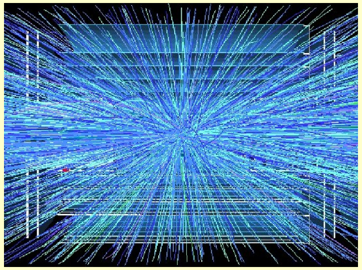
WIT2012 Workshop on Intelligent Trackers



A Self Seeded First Level Track Trigger for ATLAS

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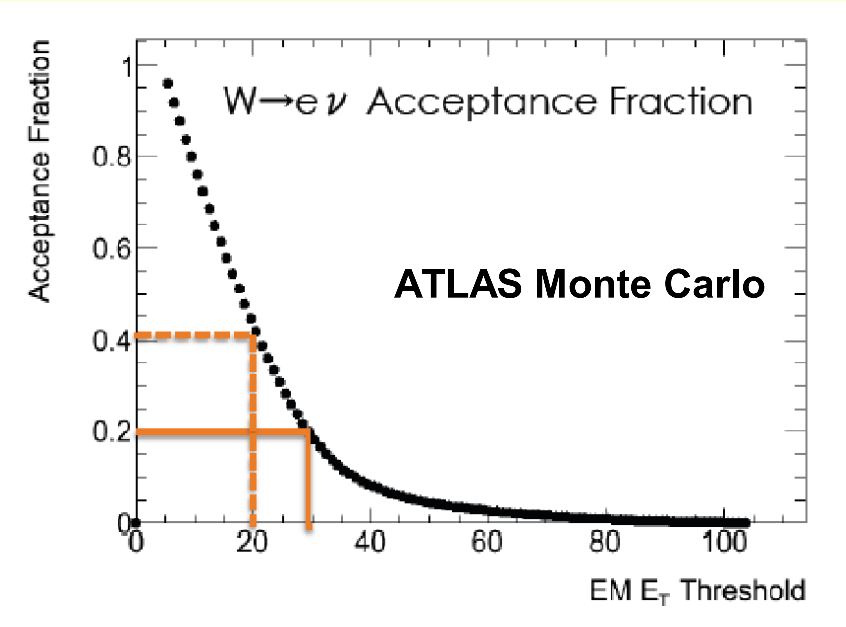
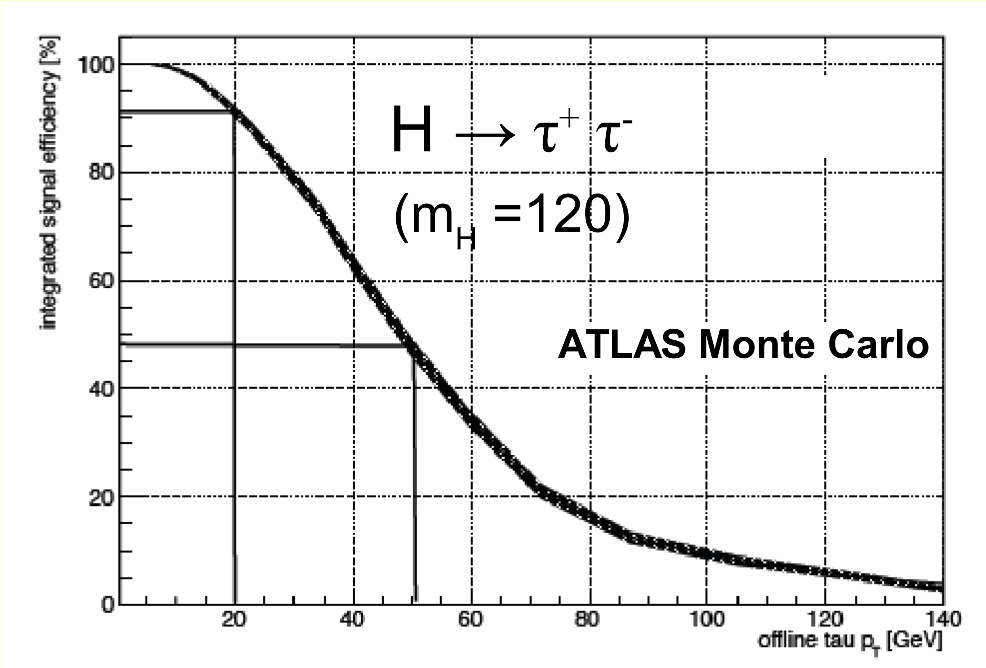
Motivation

- Today, no clear picture about full spectrum of physics analysis at Phase II (L=5·10^{34} cm^{-2} s^{-1} , Year>2022)
- Need to design a robust and flexible L1 Trigger system that can cope with the unexpected, i.e. with enough redundancy
- Many of the scenarios we can think of today involve objects at (or near) the **electroweak scale**

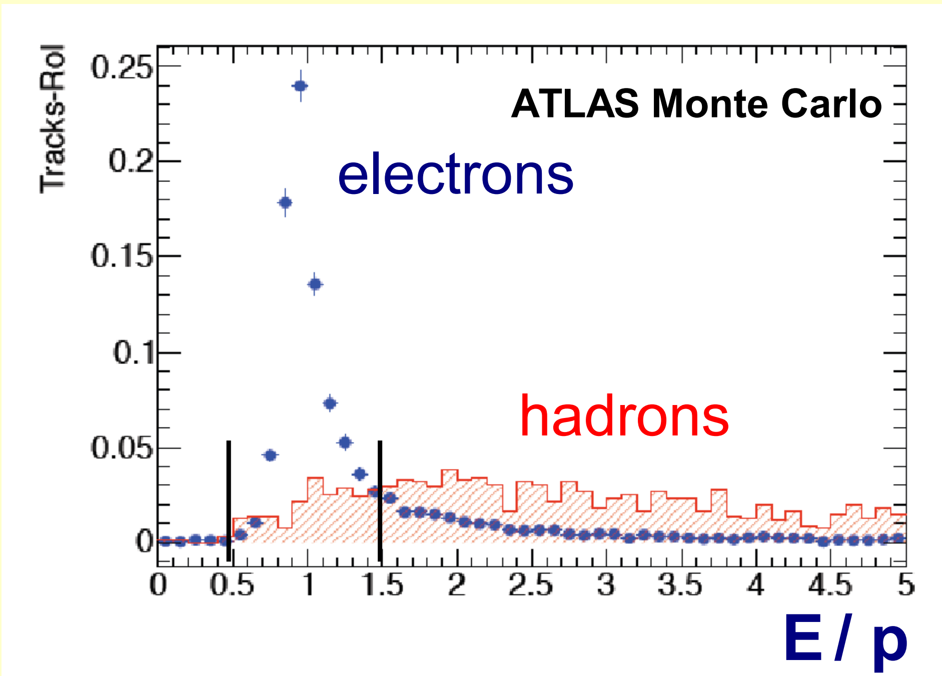


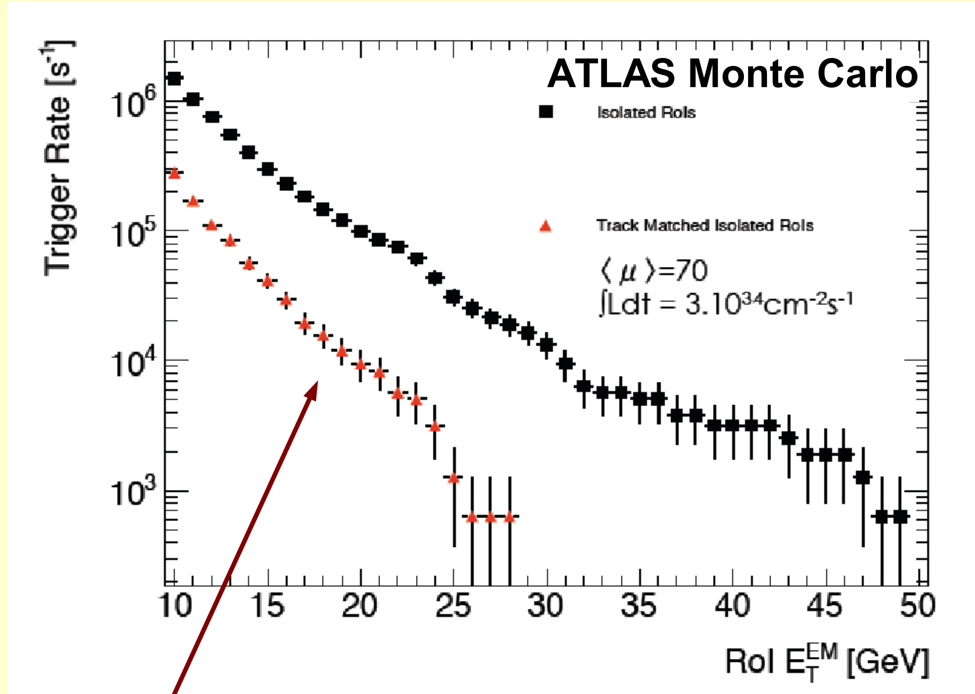


First studies show that track matching at L1 allow for **~20 GeV** object triggers (**e,μ, τ**)

Rate Reduction using Track Cluster Match

Using track-cluster matching in **E_T / p_T**, a rate reduction of up to a factor **~10** can be achieved





matched

Challenges of L1 Track Trigger

Challenges

$O(10^7)$ channels in strip detectors

$O(10^8)$ channels in pixel detectors

O(5000) central tracks per collision at LHC phase II

O(10) Tbit/s data in tracker central region

Simplifications → Data Reduction

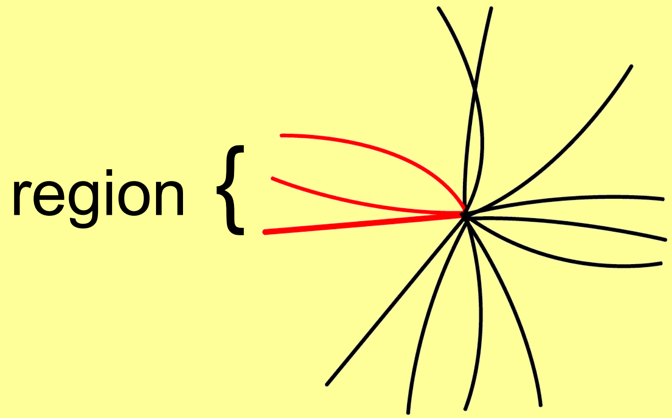
- **only (selected layers of) strip detectors**
- **reduce data rate by:**
  - **regional filtering → Region of Interest Track Trigger**
  - **kinematical filtering → Self Seeded Track Trigger**

Trigger Bandwidth Solutions

two baseline concepts for L1 Track Trigger in ATLAS:

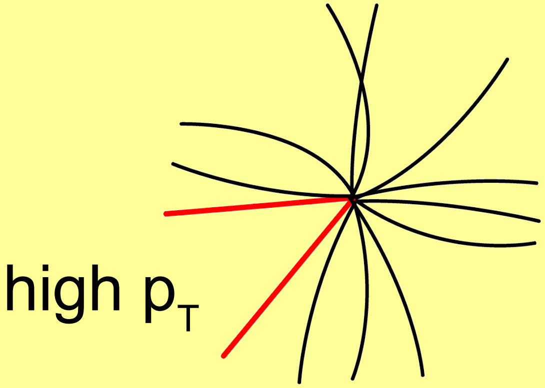
"Region of Interest"

- spatial cluster filter
- external trigger information (calo, muon, ...)
- new level L0 trigger required
- all tracks in regions



"Self Seeded Track Trigger"

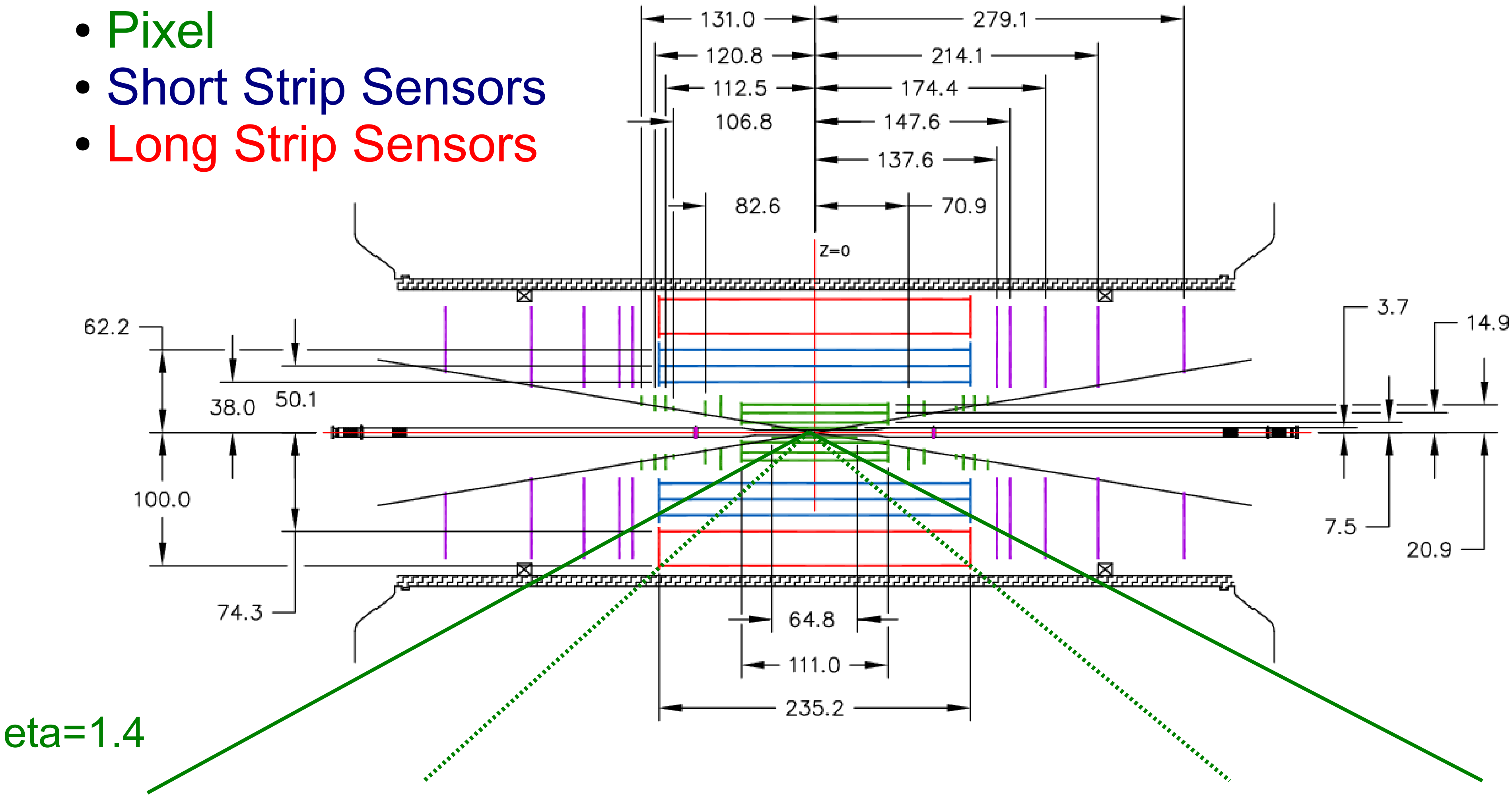
- momentum filter of clusters
- cluster size + local coincidence
- special HW design required
- all high p_T tracks



Double Frontend Buffer → talk D.Wardrope

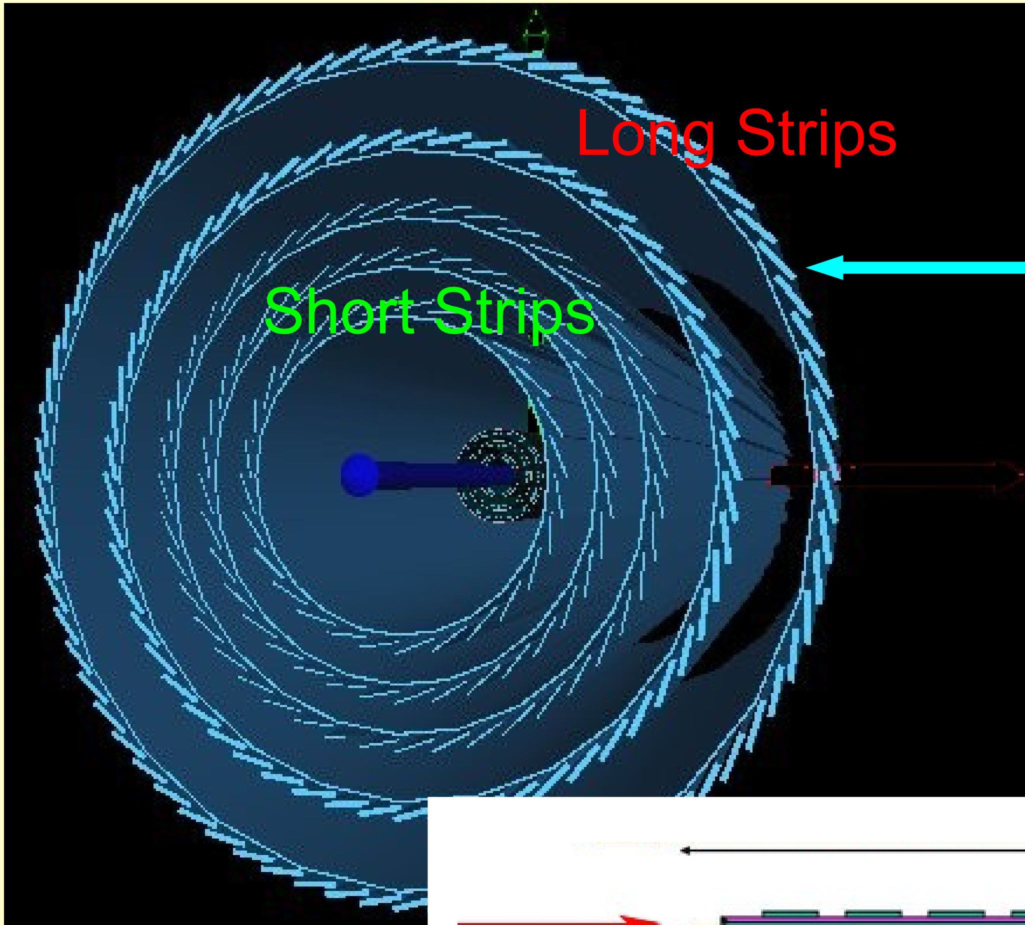
Utopia Geometry

- Pixel
- Short Strip Sensors
- Long Strip Sensors



studies only for central region

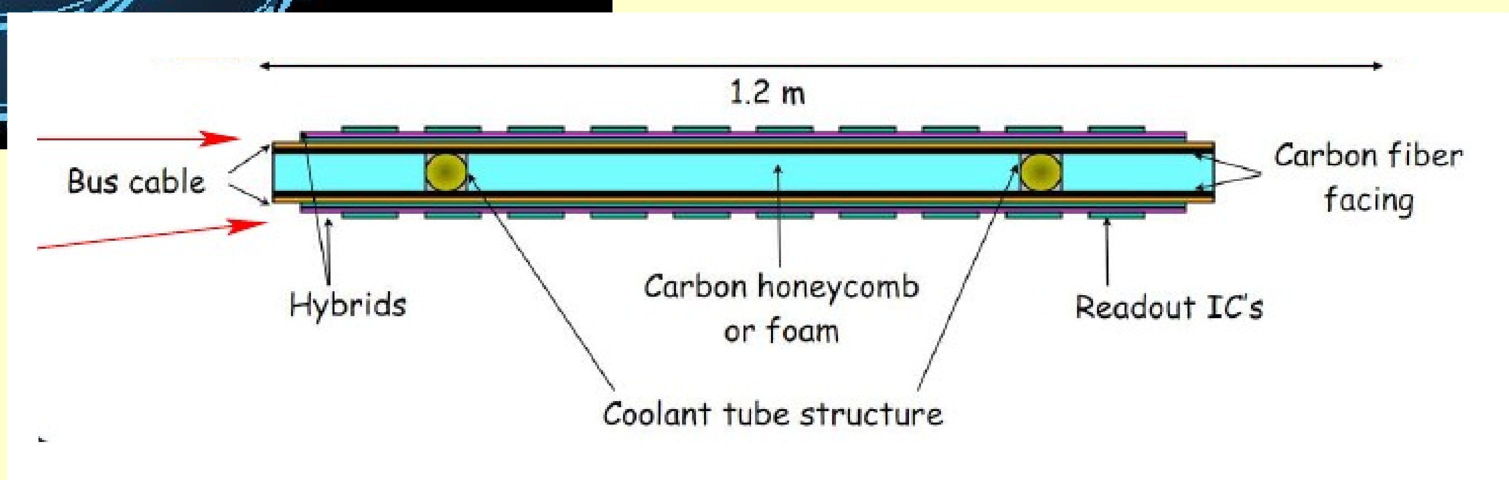
ATLAS Utopia Strip Layer Design for Phase II



Double strip layers

- gap 7.35 mm
- tilted by 10 (16) degrees
- 80 μm pitch
- stereo angle (standard)

→ no stereo angle for track trigger

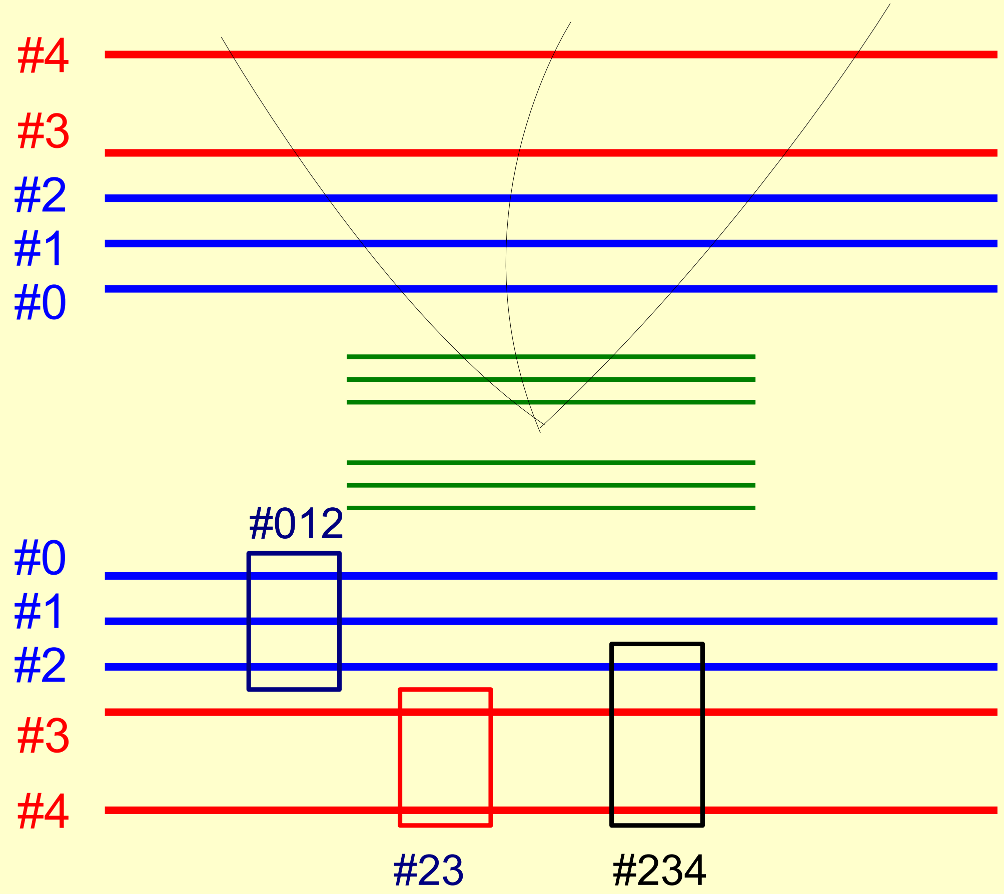


Pixel + Strip Sensor Layers

Long Strips (*Δz=10cm*)

Short Strips (*Δz=2.5cm*)

Pixel (not used)



Layer combinations studied for track trigger:

- #0, #1, #2 (only short strips)
- #3, #4 (only long strips)
- #2, #3, #4 (mixed, outer layers)

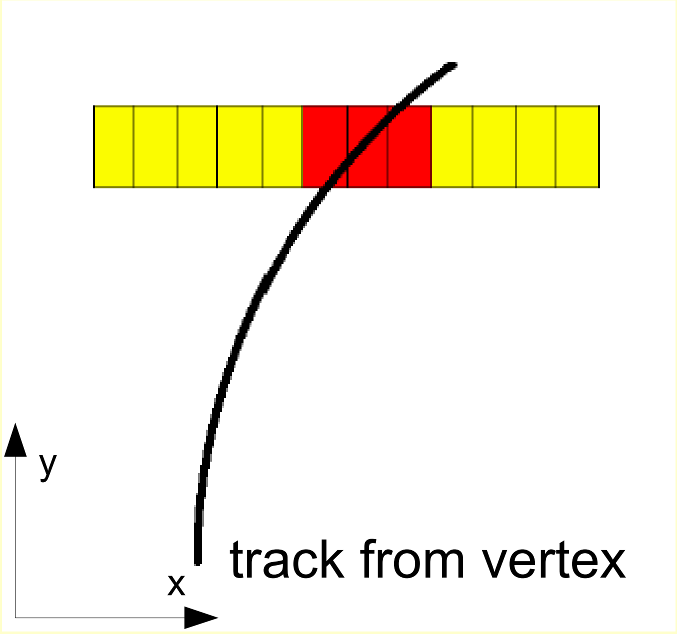
Questions addressed

- **Study of high p_T local filter algorithms (Frontend)**
  - cluster size filter algorithm
  - "offset method"
- **Best number of silicon double layers for triggers (2,3,4,...)?**
- **Best layer combinations?**
  - study combinations "012", "34", "234"
- **Performance:**
  - data reduction versus p_T-threshold
  - data reduction versus track finding efficiency

Cluster Size Filter

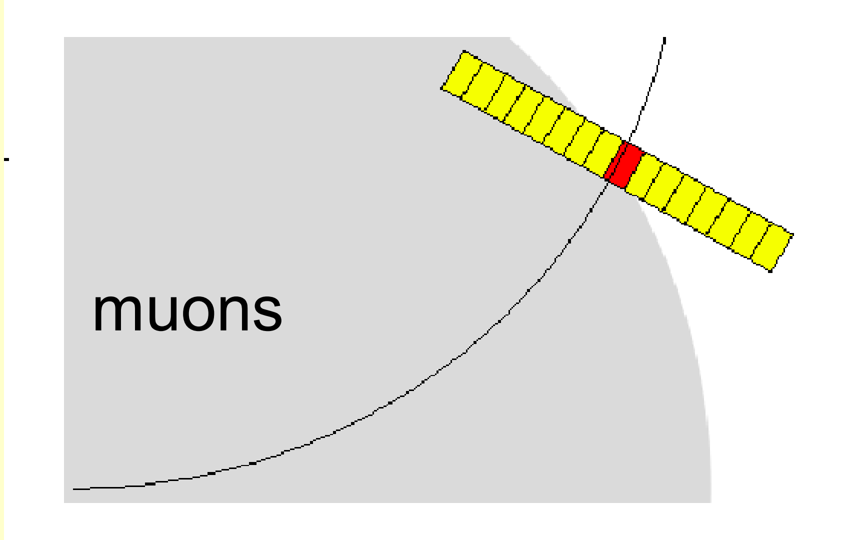
Due to the rectangular strip geometry several strips collect charge if low momentum tracks are bent in the magnetic field

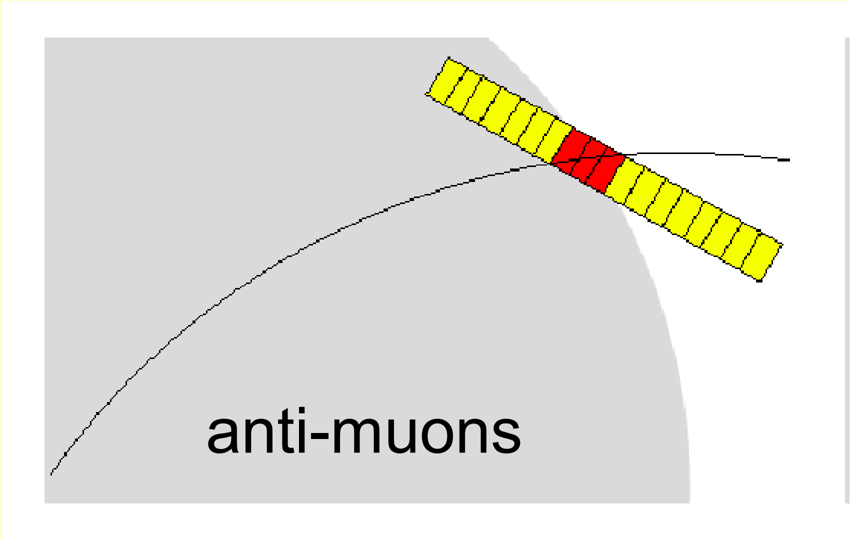
"cluster size method"

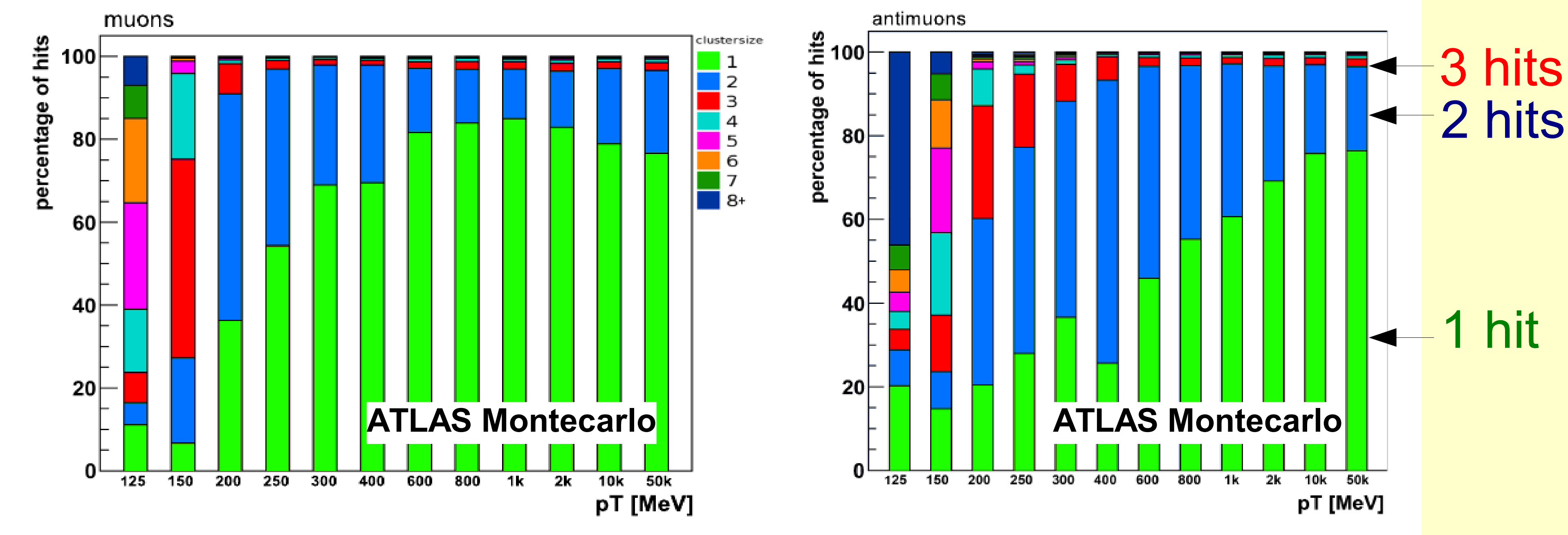


Complication: strip layers are tilted (10 degrees)

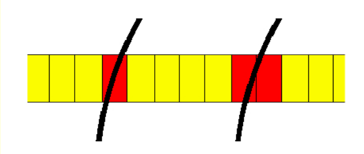
Results Cluster Method (layer #0)





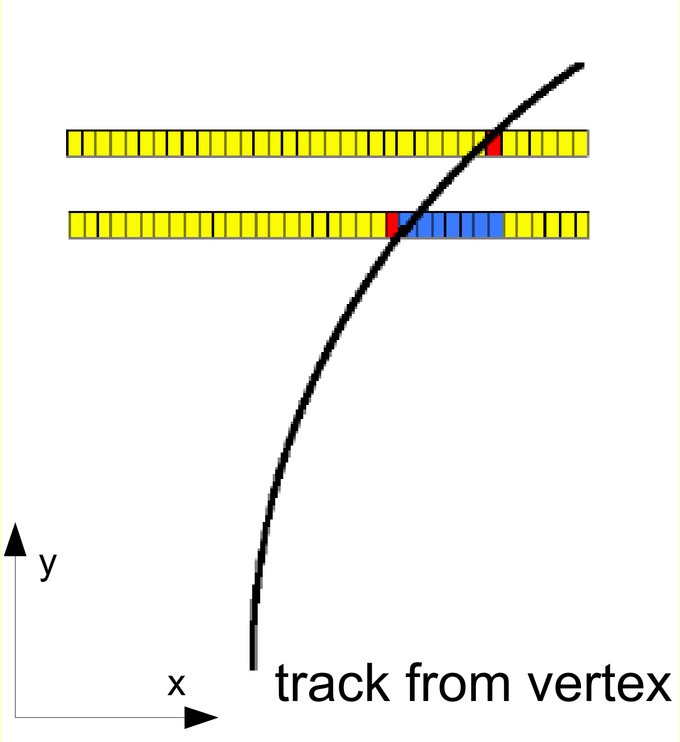


keep clusters with 1 or 2 hits



Coincidence "Offset" Method

"offset method"



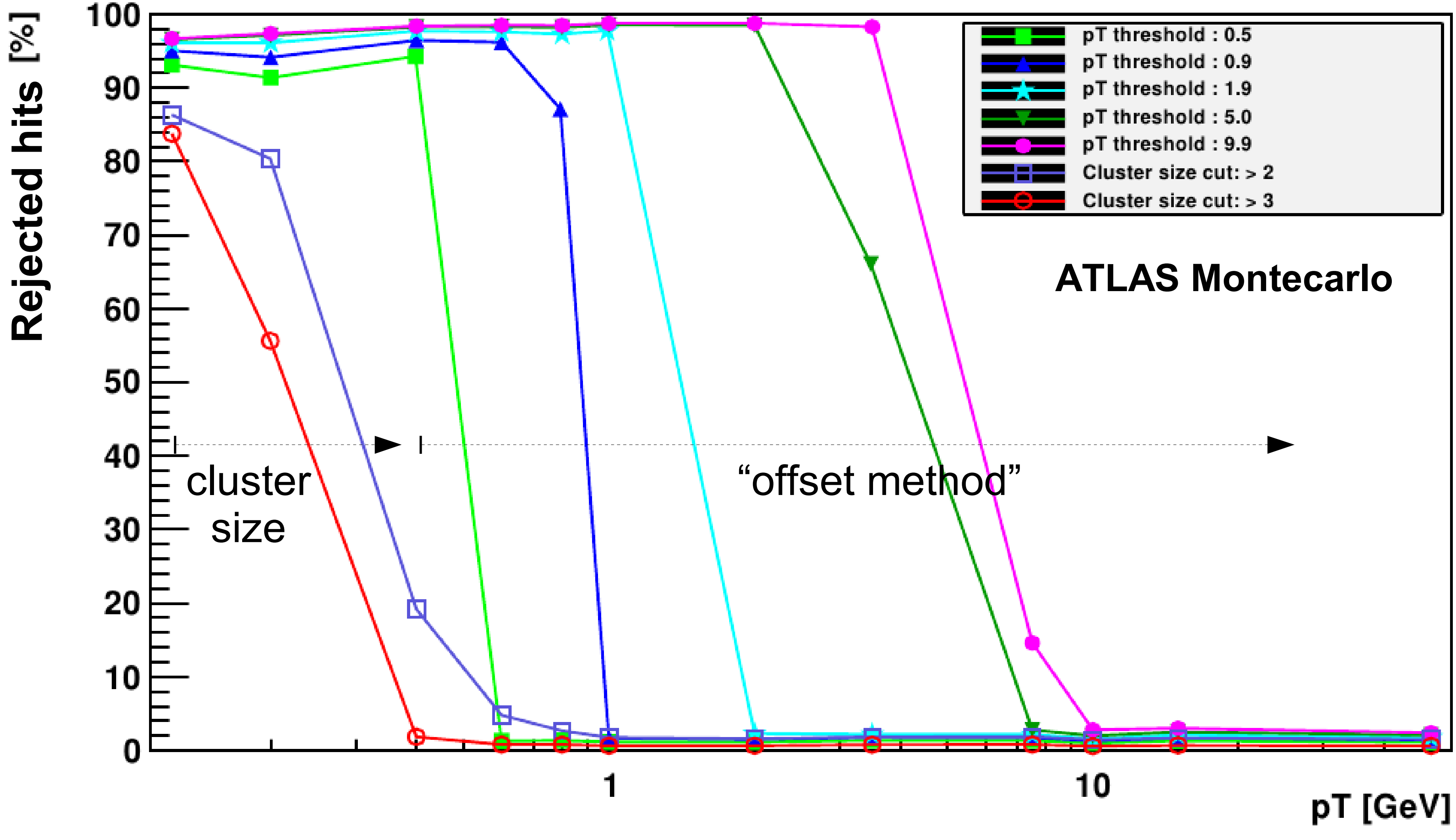
rejection of low momentum hit pairs

<u>Two steps:</u>

- find coincidence
- measure distance ("offset") between hits

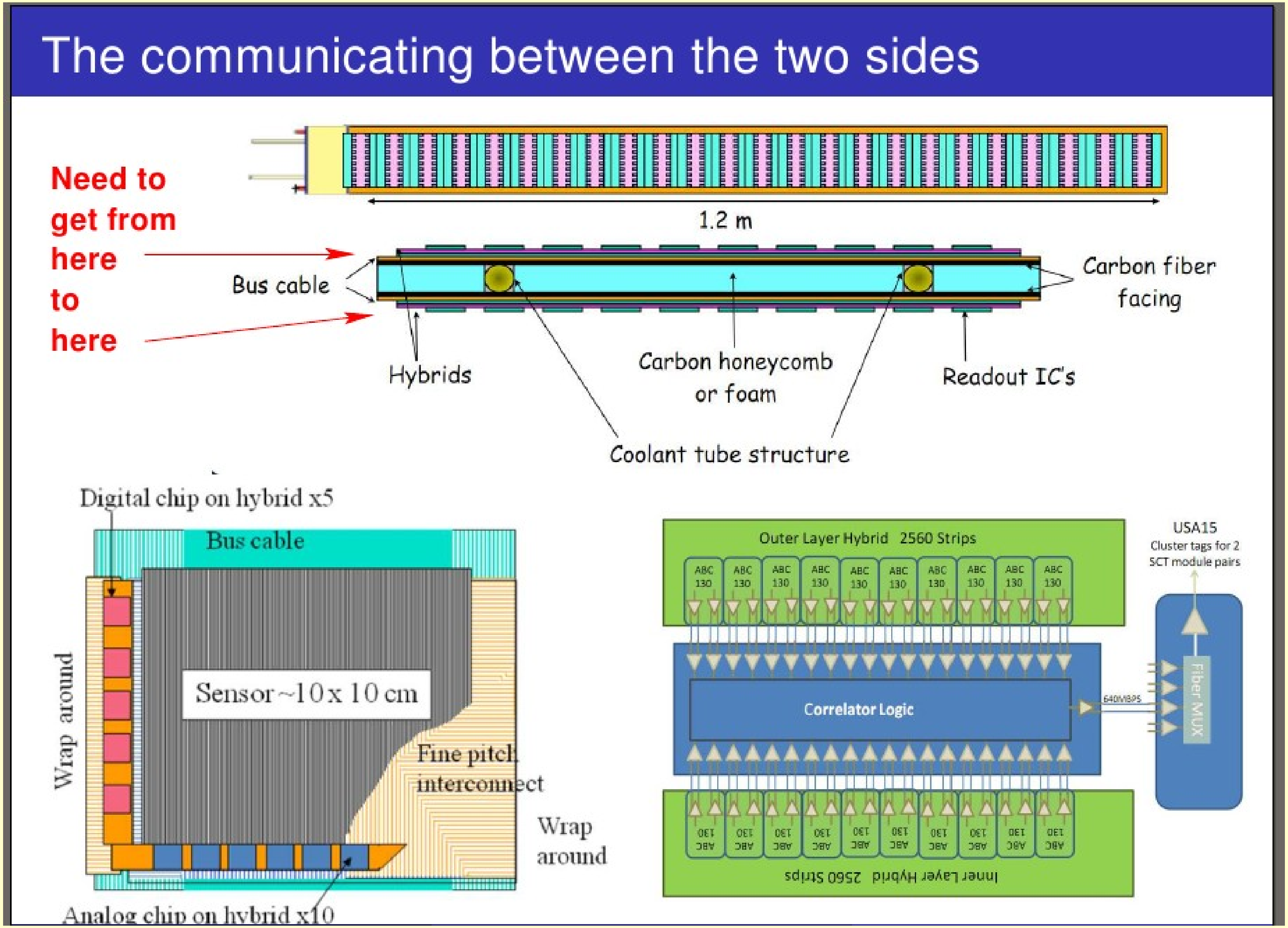
➜ **can be combined in a single step by defining acceptance windows**

Muon Momentum Selectivity (layer #0)



Good momentum discrimination!

Possible Hardware Realisation



Fast Clustering Block → M.Newcomer

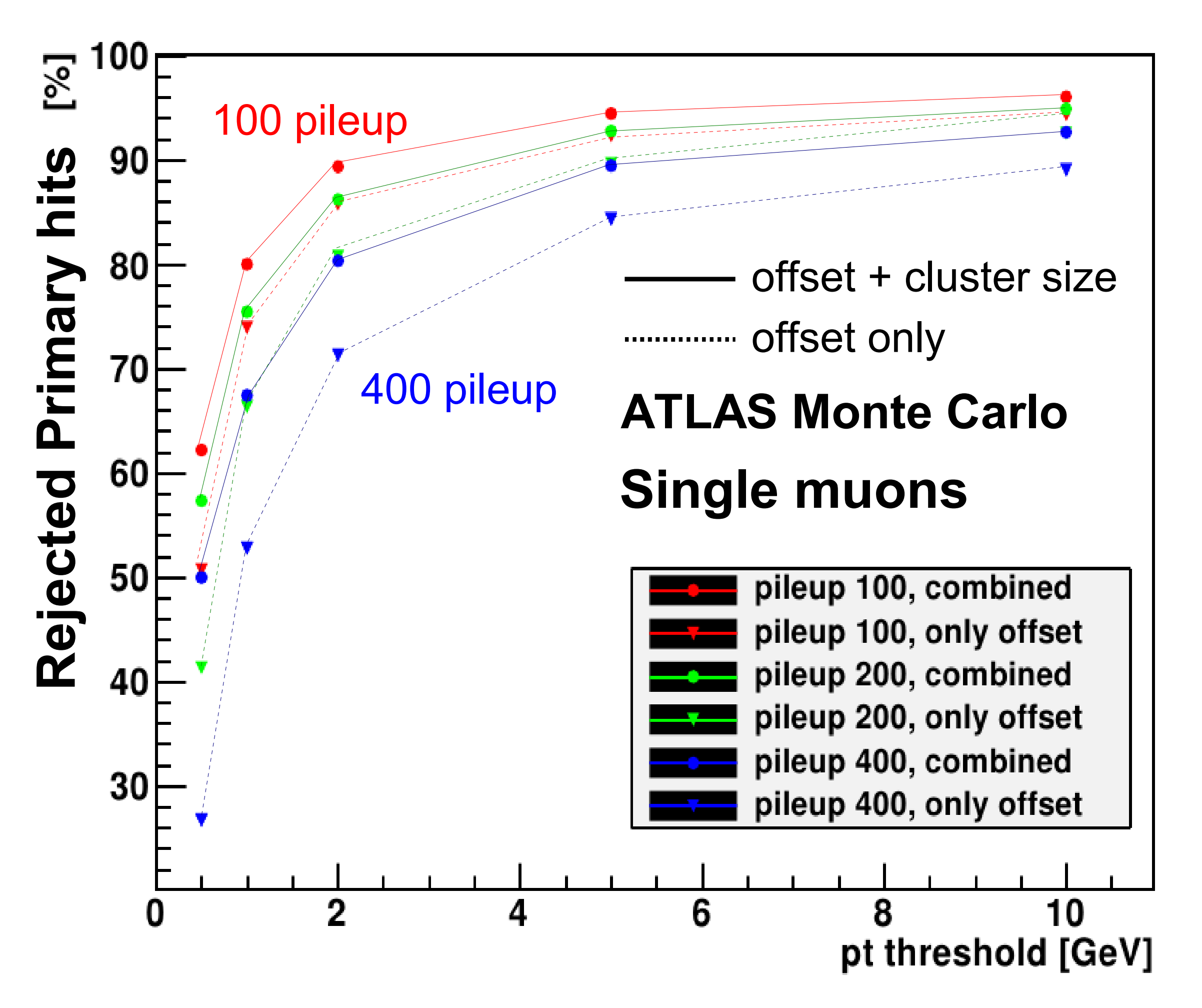
Simulation

- **GEANT4: ATLAS modified Utopia layout**
- **Strip Sensors**
  - tilt angle 10 degrees
  - no stereo angle
- **Minimum Bias Events (PYTHIA) with 50, 100, 200, 400 events**
- **Signal tracks:**
  - high p_T muons implanted in Minimum Bias events
- **Chi^2 fit simulates track trigger processor (varied Chi^2 cut)**
  - **trigger rate calculation**
- **Matching with truth information**
  - **efficiency calculation**
  - **purity calculation**

Rejection as Function of p_T Threshold

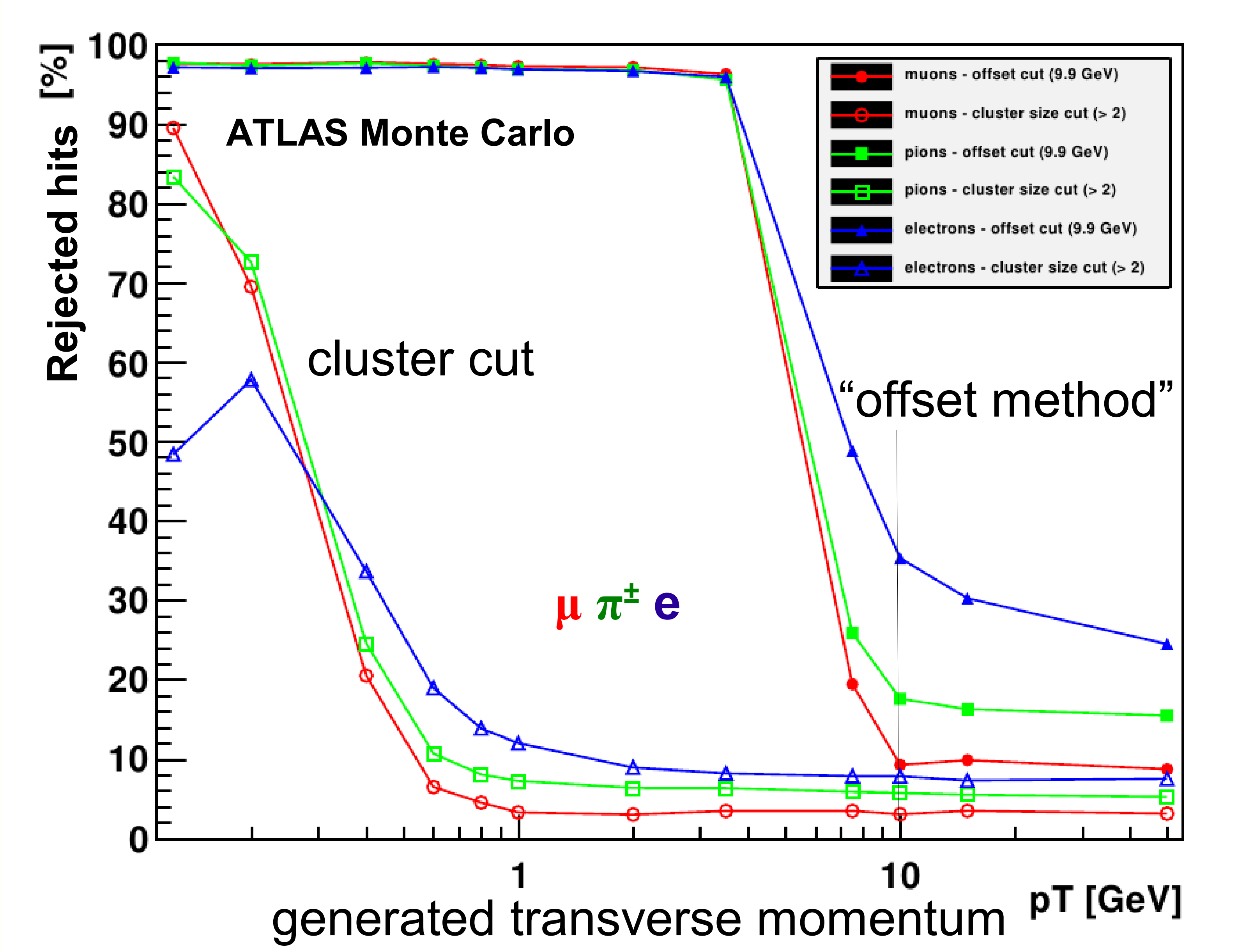
Rejection of Primary Hits

Minimum Bias Events



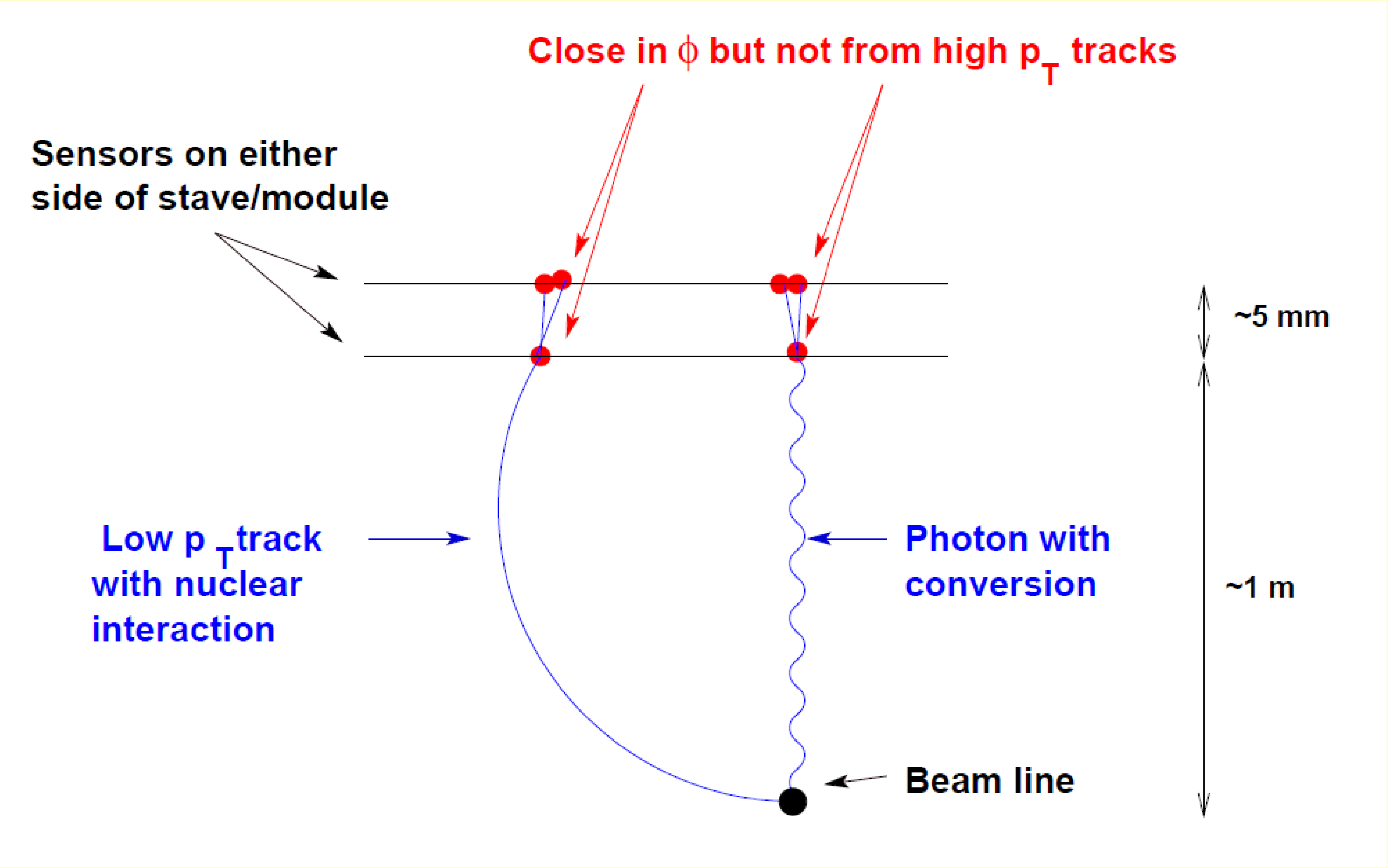
- most tracks (at low p_T) are rejected already with a low p_T threshold
- rejection power higher if cluster size and offset cut are used
- rejection power affected by high pileup

e, μ, $\pi^{\pm}$ Rejection (single particle)



hit reduction also above p_T threshold due to secondary IA

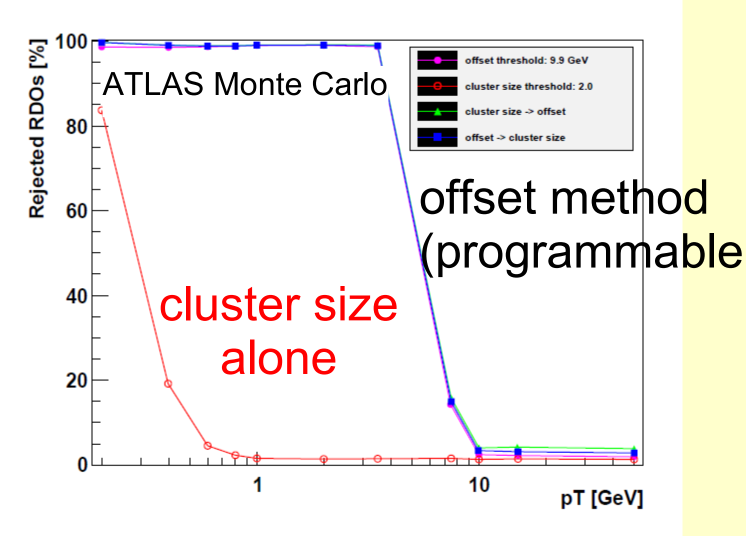
Secondary Interactions



Source of (low momentum) background

Performance of Detector Filters

- pileup 100 minimum bias (Pythia)
- p_T>10 GeV (offset)



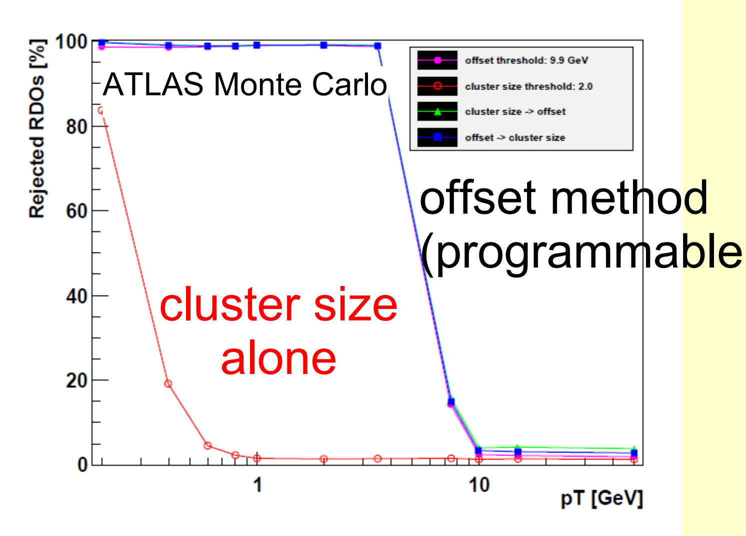
offset cut only

	# hits (layer)	27-153 degrees # hits (SS 3 accept.)	40-140 degrees # hits (LS 2 accept.)
SS 1:	6.4%	4.3%	2.8%
SS 2:	5.5%	4.7%	2.9%
SS 3:	5.1%	5.1%	3.4%
LS 1:	8.0%	8.0%	6.2%
LS 2:	6.5%	6.5%	6.5%

Reduction factors of: 15-30 on short strip layers

~15 on long strip layers

Performance of Detector Filters



- **pileup 100 minimum bias (Pythia)**
- **p_T>10 GeV (offset)**

cluster+offset cut

	# hits (layer)	27-153 degrees # hits (SS 3 accept.)	40-140 degrees # hits (LS 2 accept.)
SS 1:	4.0%	3.7%	1.7%
SS 2:	3.4%	2.9%	1.8%
SS 3:	3.2%	3.2%	2.1%
LS 1:	4.5%	4.5%	3.5%
LS 2:	4.0%	4.0%	4.0%

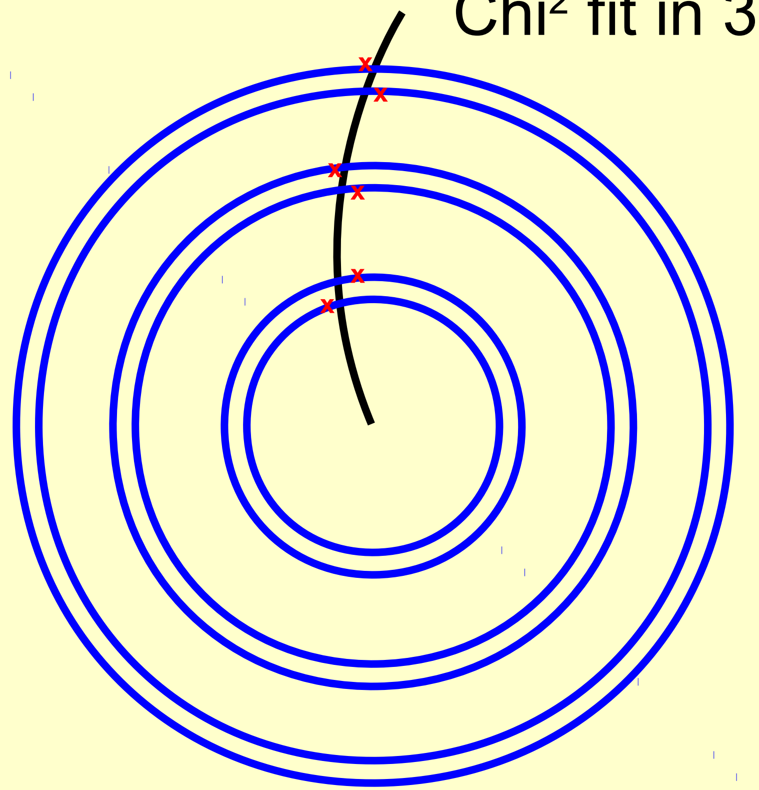
Reduction factors of: 25-50 on short strip layers

~25 on long strip layers

Simulation of Full Track Trigger

- **Local hit filtering (cluster size + offset method)**
- **Link hits in all used layers (no redundancy)**

Chi^2 fit in 3D



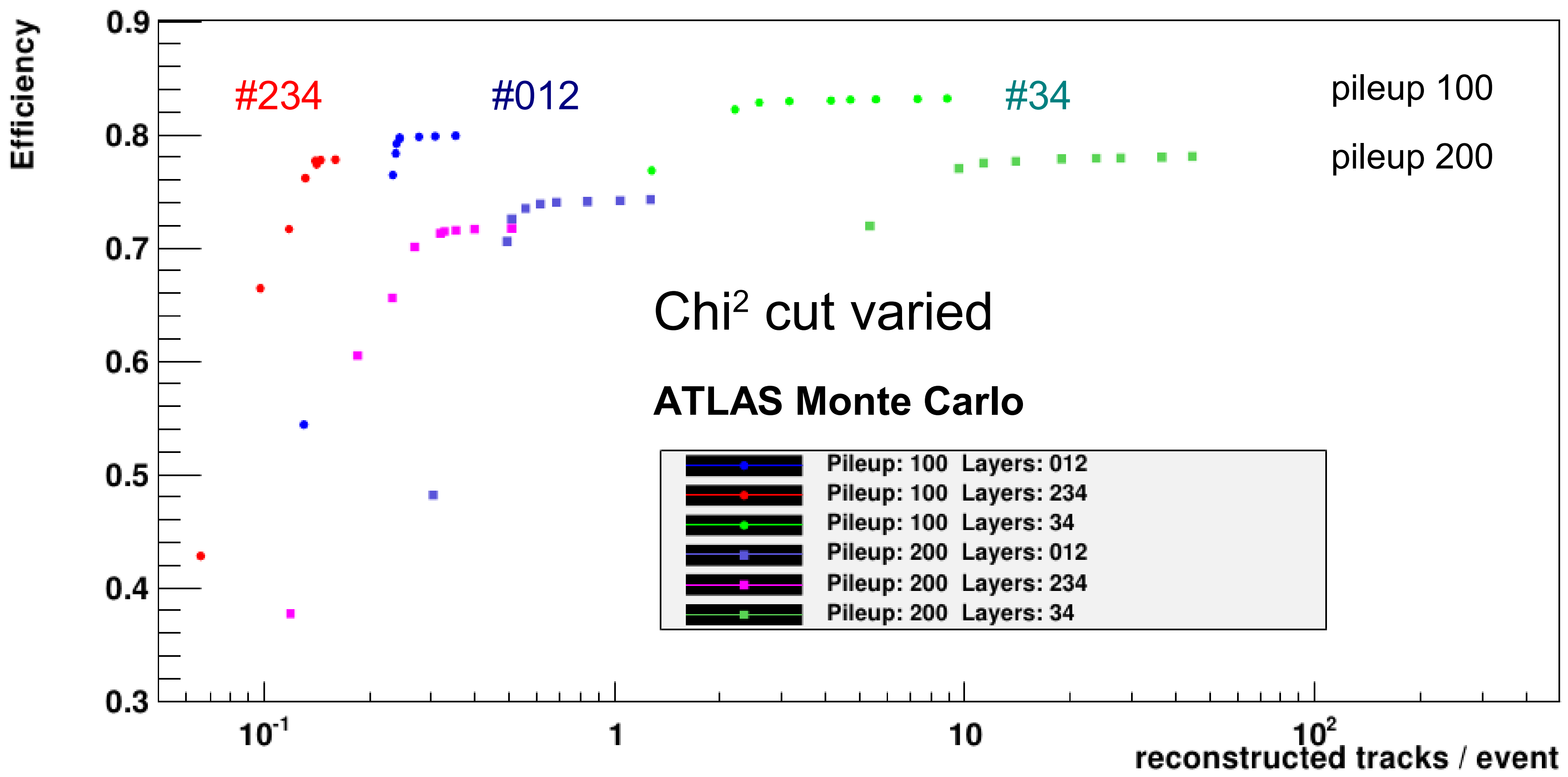
Hardware Implementation:

fast lookups using next generation of associative memory chips (→3D)

Track Efficiency vs Track Rate

cluster size
+
offset cut p_T>10 GeV

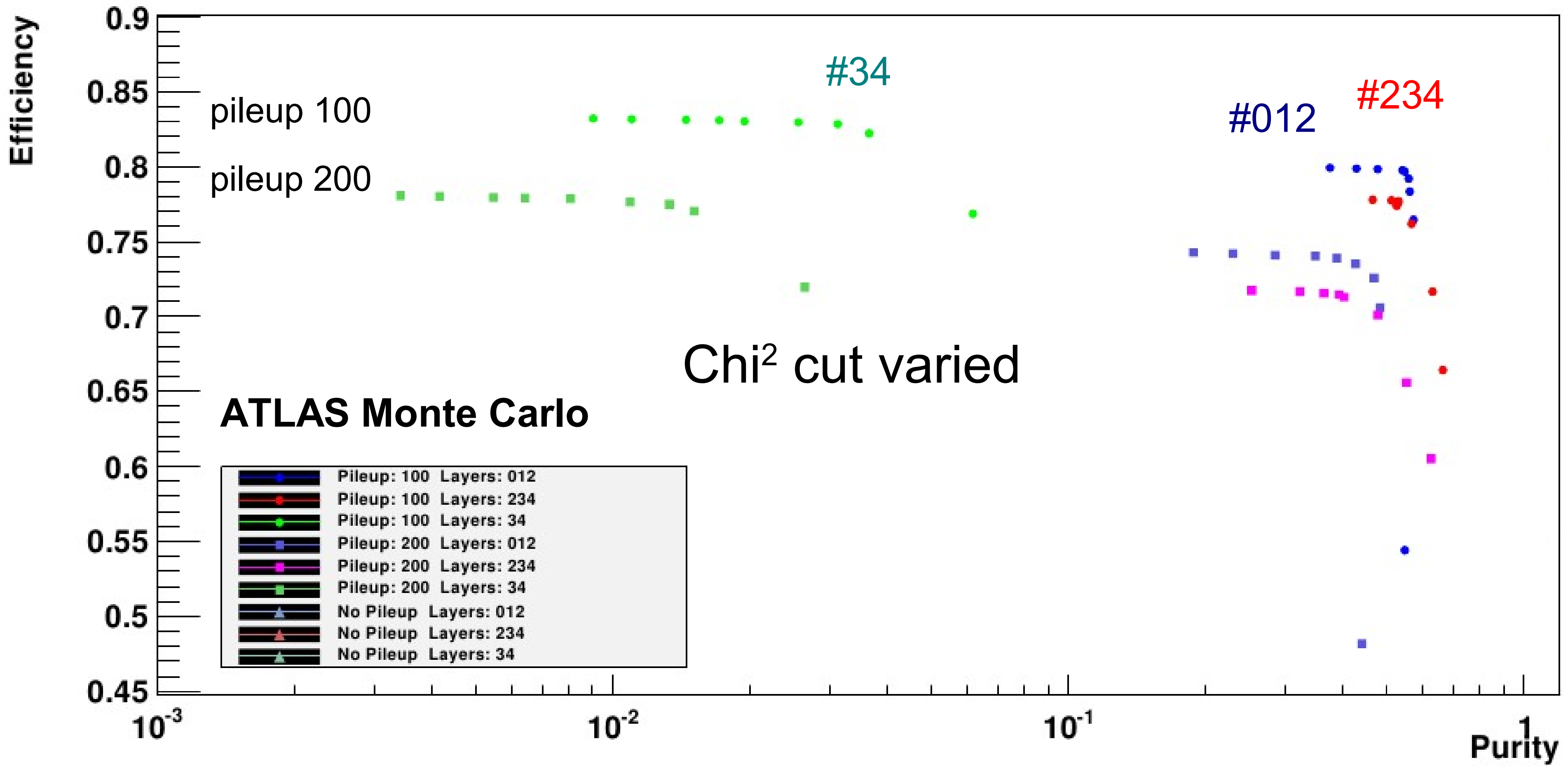
➜ 3 double layers give sufficient low rate



Track Efficiency vs Purity

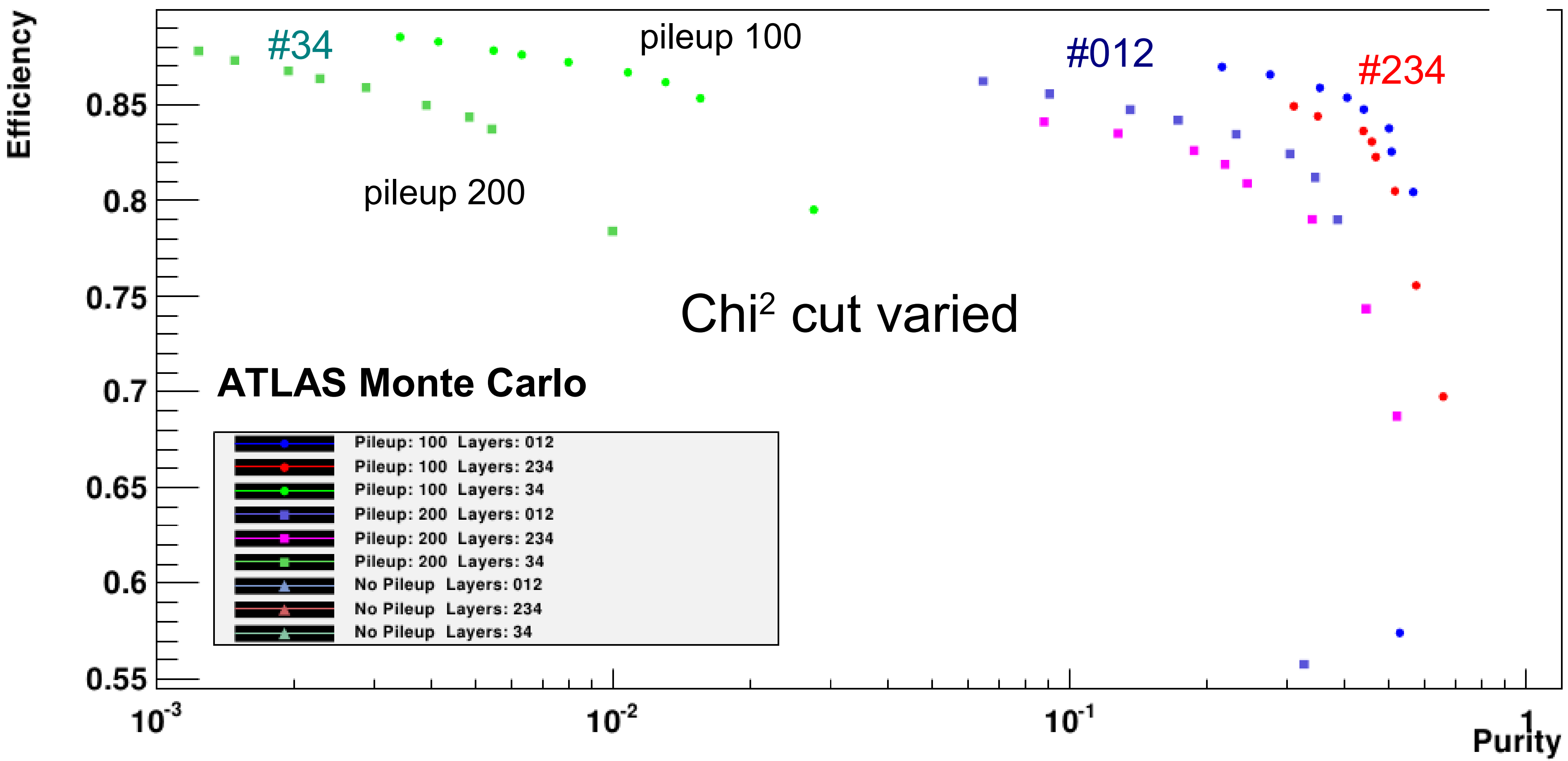
cluster size
+
offset cut **p_T>10 GeV**

3 double layers good purity



Track Efficiency vs Purity

only offset cut p_T>10 GeV → **higher efficiency w/o cluster size cut**



Parameter Studies

Choose chi^2 cut which maximises product: *efficiency^2 * purity*

ATLAS Monte Carlo		with cluster size cut			
p_t threshold	layer set	efficiency	purity	rate	χ^2-cut
10.0	0/1/2	0.726	0.468	0.507	12.0
	2/3/4	0.656	0.551	0.231	12.0
	3/4	0.720	0.026	5.349	6.0
15.0	0/1/2	0.743	0.309	0.097	10.0
	2/3/4	0.640	0.750	0.029	10.0
	3/4	0.746	0.006	3.312	6.0

For p_T threshold of 15 GeV rates of “only” 0.1 tracks/event

Analysis of Efficiency Losses

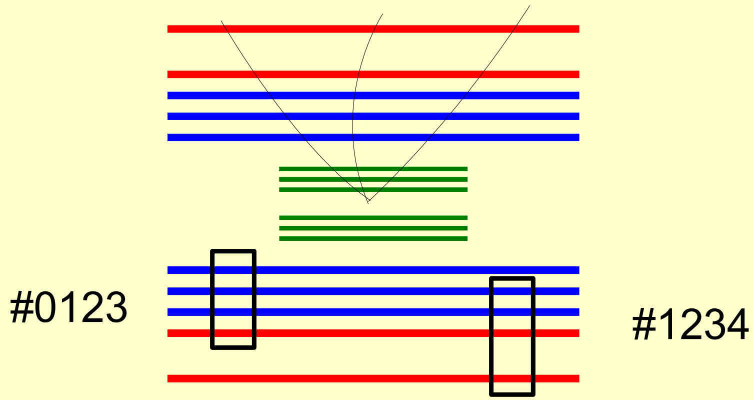
<u>Set #012 (short strips)</u>

single hit efficiency ~98% in six layers → ~12% loss
cluster size cut ~1% per layer → ~6% loss
inefficiency of offset method ~0.4% → ~1.2% loss
inefficiency track fit → >1% loss

filtering algorithms affected by high pileup by up to 5%

Higher efficiency >95% possible be adding **more redundancy**:

- e.g. requiring 2x3 hits out of **four double layers**



- **more studies required**

Summary

- Design of a Self-Seeded First Level Track Trigger studies
- Local filtering algorithms: cluster size and coincidence
- At least 3 double layers for reasonable purity and trigger rate
- Design with more redundancy (4 double layers) would improve track efficiency
- Self Seeded Track Trigger at ATLAS possible with “minor” design changes of the Utopia design (no stereo angle, frontend electronics)