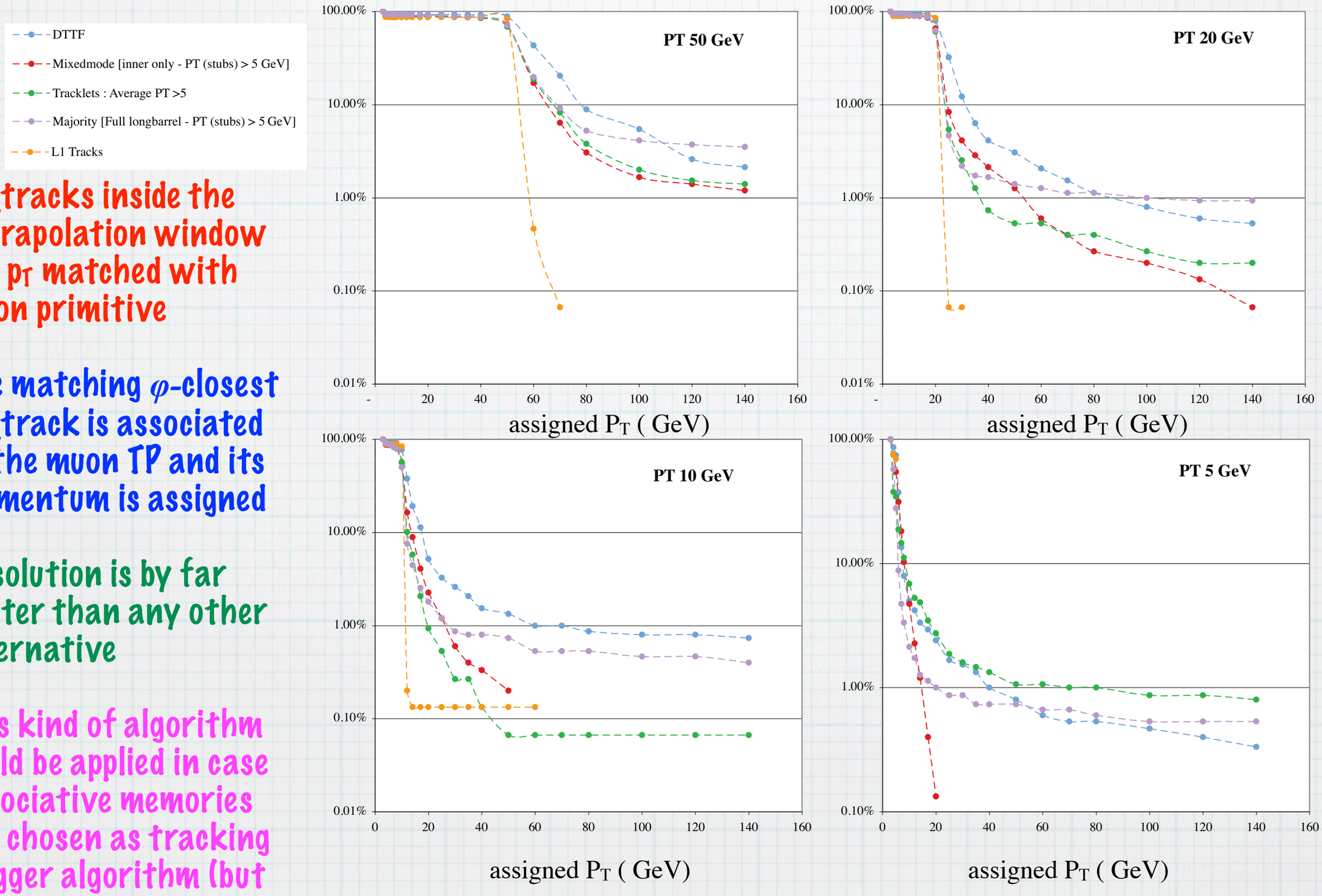
Matching with L1_tracks

L1_tracks inside the extrapolation window are p_T matched with muon primitive

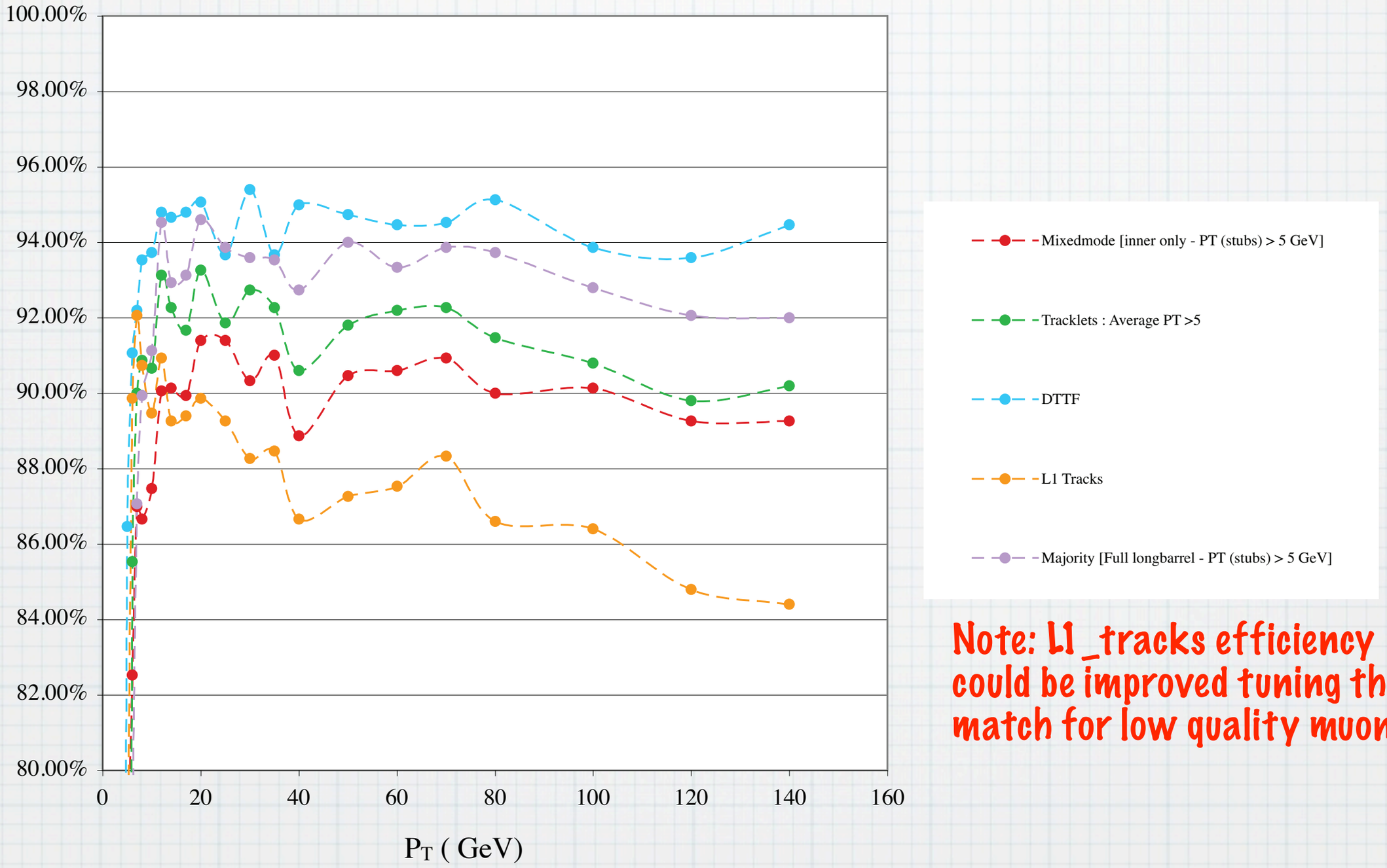
The matching φ-closest L1_track is associated to the muon TP and its momentum is assigned

Resolution is by far better than any other alternative

This kind of algorithm could be applied in case associative memories are chosen as tracking trigger algorithm (but resolution?)



Efficiencies

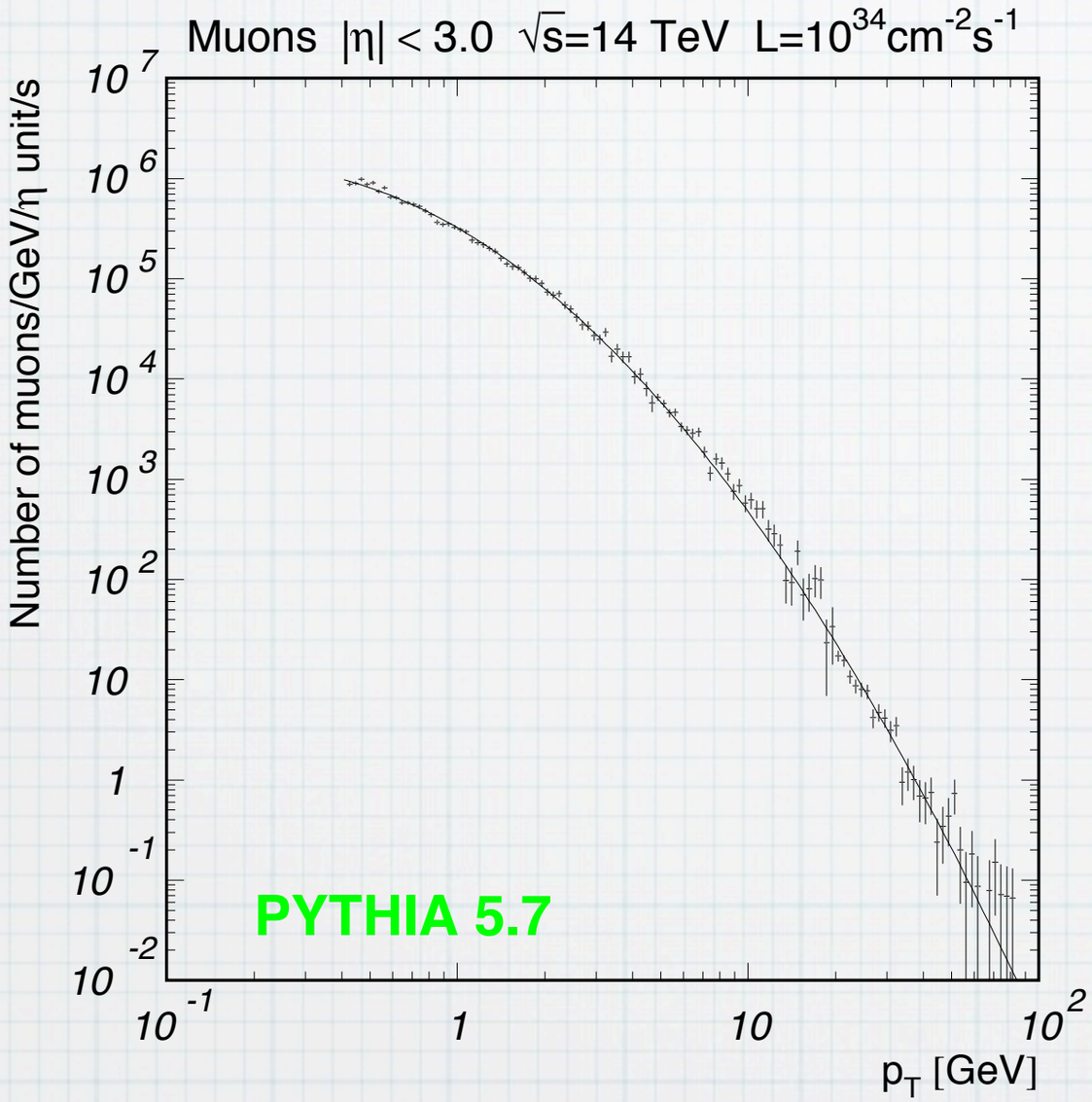


Note: L1 _tracks efficiency could be improved tuning the p_T match for low quality muon TPs

REDUNDANCY IS A KEY POINT

more information available means better resolution and/or efficiency

Rates



$$\frac{dN}{d\eta\, dp_t} = a\, \exp\Big[- \frac{(x-\mu)^2}{2\sigma^2}\Big]$$

$$x = \log_{10}\ p_t\ [\mathrm{GeV}]$$

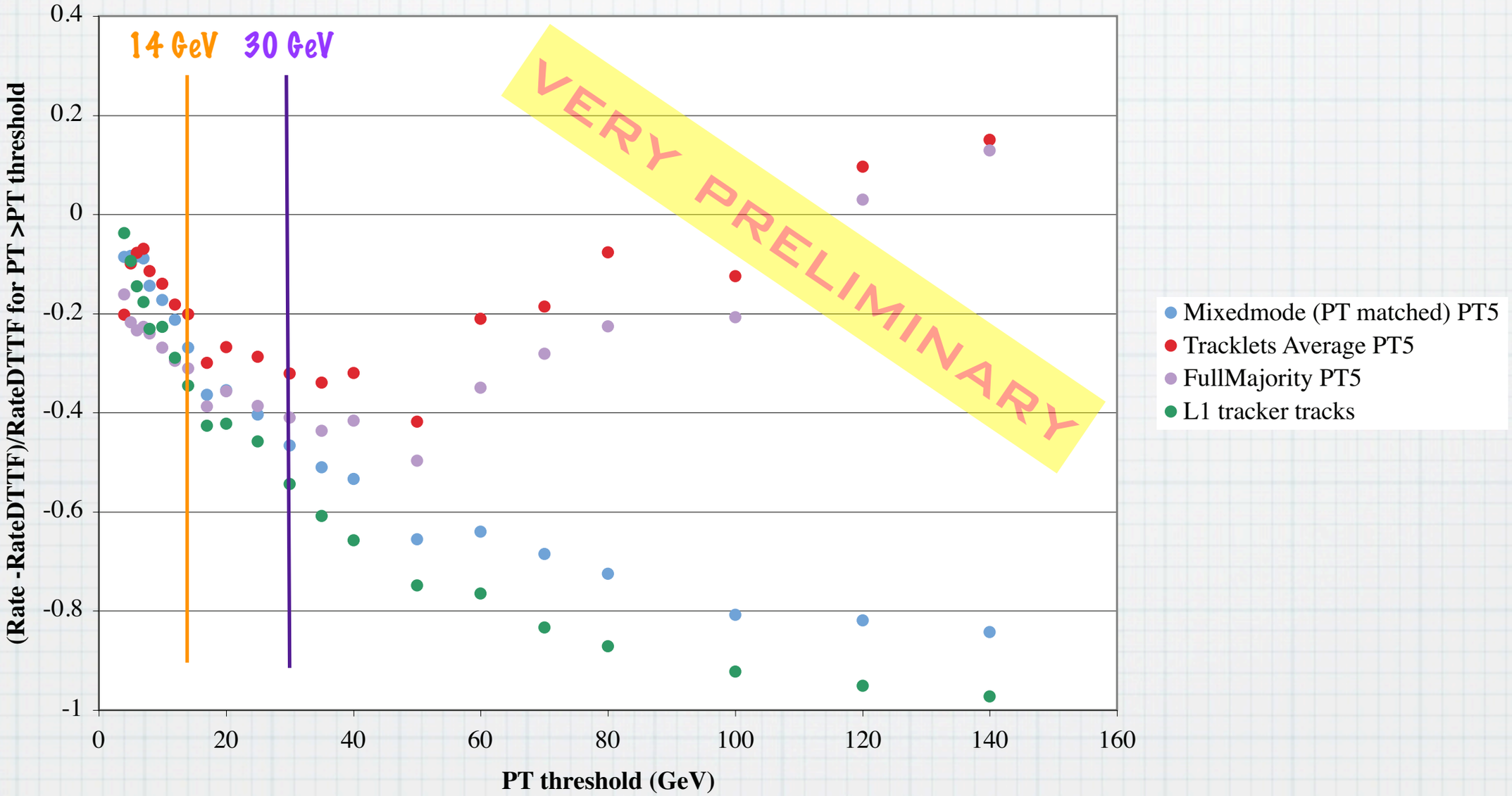
$$a = 1.3084 \cdot 10^6$$

$$\mu = -0.7250$$

$$\sigma = 0.4333$$

A first attempt to estimate the improvement in L1 muon rates with respect to DTTF was done by covoluting the minimum bias muon rate parameterization of CMS TN/95-150 with the p_T assignment frequencies for few algorithms

L1 Trigger rate difference w.r.t. DTTF



The statistics is rather low: big fluctuations in the tails especially for low p_T muons

Outlook

Still to do

- Optimization: fully exploit p_T matching
- Study of out of time trigger
- Study of in-time fake triggers
- More statistics

The code provides a framework offering a generic flow which can be adapted to

- Input from Track Finder or Global Muon tracks as seeds
- Interaction with other muon detectors (RPCs or scintillators or GEMs)
- Association with other tracker objects
- Association with other tracker layouts
- Other momentum assignment algorithms

Warnings

- Redundancy is a key point: more information is available from tracker and/or muon better are resolution and efficiency
- 1 MHz BW & 20 μs latency will dramatically change the muon perspectives: no need for large p_T improvement; room to move HLT algorithms (full standalone track determination); tracker information just limited to state muon isolation by means of extrapolation and track counting in a preset window