DAQ TDR & Tracker

Lucia Silvestris

INFN Bari

Tracker General Meeting

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DAQ Technical Design Report

The Trigger/DAQ project

Data Acquisition & High Level Trigger

Part1 DAQ architecture and design

Part2 Data Flow

Part3 Control and Monitor

Part4 High Level Trigger

Part5 Project Organization, Costs and Responsibilities

Technical Design Report

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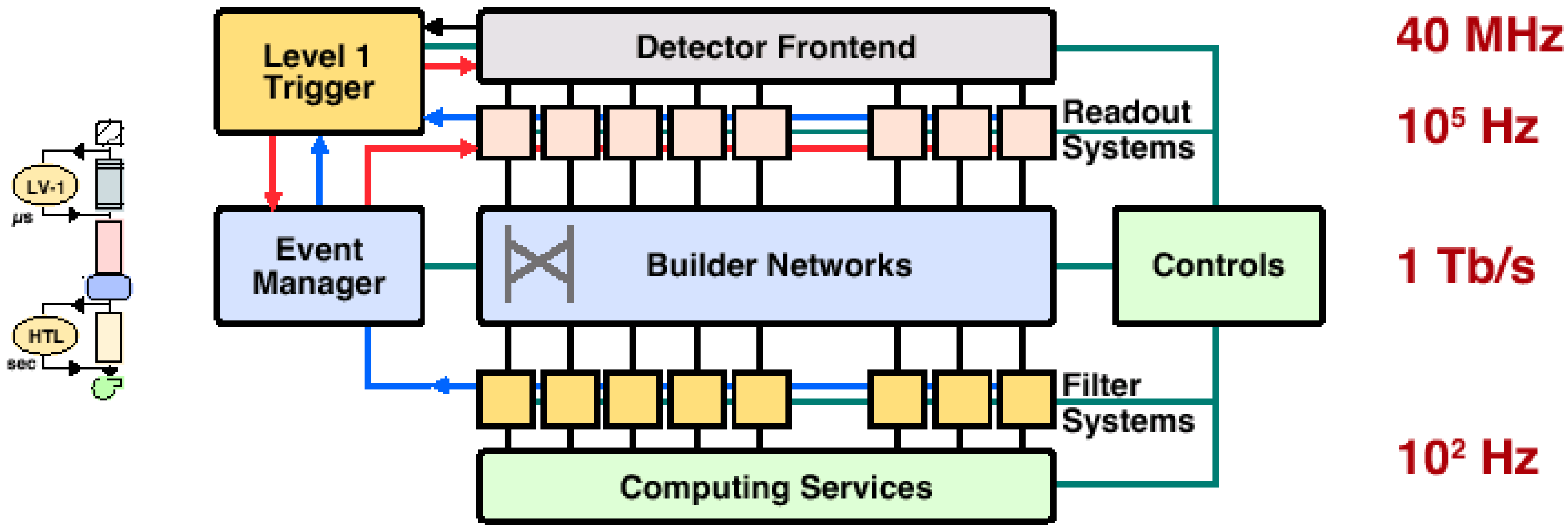
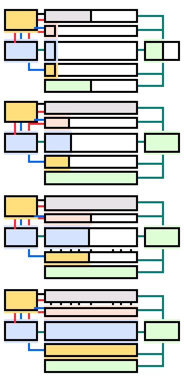
Revision:	0.2α
Reference:	CMS TDR-6.2
Created:	02 October 2001
Last modified:	04 October 2001
Prepared By:	CMS/TriDAS Collaboration

CMS DAQ Baseline (TP 1994)



Level-1 maximum trigger rate	100 kHz	No. Readout systems	≈512
Average event size	1 Mbyte	No. Filter systems	≈512 x n
System dead time	≈ ..%	No. (C&D) network ports	≈10000
Builder network	1 Terabit/s	No. programmable units	≈10000
Event filter computing power	≈5 10^6 MIPS	Event flow control	≈10^6 Mssg/s

Staged Event Builder



2004. Pre-series (64x64 EVB)

2005/6. DAQ-0 (DataLink 100%, DAQ 25%)

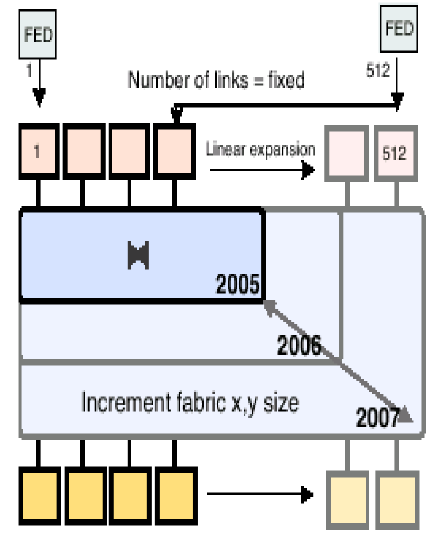
2006/7. DAQ-1 (DataLink 100%, DAQ 50%)

2007/8. DAQ-2 (DataLink 100%, DAQ 100%)

EVB staging by switch expansion:

- Readout unit must allow multi-FED link merging
- Expand the switch via a fabric structure

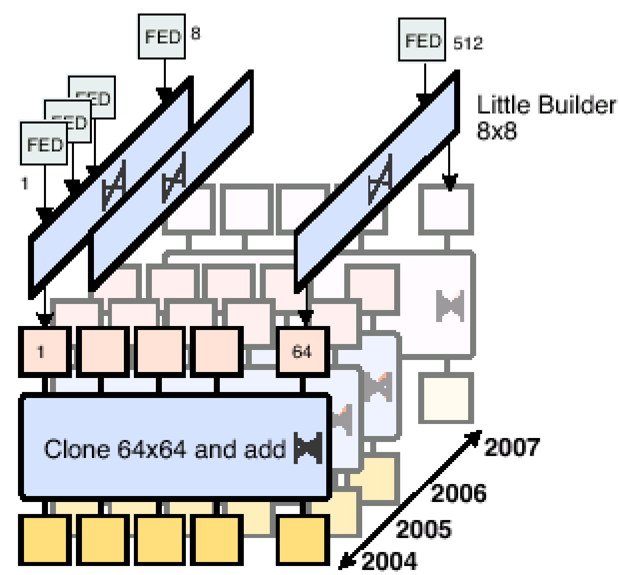
- RU Design and choice of technology in 2003
- EVB stages are based on the same technology
- Performances must scale with size
- System efficiency is highly factorized (failures in one RU or one switching node halt the entire system)



EVB staging by event mutiplexing and DAQ slices

- 64 8x8 (*) switches (FED builders. FB) group FED fragments by 8 and divide the time (events) into 8 domains (NoEv Modulo 8). The result is a DAQ made of 8 independent systems (slices).
Each slice consists of 64 RU, a 64x64 EVB, 64 BU and associated FUs. A slice can read up to 12.5 kHz
- Allow easy staging (e.g. in 8 steps) each step runs as an independent system and it may be implemented with a different technology
- Use the 64x64 preseries as basic unit

(*) 8x8 FB is a simplification it is NxM where M is the number of slices



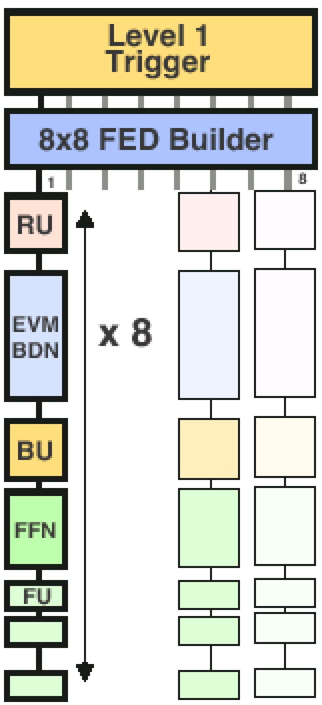
General DAQ Architecture

Data to surface:

Average event size	1 Mbyte
No. FED s-link64 ports	> 512
DAQ links (2.5 Gb/s)	512+512
Event fragment size	2 kB
FED builders (8x8)	≈ 64+64

The DAQ system consists of two parts:
- The front end electronics readout and the data link to surface
- The DAQ core implemented as 8 DAQ slices each processing a fraction of the trigger rate

'Side' View

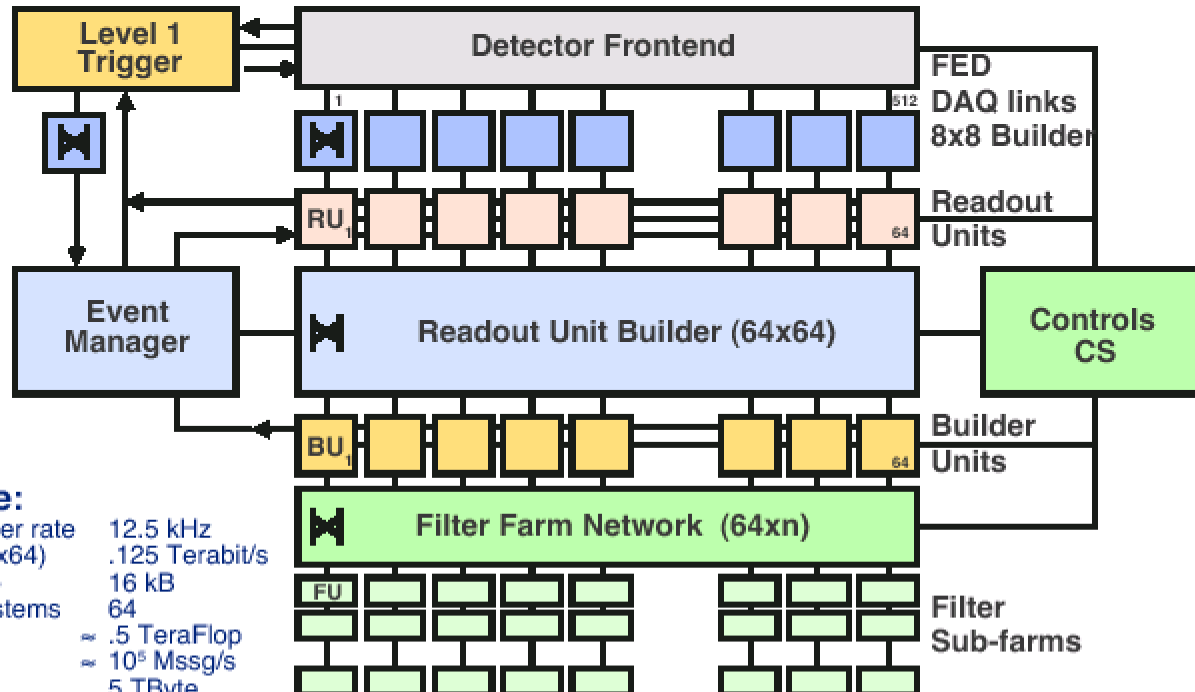


1/8th DAQ slices

1/8th DAQ slice:

Lv-1 maximum trigger rate	12.5 kHz
Builder network (64x64)	.125 Terabit/s
Event fragment size	16 kB
Readout/Builder systems	64
Event filter power	≈ .5 TeraFlop
Event flow control	≈ 10^5 Mssg/s
Local mass storage	5 TByte

'Front' view



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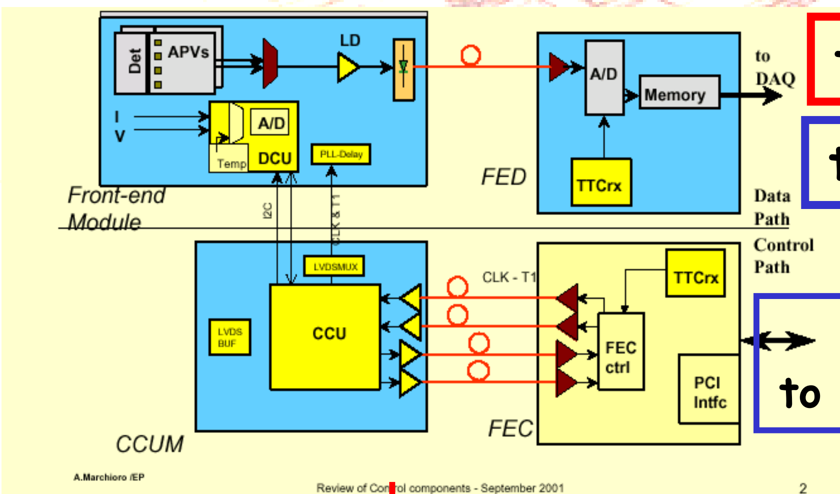
Tracker & TriDAS

Detector

FED



to DAQ

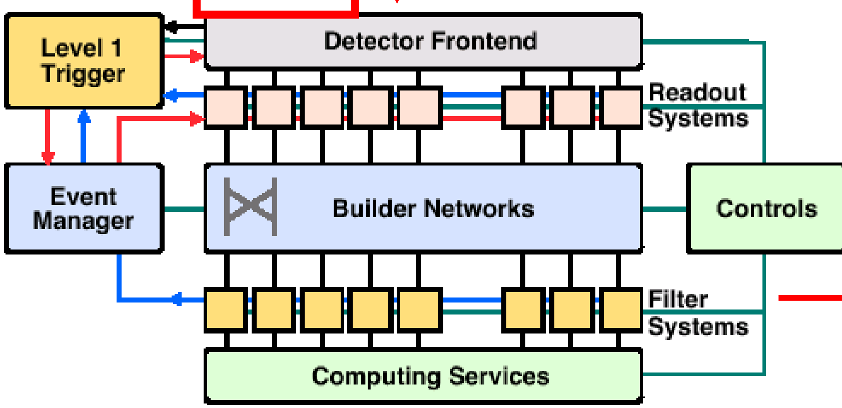
to VME (spy channel)

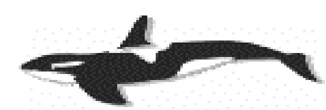
VME

Control Path

to VME (spy channel)

DAQ





ORCA

Expected Tracker data Rates

- Study exists, but must be improved for DAQ TDR
  http://tomalini.home.cern.ch/tomalini/readout.pdf

Data-Handling
Mini-workshop Dec 2001
Ian

Results depend on -

- Tracker strip occupancy:
  (PYTHIA simulation ? Heavy ion collisions ? detector simulation ? Clustering cuts ?)

- Knowledge of readout electronics
  (Detector->FED cabling map ?)

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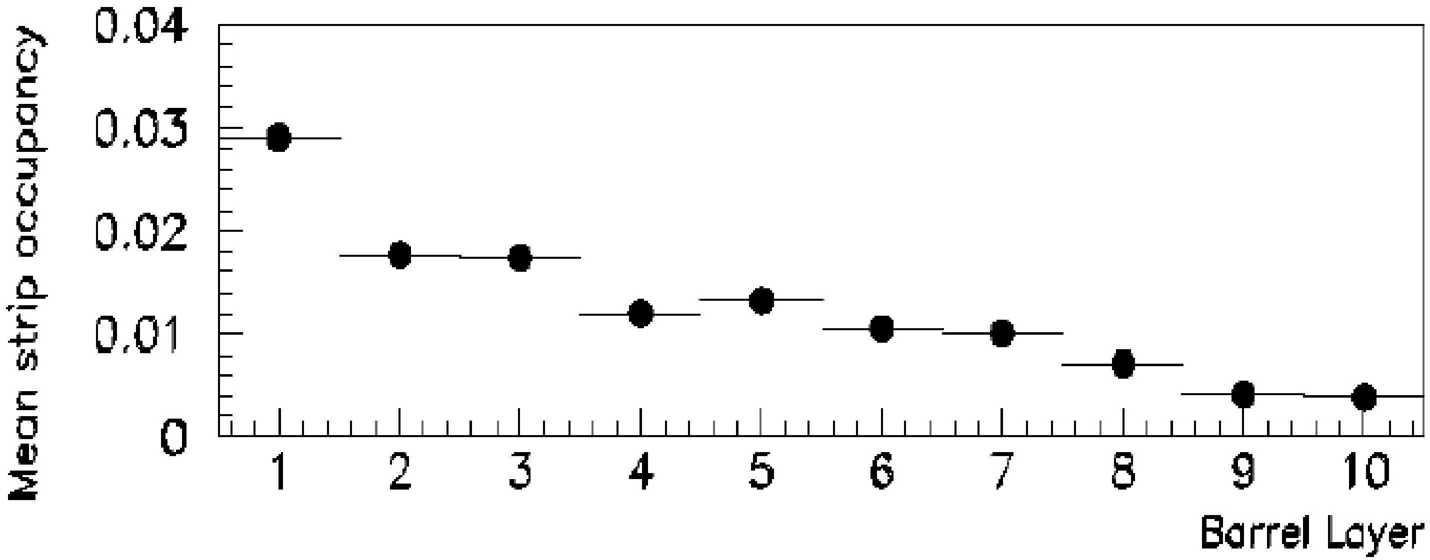
Tracker Strip occupancy

Strip occupancy -- fraction of strips associated with clusters by FED (on-line) cluster finder.



Barrel−rφ detectors

Data-Handling
Mini-workshop Dec 2001
Ian

Tracker Strip occupancy

PYTHIA Mini-Bias Tuning

- MSEL=1 or 2 ? (Exclude/Include non-elastic,diffractive events).
  - LHCb says double-diffractive events non-negligable.

- Number of superimposed events at high luminosity ?
  - MSEL=1 $\Rightarrow$ σ=55 pb $\Rightarrow$ 17.3 events
    - All CMS-PRS groups do this except us !
  - MSEL=1 + double-diff. $\Rightarrow$ σ=70 pb $\Rightarrow$ 24 events
    - LHCb do this correctly, and ATLAS and b-tau don't !
  - Systematic error ? ATLAS estimate $\pm$ 28%.

Data-Handling
Mini-workshop Dec 2001
Ian

- Parameter tuning ?
  - CMS uses fit to old Tevatron data. LHCb uses fit to newer data.
  - How reliably is momentum spectrum predicted ?

Tracker Data Rate per FED

- Raw Data mode : rate = T x [112 + 2x128*(96f x10/8)]
- Zero Supp. Mode: rate = T x [112 + S x2x128*(96f x2)]
  - – data format dependent (see next talk).

Data-Handling Mini-workshop Dec 2001 Ian

- Data rate from a FED depends on occupancy of the detectors it reads.
  - So need Detector → FED cabling scheme (from F. Vasey *et al.*)
  - Scheme currently implemented in EXCEL !!! *Should be in ORCA.*

- 2 or 3 FEDs connected to each DAQ Switch input.
  - We must help device FED → DAQ Switch connection scheme.
  - We must estimate data rate to each switch input.

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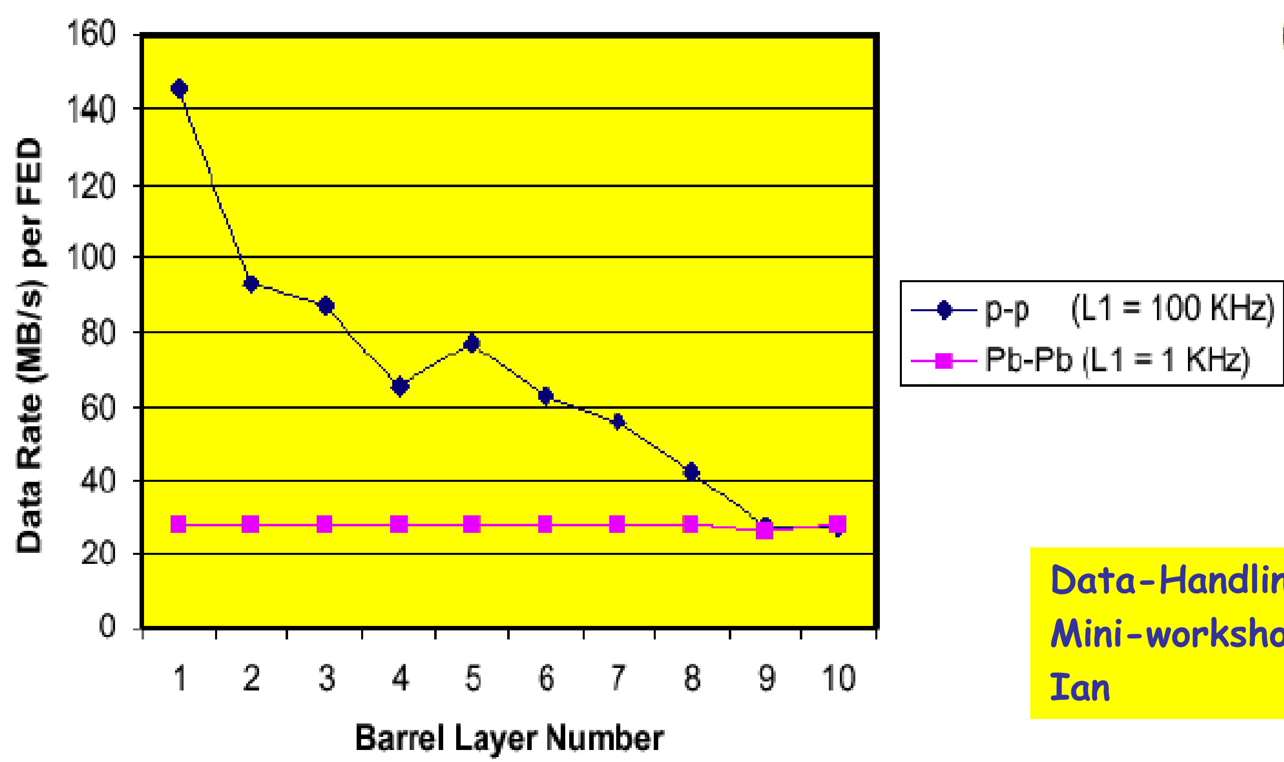
Tracker Data Rates per FED

Data rate per FED < 200 MB/s (DAQ capacity) everywhere !



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Tracker Data Rates per FED

Data-Handling
Mini-workshop Dec 2001
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More detailed numbers also exist …

(Variation in FED occupancy within a barrel layer or end-cap disk.)

Level 1 rate (KHz) 100

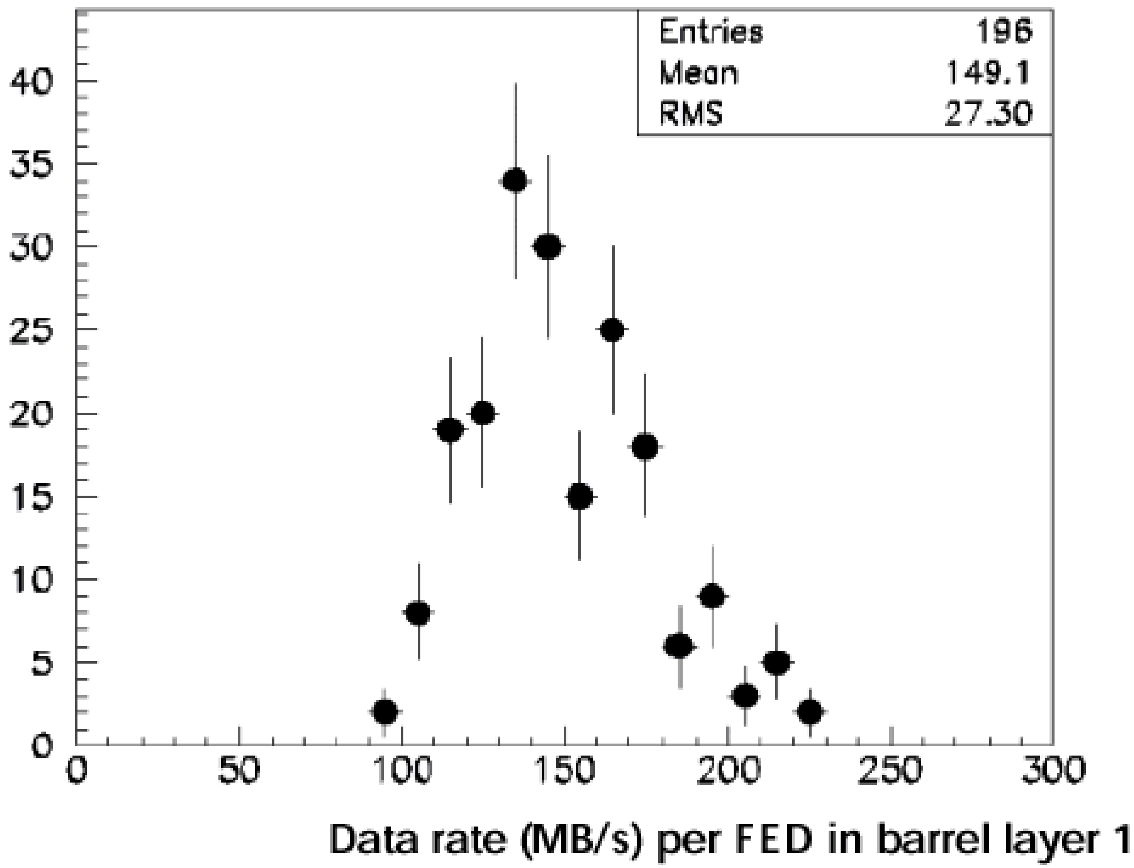
# of header bytes 112

Barrel	TIB1	TIB2	TIB3	TIB4	TOB1	TOB2	TOB3	TOB4	TOB5	TOB6
# of phi sector	28	38	46	54	42	48	54	60	66	74
# Det / phi sector	6	6	6	6	6	6	6	6	6	6
Total # dets / layer	168	228	276	324	252	288	324	360	396	444
APV/det: r-phi	6	6	4	4	6	6	4	4	6	6
APV/det: stereo	6	6	0	0	4	4	0	0	0	0
Total # APV / layer	2016	2736	1104	1296	2520	2880	1296	1440	2376	2664
Mean strip occupancy: r-phi	0.029	0.018	0.017	0.012	0.013	0.010	0.010	0.007	0.004	0.004
Mean strip occupancy: stereo	0.031	0.019	0	0	0.018	0.015	0	0	0	0
Max possible # APV / FED	192	192	192	192	180	180	192	192	192	192
Min possible # FED's	11	15	6	7	14	16	7	8	13	14
Max possible # Dets / FED	16	16	48	48	18	18	48	48	32	32
# of 'more full' FEDs	7	9	4	5	14	16	5	4	10	14
Det / FED	16	16	48	48	18	18	48	48	30	30
Rows / FED	2.67	2.67	8.00	8.00	3.00	3.00	8.00	8.00	5.00	5.00
# Unused fibers / FED	0	0	0	0	6	6	0	0	6	6
Data Rate / FED (MB/s)	151.3	97.4	90.4	66.9	76.6	63.4	57.6	44.0	28.3	27.4
# of 'less full' FEDs	4	6	2	2	0	0	2	4	4	1
Det / FED	14	14	42	42	0	0	42	42	24	24
Rows / FED	2.33	2.33	7.00	7.00	0.00	0.00	7.00	7.00	4.00	4.00
# Unused fibers / FED	12	12	12	12	0	0	12	12	24	24
Data Rate / FED (MB/s)	133.7	86.6	80.4	59.9	0.0	0.0	51.7	39.8	24.7	24.0
Total FED's	11	15	6	7	14	16	7	8	14	15

Tracker Data Rates per FED

Data-Handling
Mini-workshop Dec 2001
Ian

Event to event data rate variation also needed.



What has been done..

- Update Tracker Geometry for TIB,TOB and TEC
- Update values (using x5b October 2001 test-beam data) for capative couplings, S/N
- Test-beam and Data Handling framework inside ORCA
  - Study PSI test-beams Data in May
  - Study Tracker Data Rate per FED
  - Study different FED cluster algorithms using test-beam data
- Started studies on Minimum bias tuning
  - Changes has been done in COBRA
  - Next report foreseen on 14 May in Tracker b tau meeting

What still missing

- Detector -> FED Cabling in ORCA
- Data Format and Data compression in ORCA
  - The studies on Data Format and compression has been done from Gabriella (see presentation in the Data-Handling mini-workshop December 2001 from PRS Tracker-b tau WEB Page)
- FED grouping in order to balance the fragment data size into the DAQ switch
- Input from Heavy ION group on Tracker occupancy
- Put dynamic range in ORCA

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Tracker Control System

- Description of Tracker Control System for the two different components
  - The standard "slow control item" I.e. High Voltage, low Voltage, gas and cooling system
  - Configuration management of the Front-end Electronics, Synchronization and Calibration done using a detector local DAQ.
- All this has been described in Tracker Online Meeting from Pier Giorgio, Maki, Fred, Laurent, Karl, Nancy….

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High Level Trigger (I)

- Overview of Physics Reconstruction and Selection
  - Strategy and reconstruction on demand
  - Trigger level definition
  - Partial event reconstruction
- Summary of Level-1 Trigger
  - Calorimeter Trigger description
  - Muon Trigger description
  - Level 1 Trigger Table
- Detector and Level 1 Simulation
  - ….
  - Detector geometry
    - Tracker, muon, calorimeter
  - Detector simulation (Digi)
    - Tracker, muon, calorimeter

High Level Trigger (I)

- **Raw data formats and basic detector reconstruction**
  - Tracker
    - Read-out Data Format
    - Zero soppression
    - Cluster Reconstruction
    - Track Reconstruction
    - Vertex Reconstruction
  - Muon
  - ECAL
  - HCAL

High Level Trigger (II)

- Physics Object Selection and Results
  - Electron/photon
  - Muon
  - Jet and Missing Et
  - Tau
  - B

Tracker @ HLT

- When the Tracker could be used in the High Level Trigger Chain??
  - None! The current DAQ design provides fully assembled events in the builder units after Level1
  - All tracker Digis available
  - The **only** constraint is CPU time
- Why we would use the Tracker as soon as possible!!

Partial reconstruction

- Basic idea: do the absolute minimum of reconstruction needed to answer a specific question
- Use the same reconstruction components as the full reconstruction
  - No need for writing, debugging, maintaining several tools for same task
  - No compromise on efficiency or accuracy except from limit on number of hits

Example: Tracker L2 muon trigger

- Conditions:
  - High Pt threshold – around 15 GeV
  - Primary muon: transverse impact parameter below 30 microns
  - Direction known from L1 with 0.5 rad accuracy
- Tracker information needed: confirm existence of track with the selection criteria above
- Using regional seeding and Pt cut in trajectory building, it takes about 10 ms to reject L1 muon candidate

Tracker can be used at Level 2!

Btrigger algorithm

Input: L1 jet

PixelSelectiveSeeds

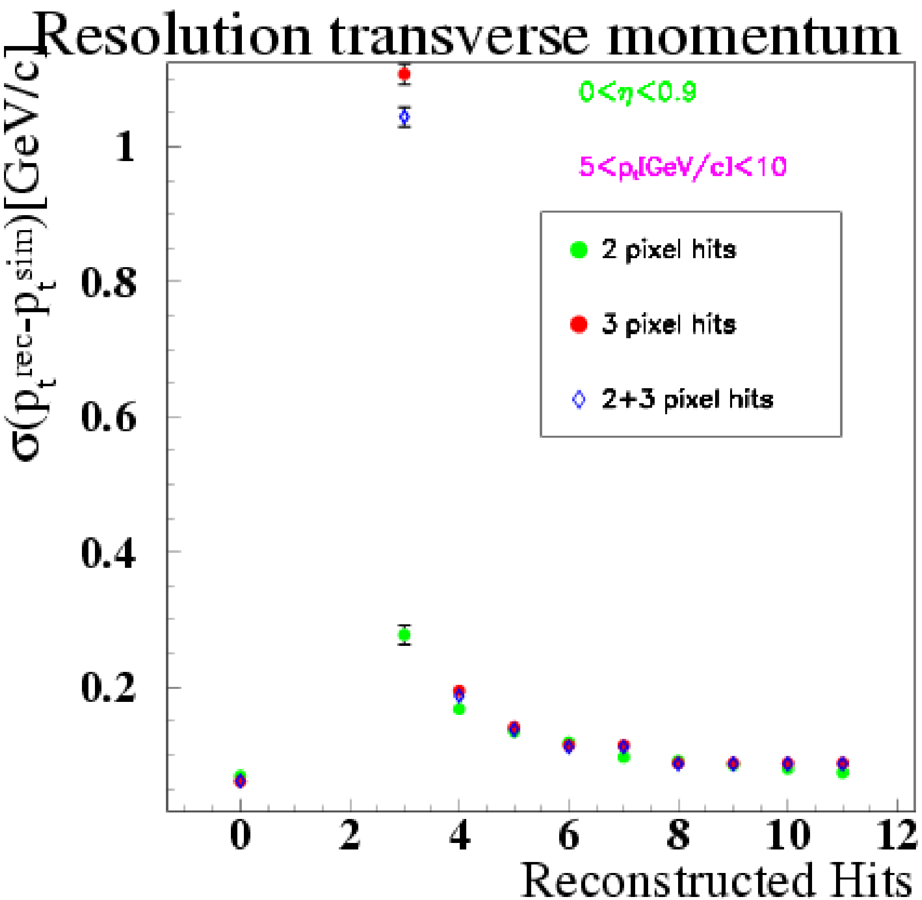
PixelLines [*Danek*]

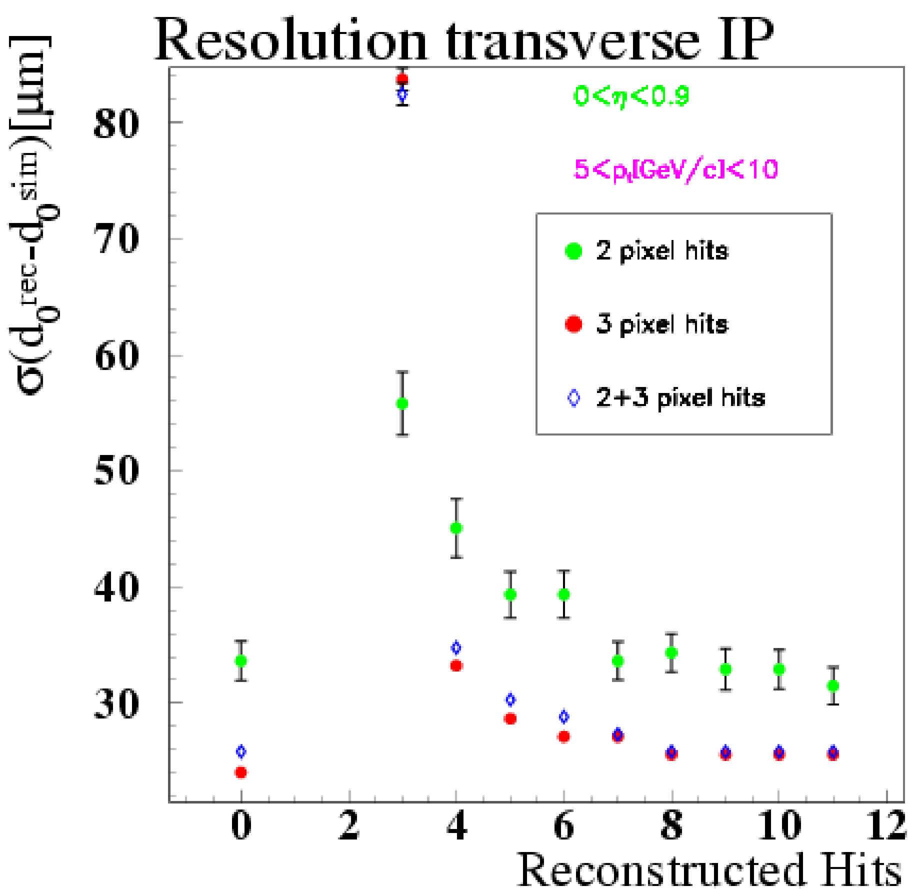
- Minitracks with pixel hits
- **PV** from pixel
- **ΔR** around jet directions

CombinatorialTrajectoryBuilder

- Stopping condition at **n** hits

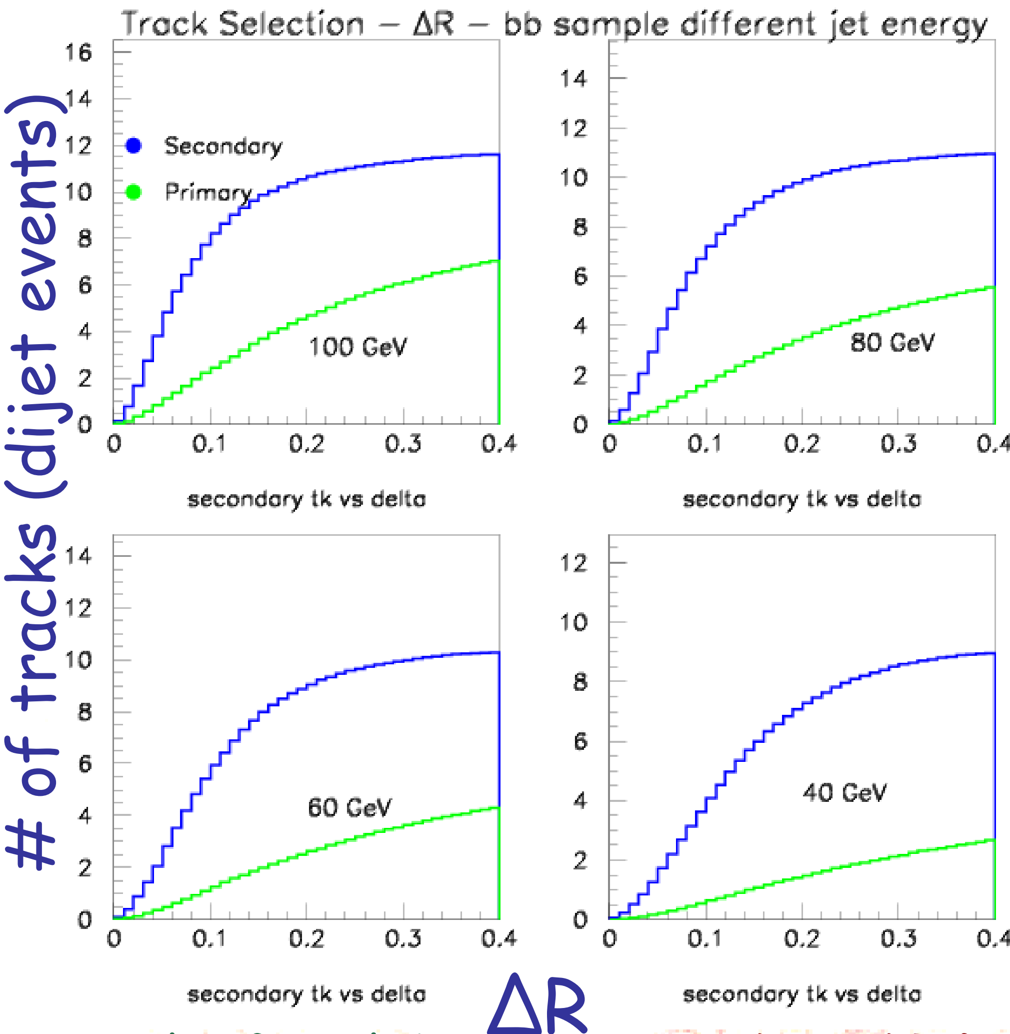
Partial Track reconstruction





Good resolution with only **5 hits** [*Riccardo*]

Region of Interest



Average number of tracks

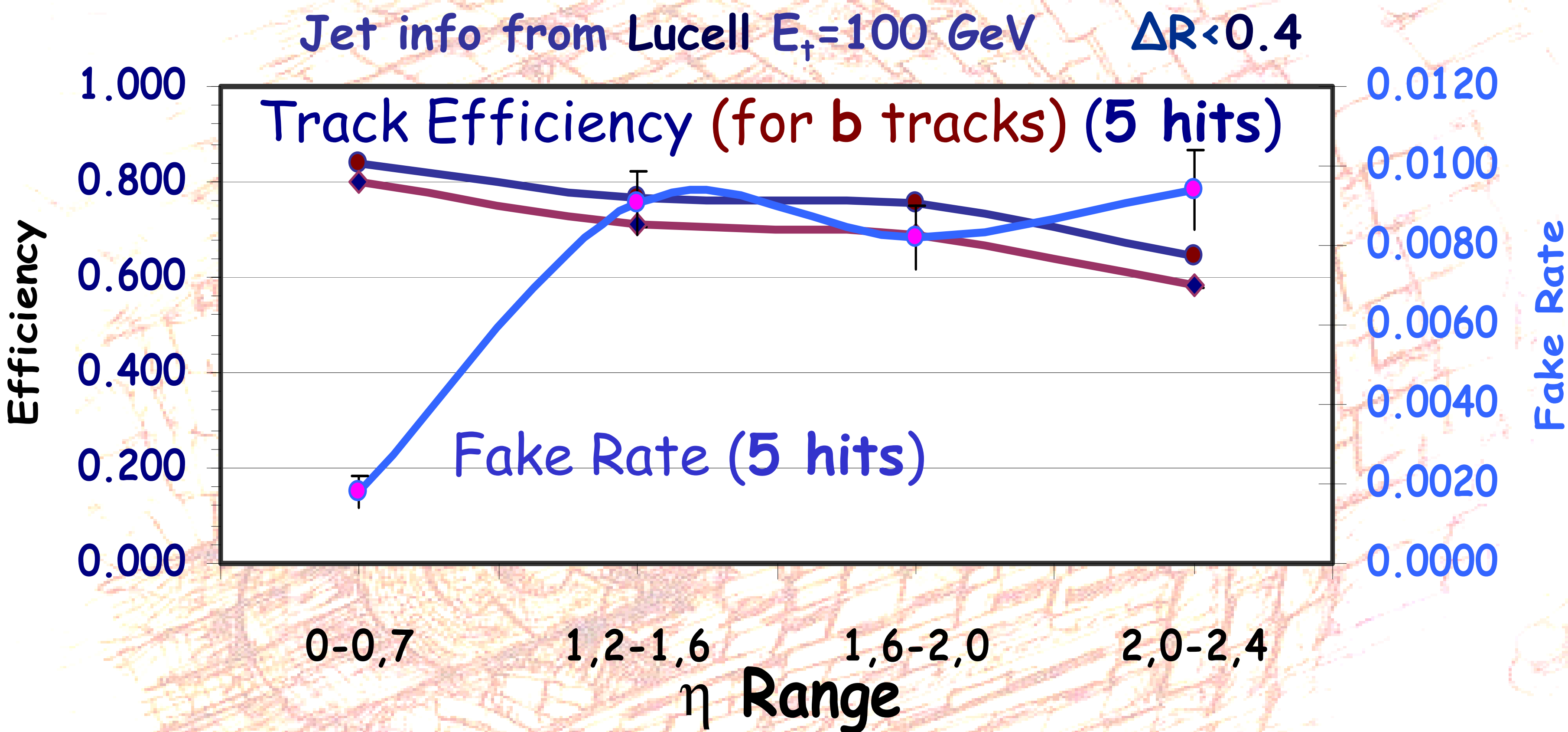
100 GeV sample [PYTHIA/Lucell]

ΔR cut	All	0.4	0.15
Primary	15	7	3.5
Secondary	12	12	10

Best Region of Interest

ΔR<0.4 [*Livio*]

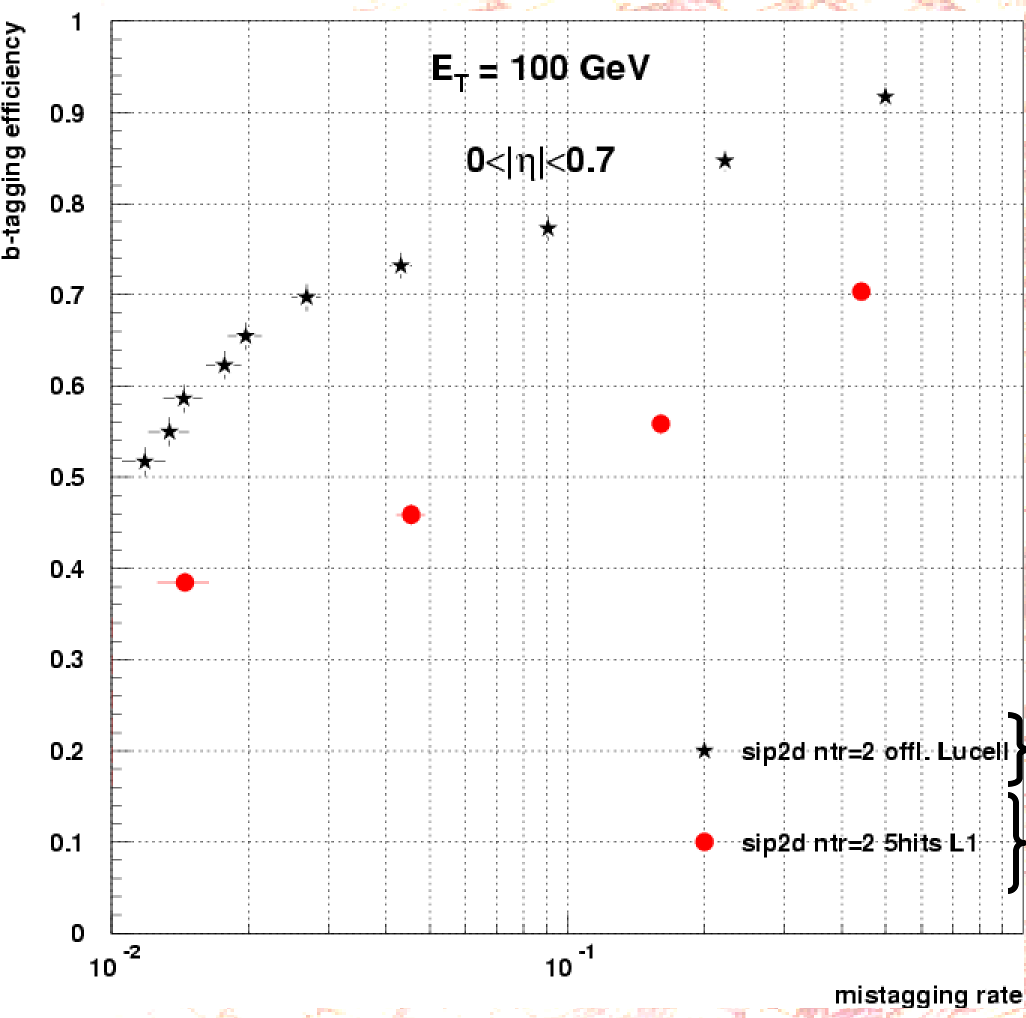
Efficiency bb jets



Fake Rate below 1%

[Riccardo]

B-tag performance



OFFLINE

HLT

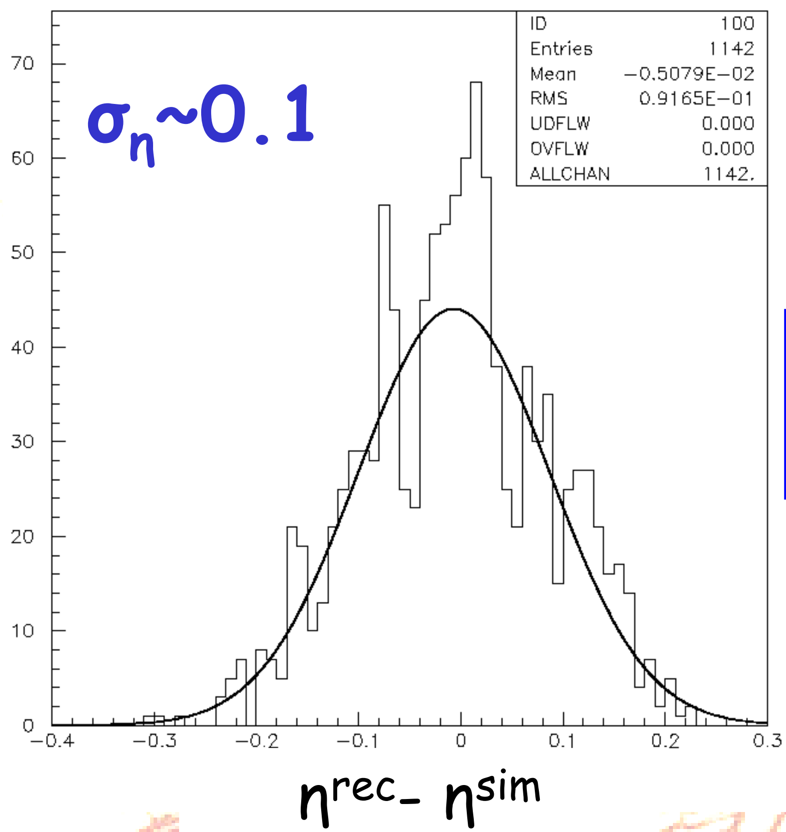
E_t=100 GeV jets barrel 0.<|η|<0.7

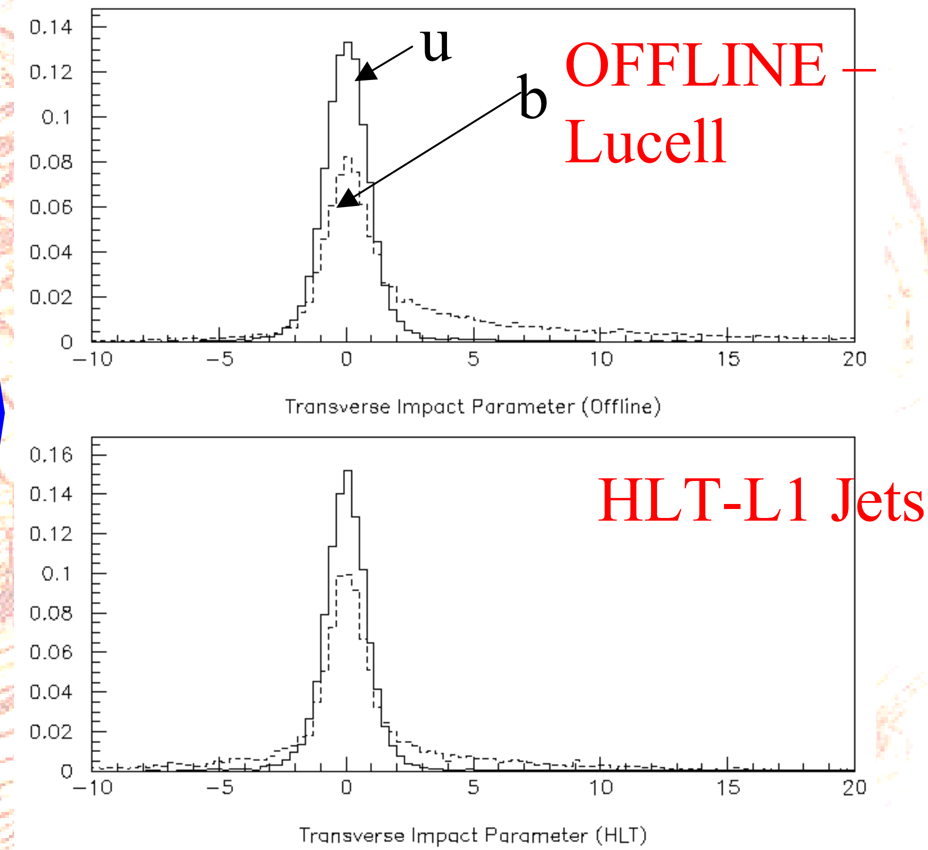
Rejection factor **u** jets **~10** with **b** jets efficiency **<80%** (online)

[*Gabriele*]

Jet-tag: 2 tracks with S_{IP}>0.5,1.,1.5,2.,2.5,3.,3.5,4.

Sign flip of IP





L1 jet (poor) resolution in η and φ (σ~0.1) [*Livio*]

2d transverse IP sign flip [*Gabriele*]

Jet axis measurements

σ_η=0.112

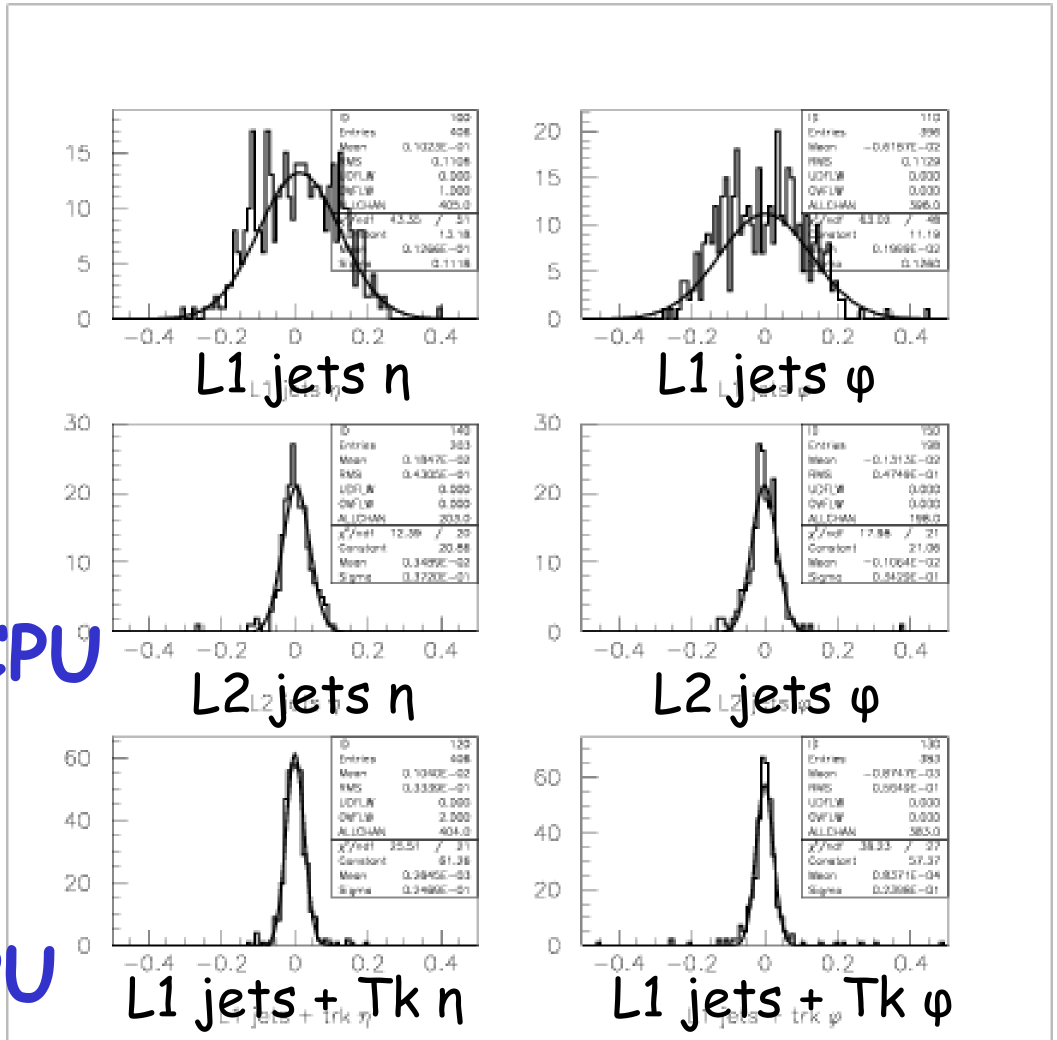
σ_φ=0.126

σ_η~0.037
+70 ms CPU

σ_φ~0.034

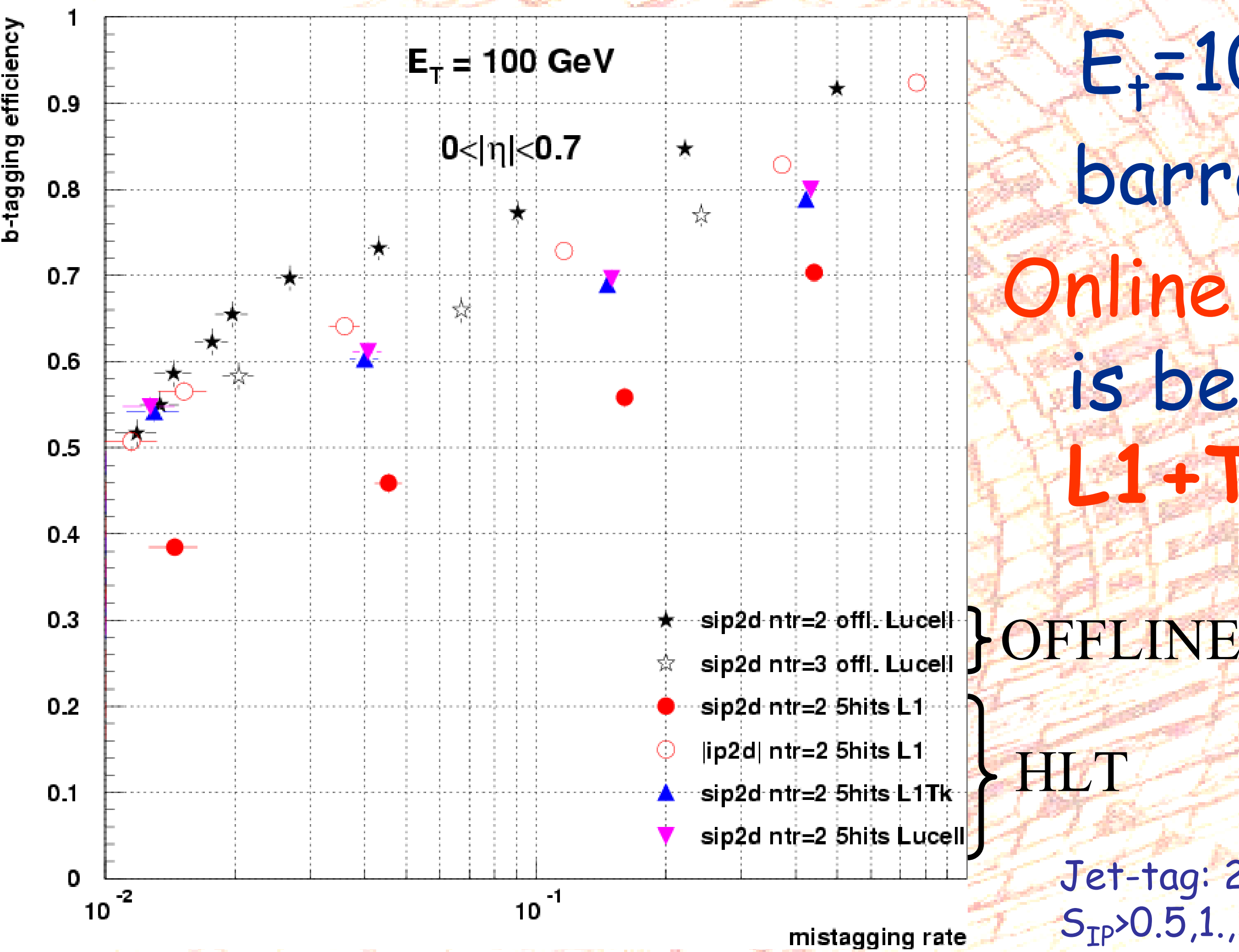
σ_η~0.025
+2 ms CPU

σ_φ~0.024



[*Livio*]

L1+Tracks B-tag



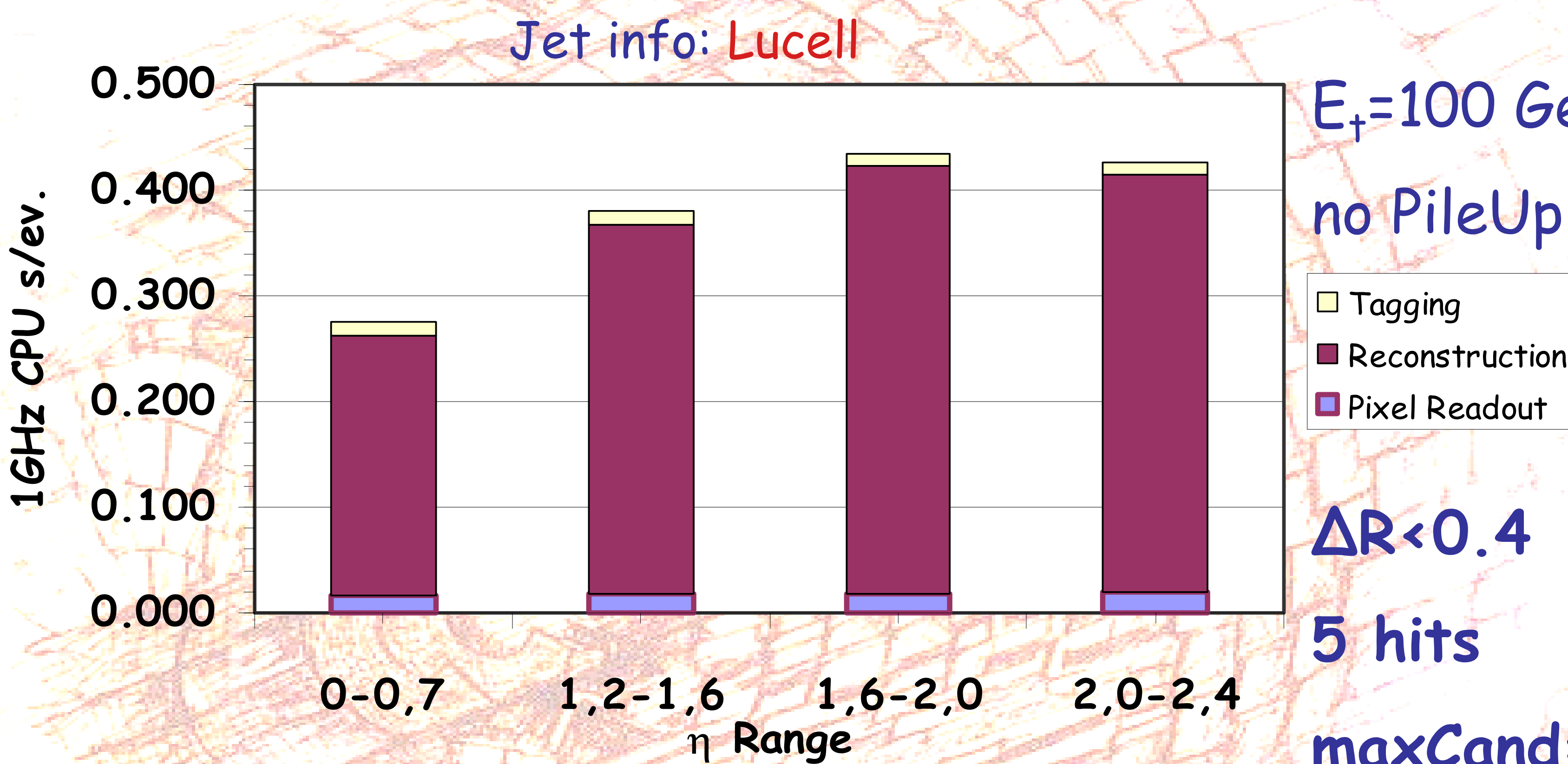
E_t=100 GeV jets barrel 0.<|η|<0.7

Online performance is better with **L1+Tk** jets!!

[*Gabriele*]

Jet-tag: 2 tracks with S_{IP}>0.5,1.,1.5,2.,2.5,3.,3.5,4.

Timing bb jets



E_t=100 GeV

no PileUp

ΔR<0.4

5 hits

maxCand=3

Increasing of reco time towards forward regions

Tagging algorithm: <10 ms/ev !!! [*Riccardo*]

Timing measurements

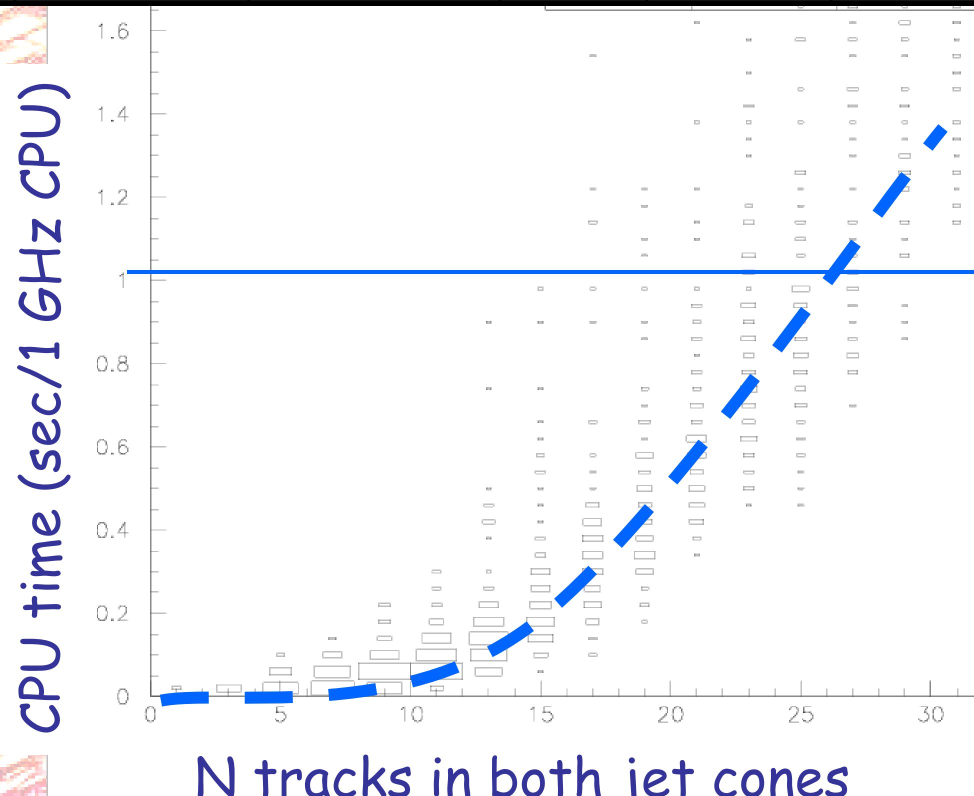
- Pixel Readout: PixelReconstruction::doIt
- Seed Generator: PixelSelectiveSeeds::seeds [< 5%]
- Trajectory Builder:
  CombinatorialTrajectoryBuilder::trajectories [>80%]
- Trajectory Smoother:
  KalmanTrajectorySmoother::trajectories [<10%]
- Trajectory Cleaner:
  TrajectoryCleanerBySharedHits::clean [~ 1%]
- Trajectory Builder: CombinatorialTrajectoryBuilder
  [ModularKFReconstructor::reco]
- Tagging: BTaggingAlgorithmByTrackCounting::isB

Secondary Vertex

[*Pascal*]

	ε_{tag}(%)	<tracks>	RMS	<t>[ms]	σ(t)[ms]
bb	61±3	10	3	90	70
uu	1.0±0.2	7	3	40	30

- CPU time rises as N^2:
  - $\mathcal{O}(N^2)$ vertex fits, i.e. track propagations + matrix algebra
- 50 GeV barrel jets
- Can be improved by at least a factor 2 doing track linearization only once

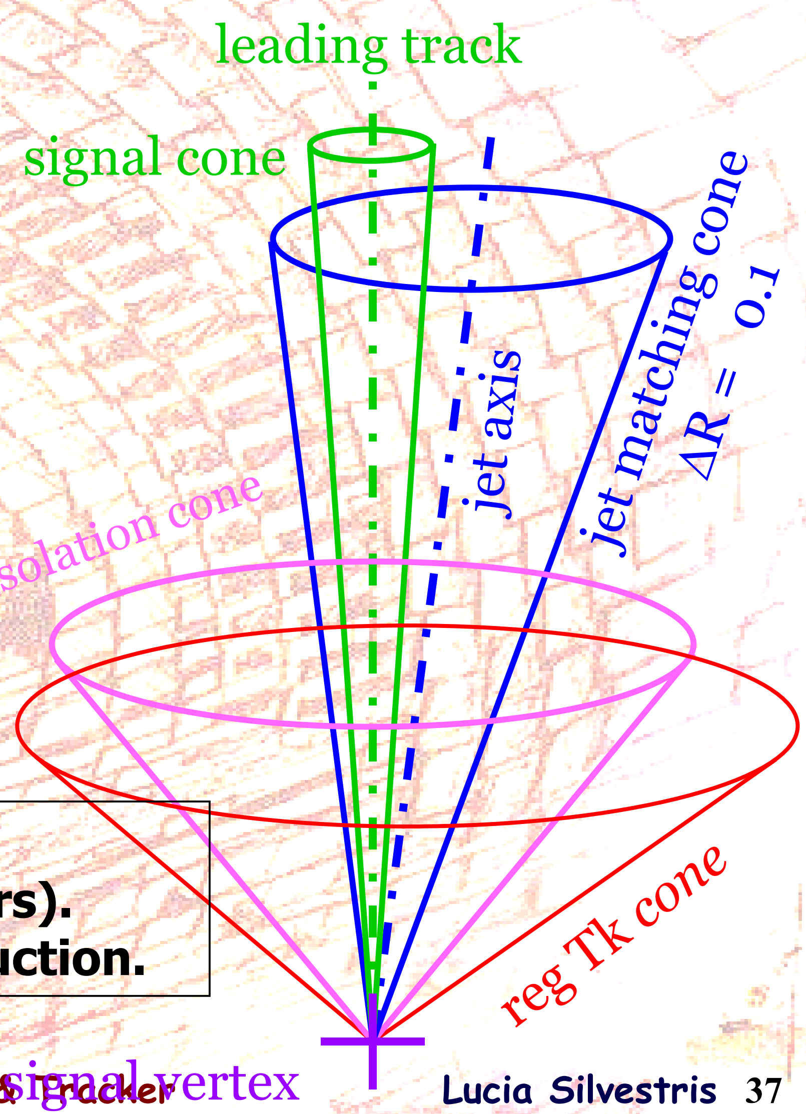


Tau case: Isolation Algorithms

Signal vertex identified by:
Pxl: leading track (P_T>3GeV)
Trk: best signal vertex candidate from pixel Reconstruction.

Both algorithms count number of tracks inside signal (N_{SIG}) cone and isolation cone (N_{ISO}). Events is accepted if leading track exists and $N_{SIG} = N_{ISO}$

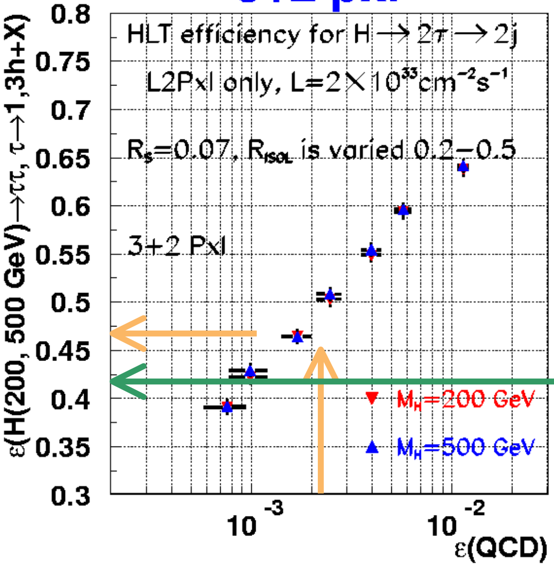
Pxl: use pixel lines (i.e. tracks reconstructed only with pixel layers).
Trk: use regional tracker reconstruction.



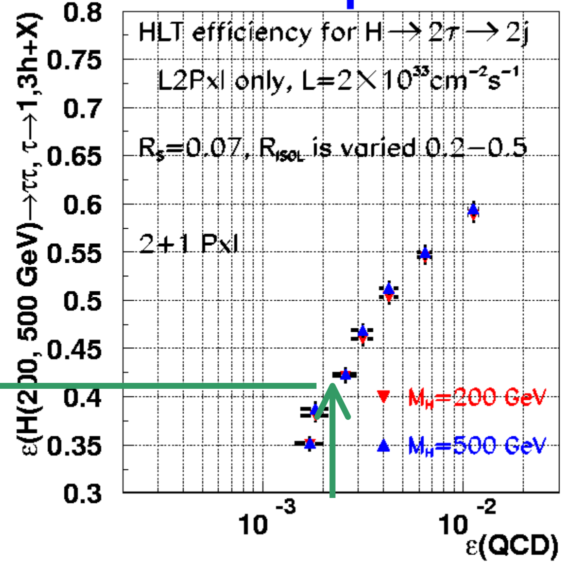
A. Nikitenko

H->2τ -> 2j selections at HLT with Pixel data only.

3+2 pxl



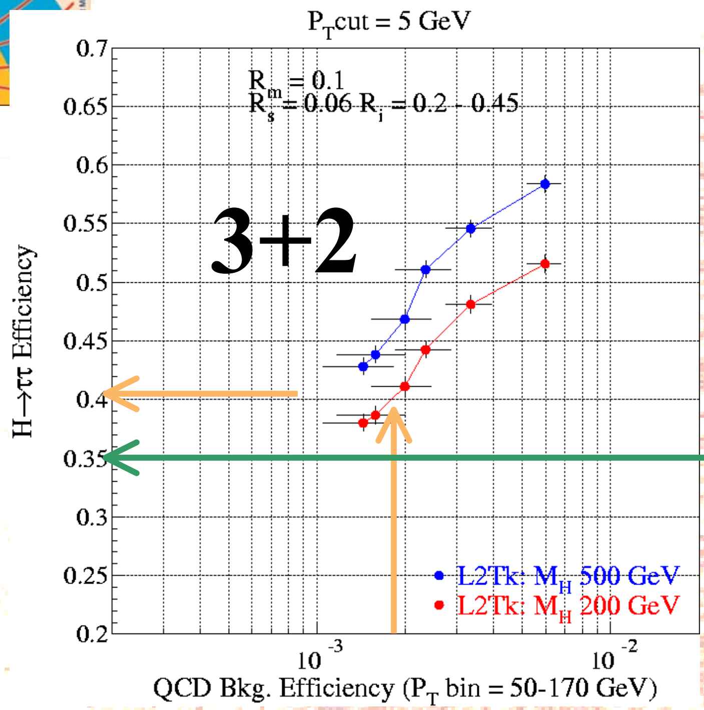
2+1 pxl

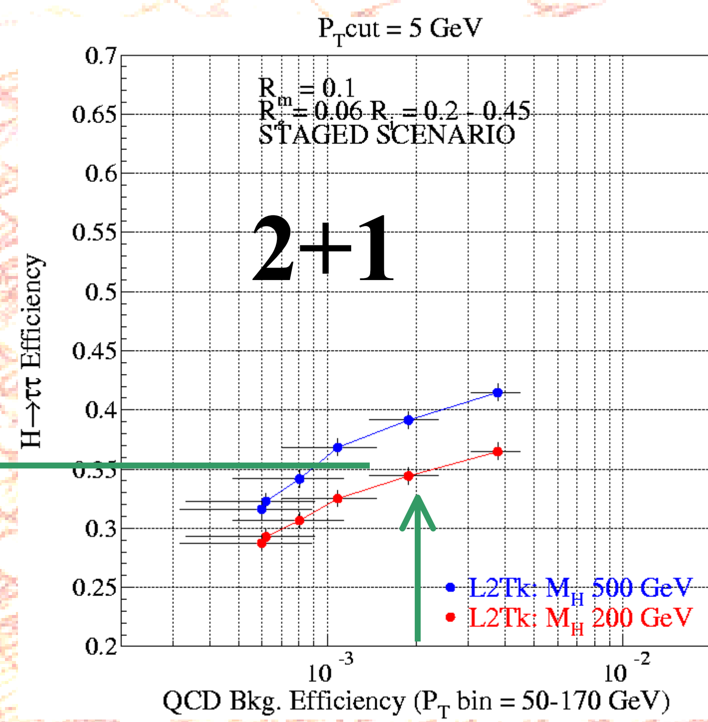


CPU estimates with Pentium III (Coppermine); cpu MHz : 600.

Pxl Tau ID steps ; Time (sec) 3+2 vs 2+1 pxl	qcd 50-80	qcd 120-170	H 200 GeV	H 500 GeV
Pixel RHits reco (getData)	0.0580 / 0.0420	0.0570 / 0.0400	0.0550 / 0.0400	0.0530 / 0.0390
Reco pxl lines and vrtx (doIt)	0.0590 / 0.0390	0.0570 / 0.0370	0.0490 / 0.0320	0.0450 / 0.0290
Pxl Tau ID for 1-st jet	~ 0.001	~ 0.001	~ 0.001	~ 0.001
Pxl Tau ID for 2-nd jet				
Total time (sec) 3+2 vs 2+1 pxl	0.1180 / 0.0820	0.1150 / 0.0780	0.105 / 0.0726	0.0990 / 0.068
Total time (sec) 3+2 vs 2+1 pxl for 1GHz CPU	0.0710 / 0.0490	0.0690 / 0.0470	0.063 / 0.0440	0.0590 / 0.041

$H \rightarrow 2\tau \rightarrow 2$ Jets Selection with Tracker

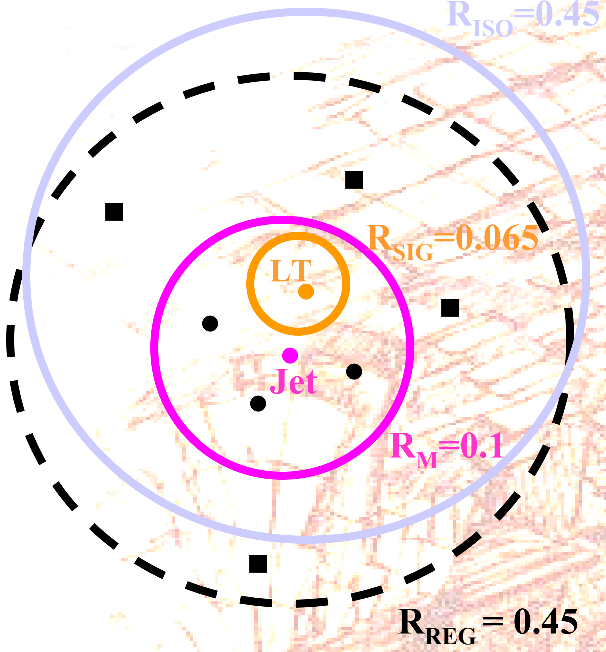




Tracker Reconstruction steps (for single jet) :Time (sec) 3+2/2+1 (1 GHz cpu)

	Bkg	mH 200	mH 500
Pxl Reco	0.070/0.050	0.060/0.044	0.061/0.044
Trk Reco 1st Jet	0.215/0.300	0.063/0.106	0.062/0.100
Isolation for 1st jet	<0.005	<0.005	<0.005
Total Time	0.290/0.351	0.124/0.152	0.127/0.145

How to reduce tracking time



- Reconstruct tracks inside R_M only
- Find LT:
  - If LT doesn't exists stop everything
  - If LT exists apply isolation on rec Tk, if it is not isolated stop everything
- If event is isolated go on reconstructing also tracks inside region between R_M and R_{REG}
- Apply isolation to all tracks.

Tracker Reconstruction steps (for single jet) :Time (sec) 2+1 (1 GHz cpu)

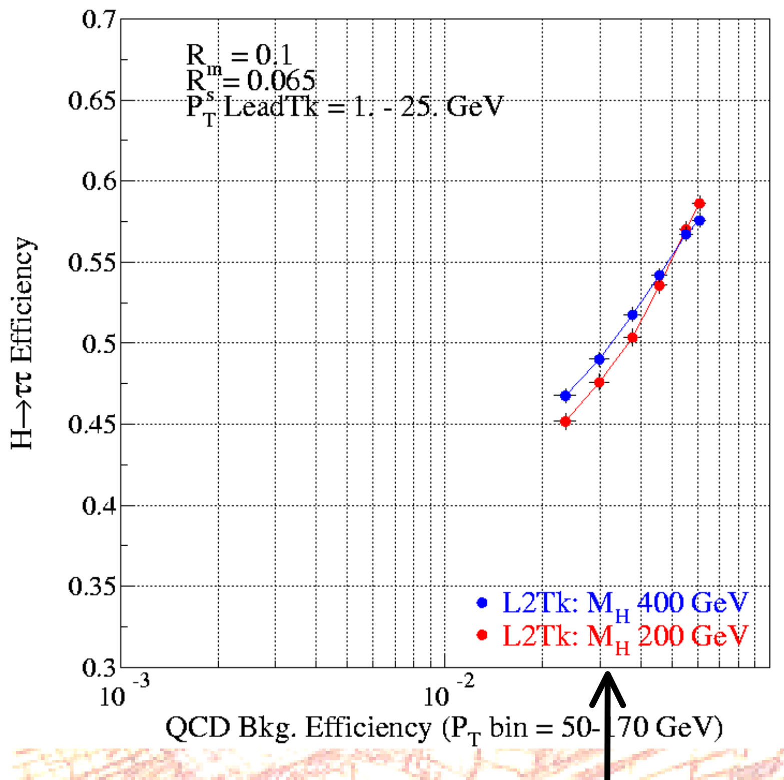
Staged scenario	Bkg	mH 200	mH 500
Total Time (pxl + Tk + iso)	0.351 -> 0.216	0.152 -> 0.136	0.145 -> 0.126

$H^+ \to \tau\,\nu \to j\ \nu\nu$ Selection with Tracker

PRELIMINARY

- Low luminosity: 2×10^{33} cm^{-2} sec^{-1}
- Only 3+2 Pixel scenario
- Higgs mass = 200, 400 GeV/c^2
- L1 Calo = 1 τ-jet, E_T > 80 GeV
- L2 = Missing E_T (MET) + L2 Tk:
  - MET > 80 GeV
  - L2 Tk: isolation + hard pt_{cut} on leading track
- Final Goal is a bkg rejection ❽ 30 after L1 and MET cut.

$H^+ \to \tau\nu \to j\nu\nu$ Selection with Tracker



L2Tk working point:

R_M=0.1, R_S=0.065, R_I=0.4

P_T LeadTk > 20. GeV

PTLeadTk > 20 GeV:

Time reduces again:

216 -> 192 msec!!!!

Simone, Giuseppe

Exclusive channels

$B_s \to J/\psi\ \varphi \to \mu\mu\ KK$

900 events cmsim122/ORCA534

Generator Level:

$p_t^{\mu}>2$ GeV, $p_t^{K}>0.5$ GeV [μ, K inside Tracker]

Timing:

@ 1 GHz CPU [s/ev]	3 Pixel	Staged Pixel
Seed Generation	0.195	0.086
Full Tracker chain	0.300	0.179

Channel reconstruction

L1 Muon trigger

ε=30.4% (no trigger cut L1 μ, at least 2 μ)

LazySeedGeneratorFromPixel

LazySeeds [*Nikita*]

$\Delta\eta$<0.5 $\Delta\varphi$<0.8 **PV**±0.5 cm

(around L1 μ direction)

CombinatorialTrajectoryBuilder

stop: p_t<2 GeV @ 5σ

hit=6 or $\sigma(p_t)/p_t$<0.02

maxCand = 2 [default: 5]

J/ψ mass reconstruction

[*Nikita*]

100 MeV window around $m_{J/\psi}$

ε=24.8% [staged pixel:19.9%]

Tracker @ HLT

- Today …
  - We achieved close to 100-150 ms CPU times (or better) for complex HLT tracker algorithms (if we consider the DetLayer improvement see Teddy presentation at Tracker General meeting) in February 2002
  - The tracker can be used at the first stage in the High Level Trigger on all events
- **Tomorrow ..**
  - **Further improvements foreseen:**
    - Regional Seeding speed up in case of PileUp and High Luminosity

Tracker @ HLT (Next Steps)

- When high luminosity samples will be available.. (already produced should be moved at CERN)
- … more and more realistic environment (Staged pixels, PileUp, High Luminosity, Mis-alignment)
  - Tau studies with high luminosity
  - B studies with low and high luminosity
  - Muon and electron studies (with PRS Muon and ECAL) at low and high luminosity.

High Level Trigger (III)

- **Physics Selection**
  - Higgs Searches
  - SUSY Searches
  - B Physics

- **Control and Monitoring**
  - Calibration
  - Alignment

Alignment Tools

- ORCA Alignment Tools (Helge, Britta)
  - MC generation with perfect geometry
  - simulate arbitrary misalignment at reconstruction level
    - study track reconstruction (efficiency/resolution)
    - test alignment procedures
    - apply alignment procedures
- reflect structure of physical components:
  - realistic misalignment scenarios
  - minimizes later alignment parameters
- Now the same tools are used also from PRS Muon (Celso Martinez)

Alignment Conclusions

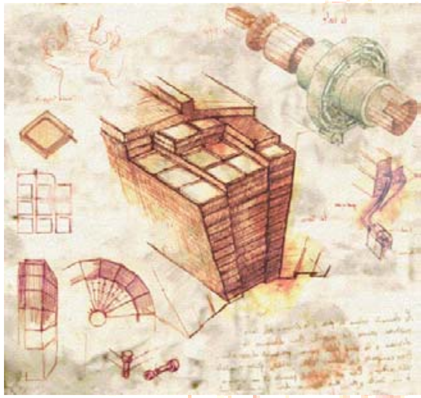
- Alignment Tools: they work ✓
  - one can still add functionality
- Alignment studies:
  - reconstruction is uncritical up to even 1mm/1mrad misalignment (10 times more than survey/laser-alignment accuracy)
- How the mis-alignment affect the Tracker at HLT…
- Be patient.. Wait July…

DAQ TDR Conclusions

- First version now frozen, on the Web, for internal consumption.
  - HLT chapters untouched wrt last version. Currently working on quick edit.
  - Major changes needed respect the first version (for Tracker at High Level Trigger)
- Nest step: non-HLT part of TDR to be edited until May 24
  - HLT-part to be updated until then
  - Contact for PRS Tracker (Ariane)
- First meeting for DAQ TDR (Tracker) 7 May 2002 14:00
- Goal: draft 1 to coll. on CMS week, June 10 (!)

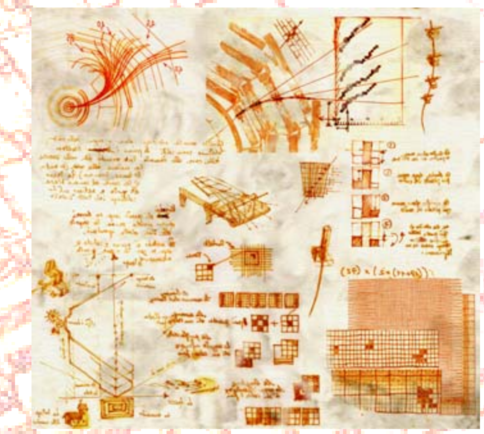
DAQ Technical Design Report

Hcal

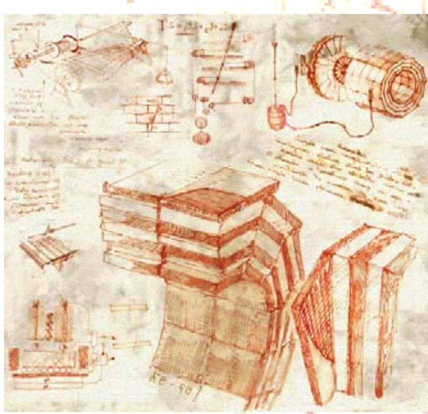


Ecal

Lv1 Trigger



Muon



Tracker

CMS

The Trigger/DAQ project

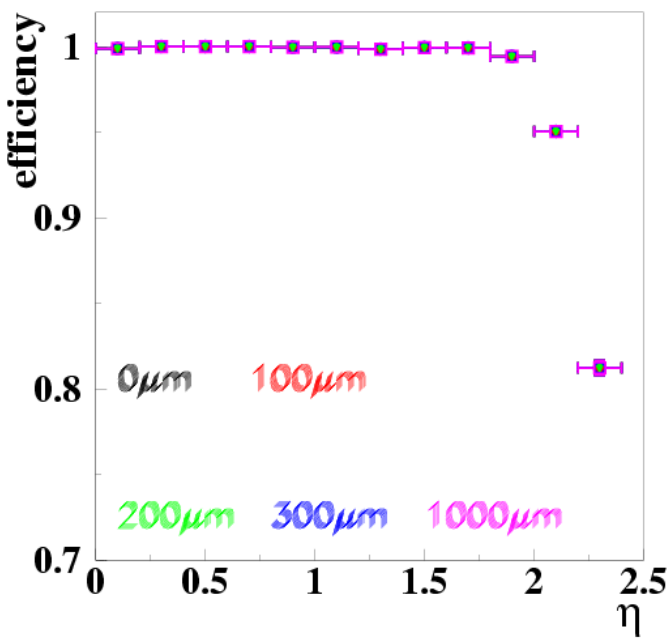
Data Acquisition & High Level Trigger

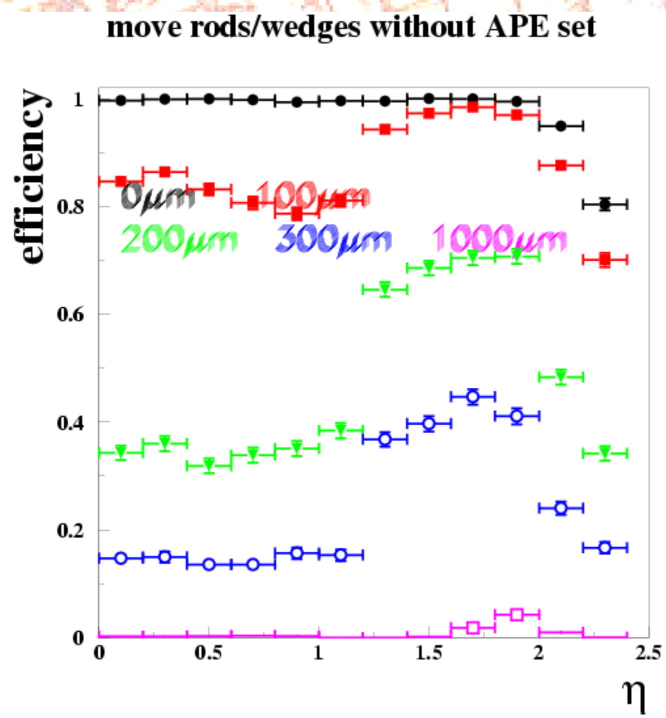
Technical Design Report

Issue:	Draft
Revision:	0.2α
Reference:	CMS TDR-6.2
Created:	02 October 2001
Last modified:	04 October 2001
Prepared By:	CMS/TriDAS Collaboration

Misalignment Studies (single-μ)

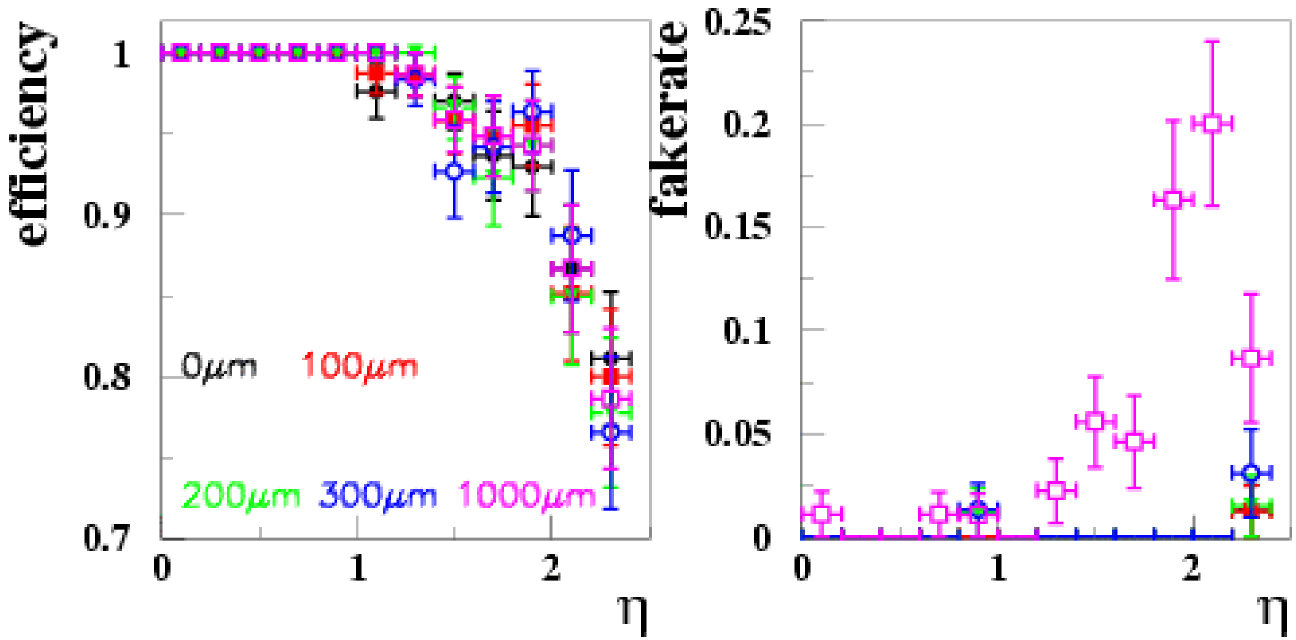
- track reconstruction (single-μ, P_t =100GeV)
- random movements of rods / wedges + setting the Ali.Pos.Err. accordingly





Z→μX events with pileup (low lumi)

- random movements of rods / wedges
- reconstruct tracks with $P_t > 10GeV$



- reconstruct Z-mass in $Z \rightarrow \mu\mu$ events
  - movement rods/wedges $\sigma_x = \sigma_y = \sigma_z = 1000\ \mu m$