Summary of PRS/Muon Activities

D. Acosta
University of Florida

- Review of past results
- Ongoing work toward HLT milestones
- Analysis environment

HLT Milestones

The PRS groups are focused on meeting several milestones on HLT development for the DAQ TDR:

- **Dec. 2001:**
  - Complete HLT selection for low-luminosity scenario
- **Mar. 2002:**
  - Determination of calibration methods and constants
  - Data rates, data formats, online clustering
  - CPU analysis for low lumi selection
- **Next step for June 2002:**
  - Complete HLT selection for high-lumi scenario
  - HLT results on B physics
  - CPU analysis for high lumi selection
  - Repeat on line selection for low-lumi

CSC Data Rates

Assumptions

- ➔ LCT occupancy is estimated using ORCA, including neutron background
- ➔ Muon content of L1 triggers is assumed to be 50%
- ➔ Jet and e/γ triggers are assumed to have a hard scale, and increased LCT occupancy is estimated from Pythia+ORCA
- ➔ Overhead for S-Link64 headers and empty events is 57.6 MB/s @ 100 kHz DAQ

Low Lumi (2×10^{33}):

- ➔ 50 kHz DAQ, ME4 staged, 16 time samples, CLCT selection
- ➔ 500 MB/s (600 MB/s with 3× safety factor on neutrons)
- ➔ Average occupancy is 1.8 segments ⇒ 10kB/event

High Lumi (10^{34}):

- ➔ 100 kHz DAQ, ME4, 8 time samples, ALCT*CLCT selection
- ➔ 1100 MB/s (1300 MB/s with 3× safety factor on neutrons)
- ➔ Average occupancy is 3.4 segments ⇒ 10kB/event

n.b. 10 kB is about 1% of the size of the tracker data volume…

DT Data Rates

U.Gasparini

- Total size: 9 KB/event

(including an estimated 35% overhead in headers-trailers; this is in a specific ROS format proposal; final one yet to be defined)

- Small amount of data => all DT data transferred to DAQ @ each L1A

- L2 input @ 100 KHz: 900 MB/s to DAQ

=> 900 MB/s / 60 = 120 Mb/s bandwidth on ROS-DDU links

HLT Single Muon Rates

What was shown in December for $L = 2\times10^{33}$:

p_T **threshold set to 22 GeV**

Single μ stream: summary

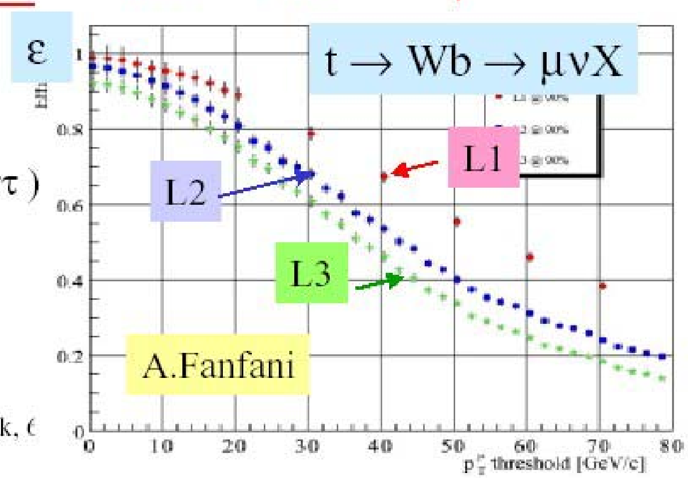
	L1	L2	L2+iso	L3	$L3_{Pxiso}$
p_T (GeV)	14.	14.	14.	22.	22.
Rate(Hz)	3600.	900.	500(calo) 300(pixel)	90.	24.
ε (W->μν)	0.85	0.78	0.75	0.55	0.50
ε (t->Wb->μνX)	0.93	0.88	0.84	0.73	0.66
ε (H_{200}->ττ->μX)	0.77	0.70	0.67	0.53	0.48
ε (Z->μμ)	0.99	0.98	0.94	0.94	0.93
ε (H_{120}->2μ2ν)	0.96	0.93	0.90	0.76	0.75

W : 11 Hz
Z : 1 Hz
b/c → μ: 10 Hz
K/π→ μ: 2 Hz

efficiencies must be multiplied by geometrical acceptance
(ε_{acc}= 0.57 for W → μν, 0.92 for H → ττ)

** all numbers are preliminary **

U.Gasparini CMS week, (



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Recent Re-Analysis of Single μ Rate

M.Konecki

PT	L1	L2	L3	L3IPx	L3IPxC
	Standalone muon measurement		With Tracker	With Pixel isolation	Isolation + pixel line
16	2500.04	717.31	252.97	89.4243	60.1642
17		591.267	195.409	67	42.4445
18	1945.23	525.119	158.483	52.9872	31.0895
19		430.511	127.835	41.6912	22.748
20	1543.63	392.41	107.195	34.7845	17.7768
21		264.101	79.764	24.9658	11.5318
22		**248.638**	**68.4177**	**20.6414**	**8.70907** +12 = 21 Hz
23		233.212	61.0832	18.8946	7.25566
24		219.454	53.538	16.7527	5.90529
25	885.173	204.444	47.3989	15.1819	4.64781

A little unclear why there is improvement

What used to be 24 Hz in Dec.

Rates only for minbias events – must add about 12 Hz W/Z for total

Di-muon rates (inclusive/exclusive)

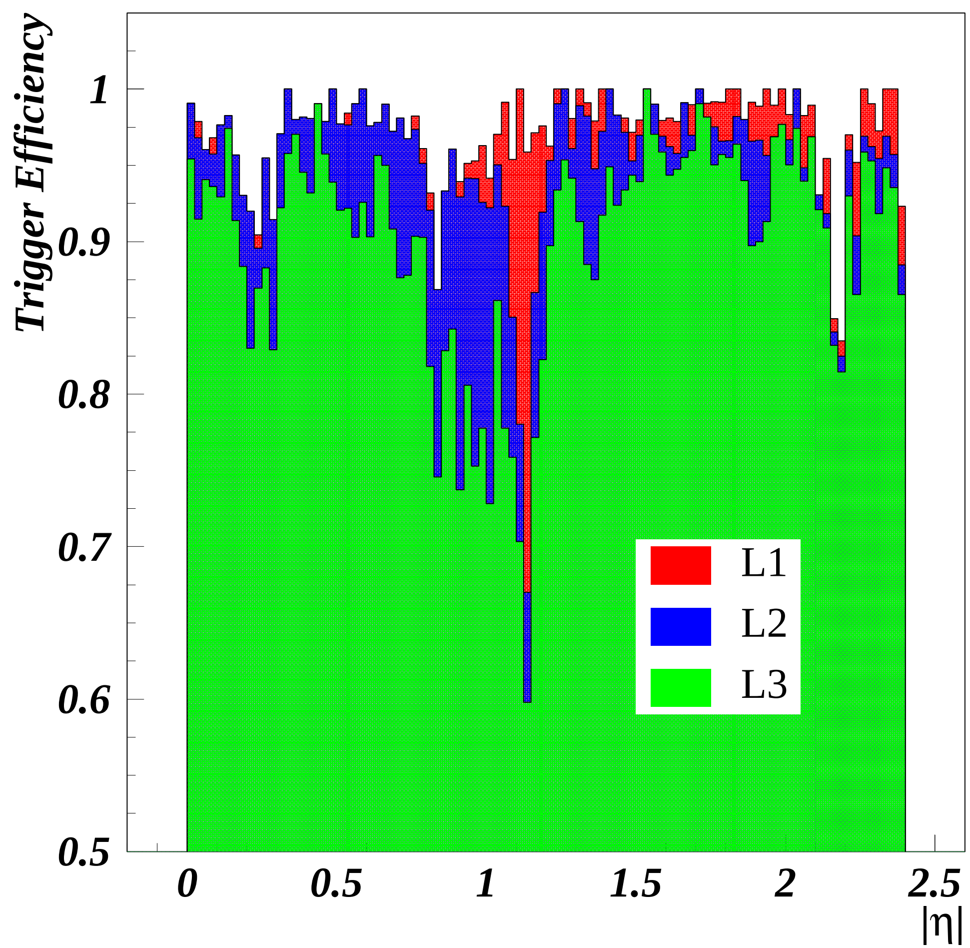
S.Arcelli, A.Fanfani

Pt cuts (GeV)	Min. Bias (Hz)	Z/g* (Hz)	Tot. Rate (Hz)
12-8 (inc)	6.5 +/- 0.6	1.59 +/- 0.04	8.2 Hz
12-8 (exc)	5.2 +/- 0.6	0.26 +/- 0.01	5.5 Hz ←
10-10(inc)	4.1 +/- 0.5	1.50 +/- 0.04	5.6 Hz
10-10(exc)	3.1 +/- 0.5	0.20 +/- 0.01	3.3 Hz

- Total L3 muon rate for $p_T > 22$ and $p_T > (12,8)$ is 27 Hz
- For ATLAS thresholds of $p_T > 20$ and $p_T > (10,10)$ the CMS muon rate is 33Hz (compared to 40 Hz ATLAS)
- Need to understand better the isolation and tracking results

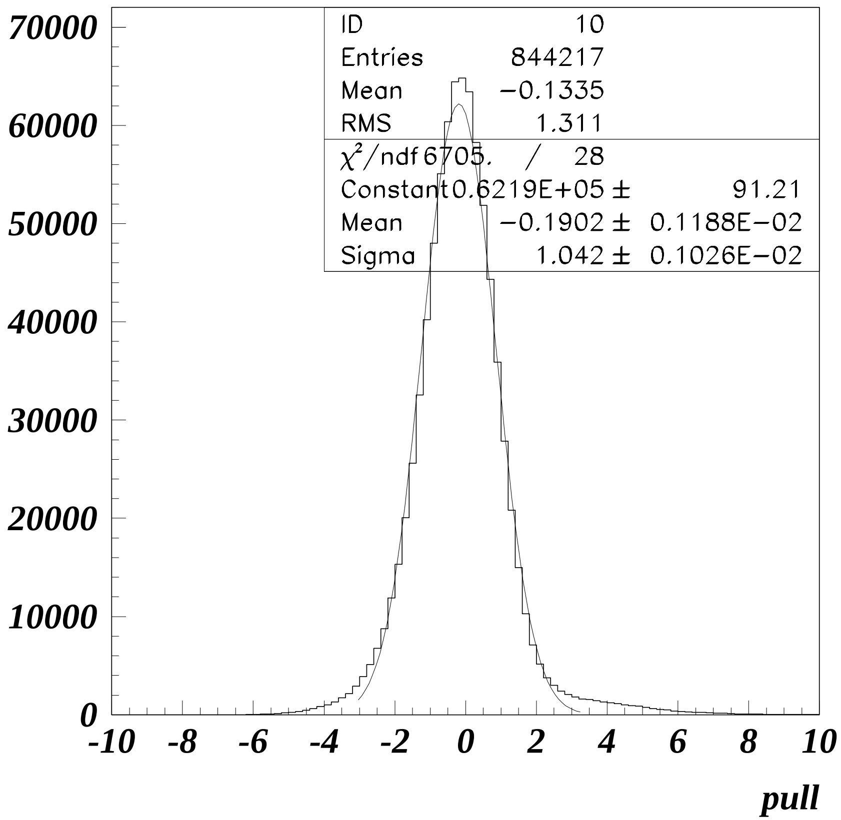
Muon reconstruction efficiency (L2 and L3: only DT+CSC)

ORCA 5 3 4

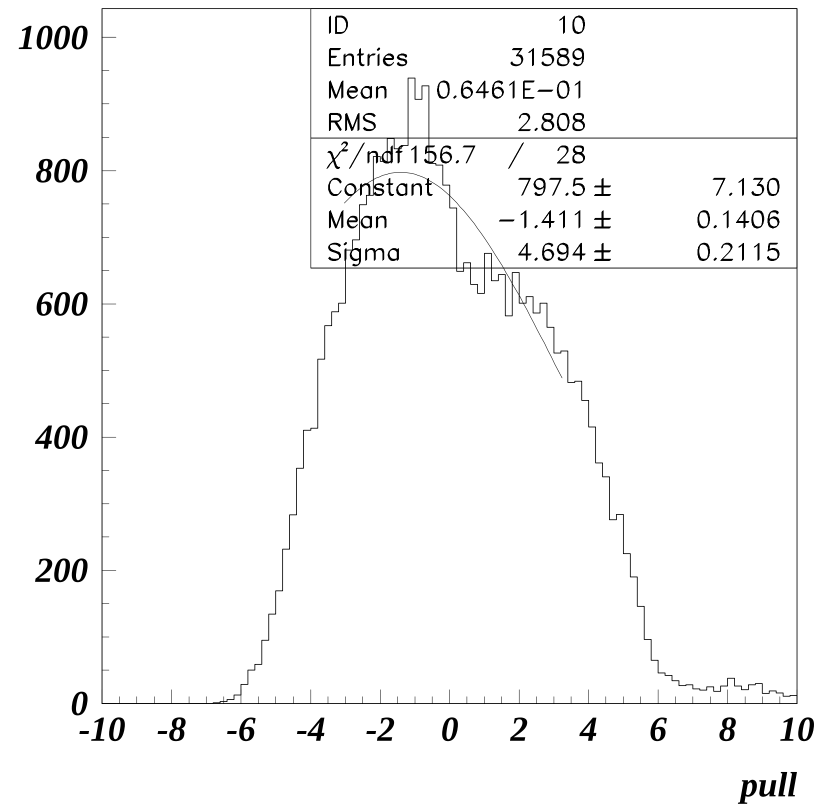


DT point pull: φ view

Total

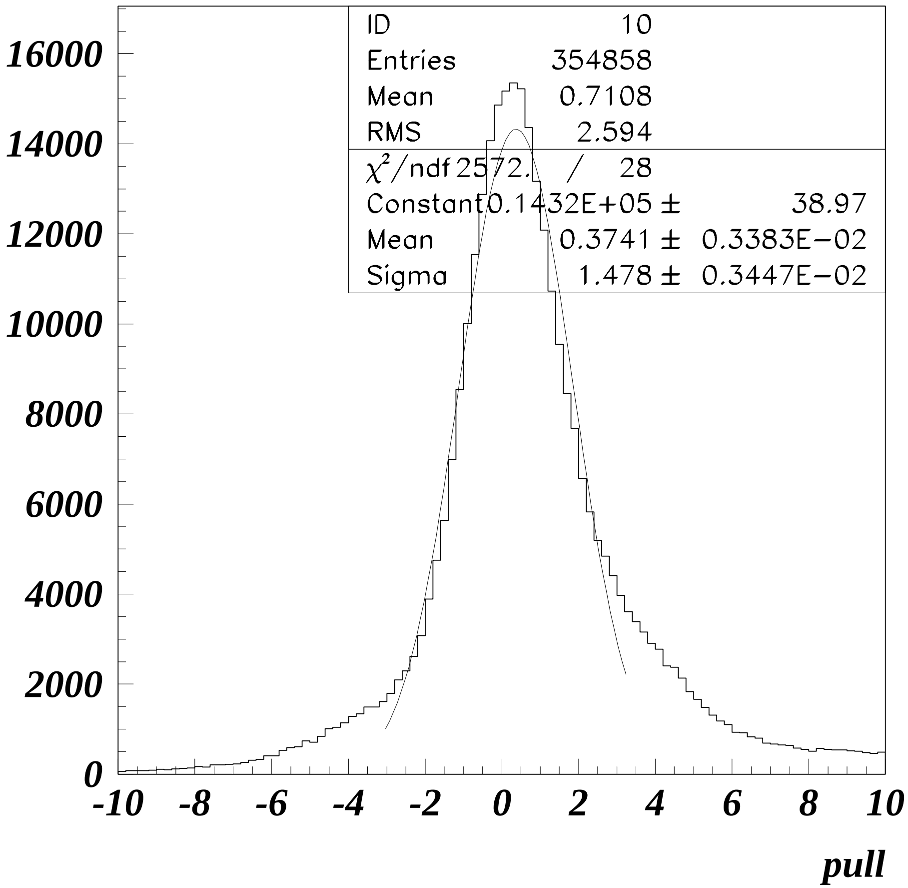


MB1 -overlap

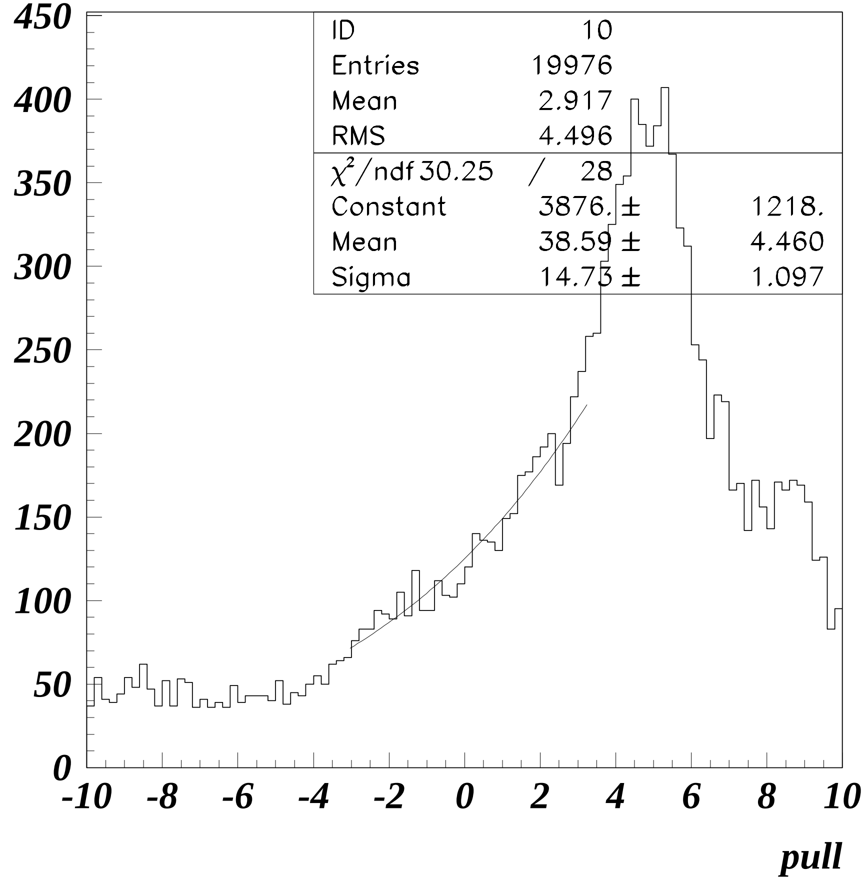


DT point pull: θ view

Total



MB1 -overlap

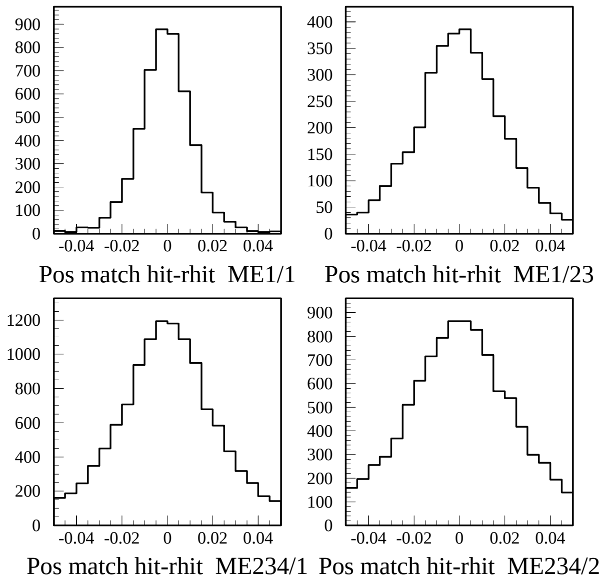


CSC Residuals

From R.Wilkinson:

RecHit Resolutions

	Resolution (μm)	Pull width
ME 1/1A	105	1.17
ME 1/23	187	1.16
ME 234/1	210	1.17
ME 234/2	237	1.36



Not clear:

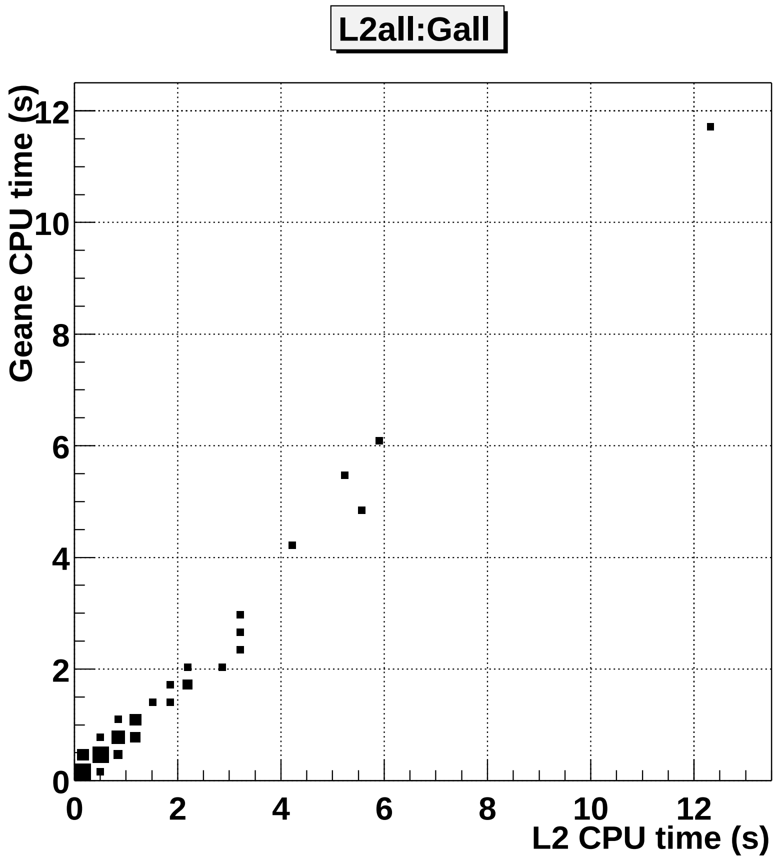
- Why a bit worse than our CMS note
- Why ME234/2 is worse than ME234/1

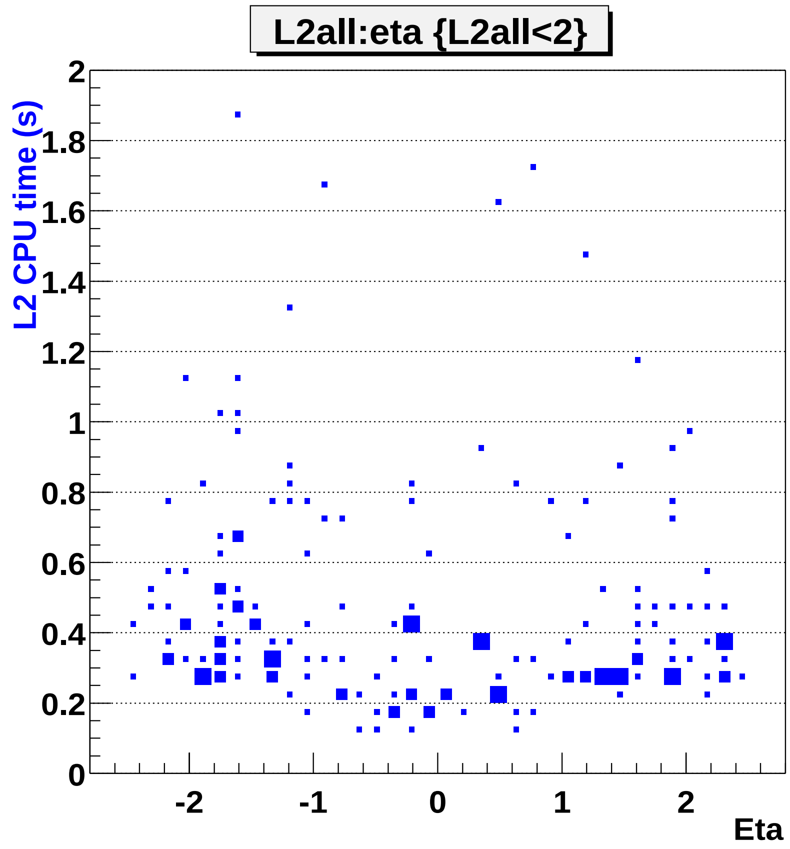
L2 CPU analysis (I):

- L2: ~ 780 ms/ev large fluctutation (see after)
  - Seed generation ~ 25 ms/ev
  - Trajectory builder: ~ 680 ms/ev
  - Vertex constraint ~ 75 ms/ev
- Trajectory builder: ~ 680 ms/ev
  - Forward K. filter (FTSRefiner): ~ 460 ms/ev (bigger initial error)
  - Backward K. filter: ~ 220 ms/ev

    of which:
    - Extrapolation inside DT/CSC chamber: ~ 30 ms/ev
    - Kalman update: ~ 20 ms/ev
    - Segment building: ~ 60 ms/ev

L2 CPU analysis (IV):





all L2 time is spent inside Geane!

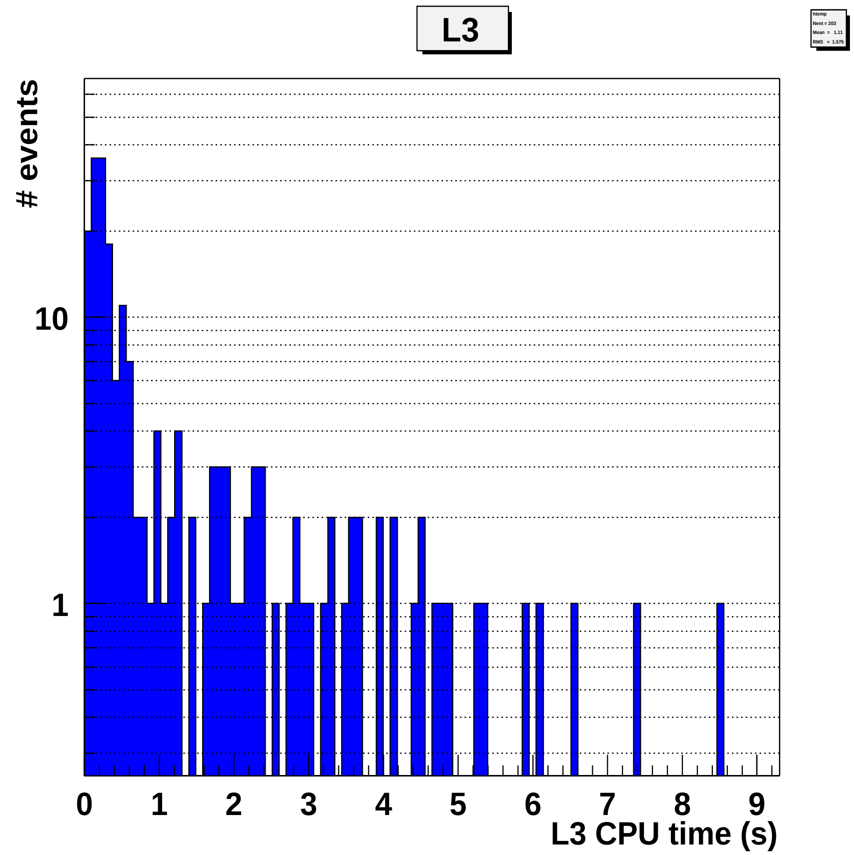
$\sim$ slower in the endcap

L3 CPU analysis:

L3: ~ 1680 ms/ev

large fluctuation (see $\Rightarrow$)

- Seed generation ~ 90 ms/ev
- Trajectory builder: ~ 1580 ms/ev
- Trajectory smoother: ~ 8 ms/ev
- no η correlation, slower for low p_T muons.



Faster L2 Algorithms

Several approaches (from conservative to extreme)

- ➔ Replace GEANE with faster propagation method based on parameterizations
  - Possibility first explored by O.Kodolova
  - Needs someone to implement method to propagate through iron in current muon reconstruction package
- ➔ Optimize detector layout in ORCA to minimize GEANE calls
  - Under development by N.Amapane to replace detector wheel (ring) with azimuthal sector (rod) →
- ➔ Minimize (or eliminate) GEANE calls by optimizing L2 segment selection and parameterize track parameters
  - Recently studied by M.Konecki using L1 information to guide L2 algorithm →
- ➔ Use *only* L1 information to swim tracks inward to pick up tracker hits at L3
  - Bypass even L2 segment building by using precision L1 segments stored in DAQ banks
  - Needs a volunteer…

Current L2 Navigation

On average, 270 calls to GEANE propagation per event!

- For each DL, 3 rings are checked
- For each ring 3 DetUnits are checked
- For each of the 9 DetUnit a full propagation thru IRON is made
  - Most of these propagations start from the same FTS and end to the same surface…

- Possible optimizations:
  - Take into account detectors only if they are REALLY compatible with FTS (using errors); as done by Stefano
  - Re-use propagated states

Do not fit in current DetLayer design!

$\Rightarrow$ A different approach investigated

- Re-design the DetLayer layout

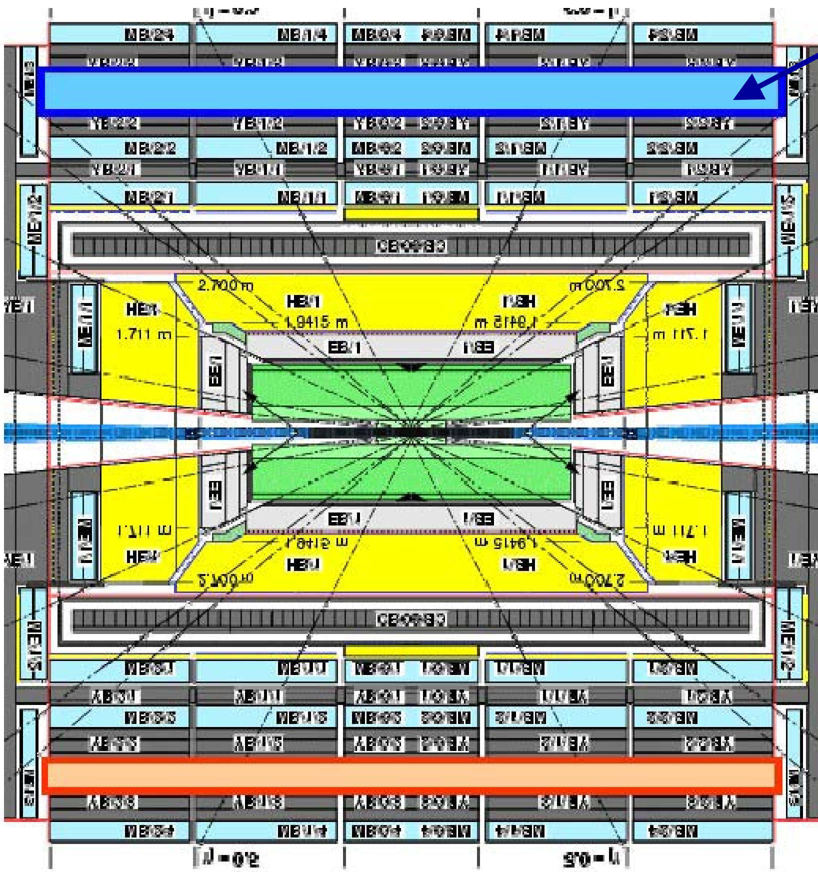
Caveats: Very preliminary results, barrel (DT) only

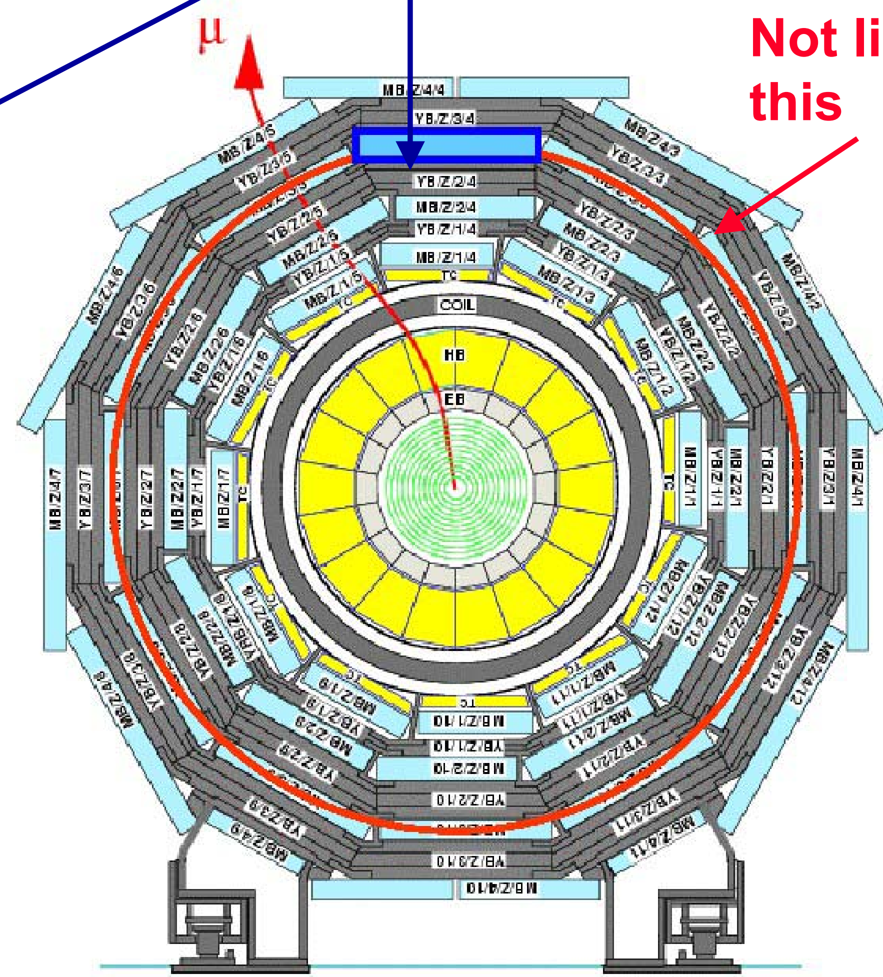
Composite Detector Organization

- MRodBarrelLayer (12/14 MDetRod)
- MDetRod (5 DetUnits)

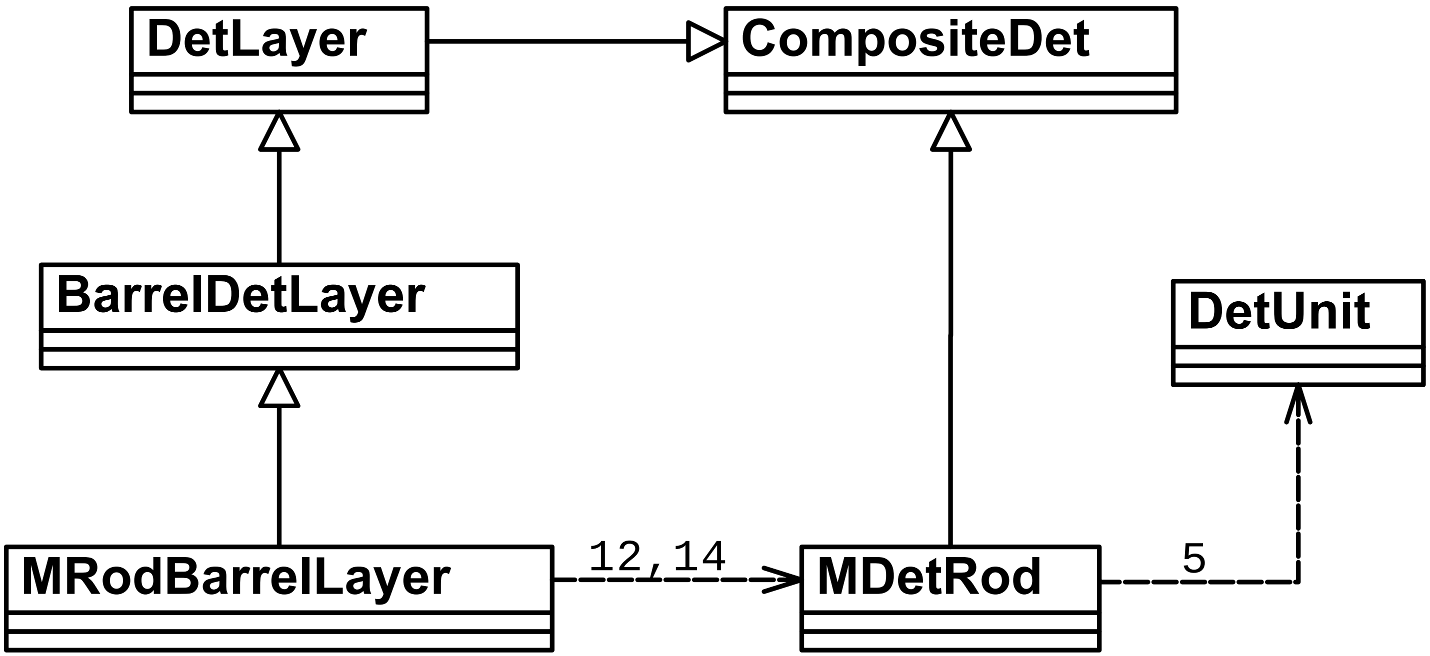
Group chambers this way

Not like this





Layer composed of Rods



- Implemented following TrackerReco's recent improvements
  - Cfr. TkRingedBarrelLayer
- DetUnits in a rod have the same surface of the DetRod
  - Makes finding compatible dets easier and re-use o propagated states natural

Status

- Very preliminary implementation
  - Still not fully refined, not optimized, mostlty unchecked…
- First Results on 100 single muons (pt100!)

Segment finding efficiency = 100.0%

w.r.t. old layout

Reconstruction with DT only

	Old layout	New layout
Geane calls/ev	68	16
Geane propagation (ms/ev)	935	93
Trajectory building (ms/ev)	980	112

Overall timing improved by a factor 8.5

Much simpler code structure

Faster Segment Selection in L2

Selection of L2 segments

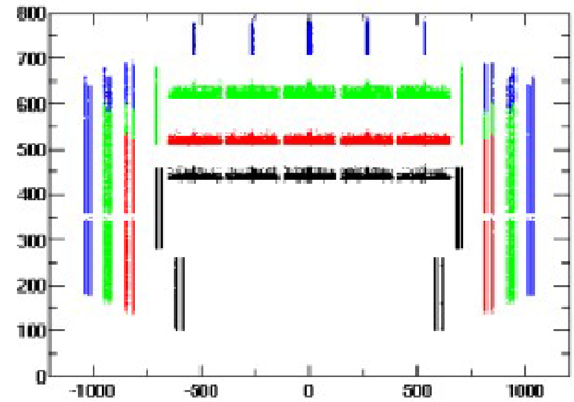
The detailed GEANE extrapolations are not necessary to select segment created by muons. One can follow L1 patterns or make use of the fact that segments are almost along straight line

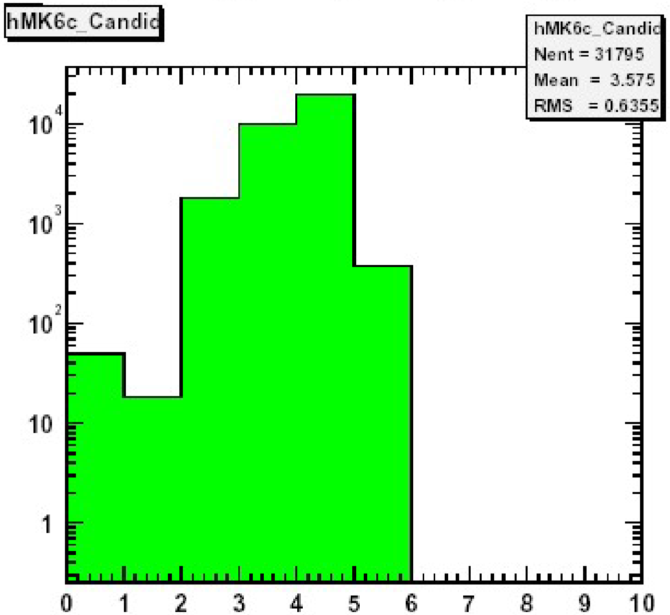
In this analysis:

- Find reference segment as the one closest to L1μ
  nhitsR, nhitsZ > 0, $\Delta\eta < 0.25$, $\Delta\varphi < 0.1$
  STATION ORDER: 2-1-3-4
- For each layer find segment closest in ΔR (or $\Delta\varphi$ if no Z hits) to the reference one. Select with $|\Delta\varphi| < 0.1$ and $|\Delta\eta| < 0.1$ cuts

$\Rightarrow$

selected L2 segments + GEANE fit should provide FAST(er) L2m





M. Konecki

PRS/μ meeting, CPT WEEK, 16 April 2002

Parameterization of Track Parameters

PHI,CHARGE,PT

$$f(p_T) = \mathrm{p0} + \mathrm{p1}/p_T + \mathrm{p2}/{p_T}^2 + \mathrm{p3}/{p_T}^3$$

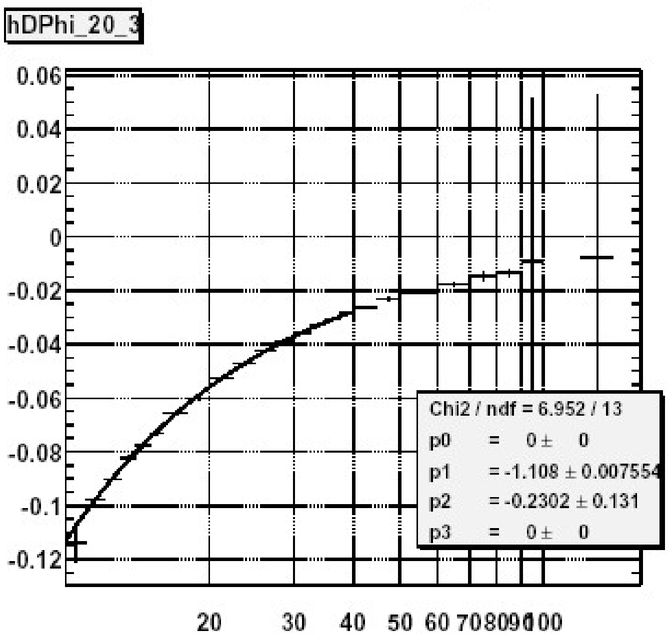
$$\varphi^i = \varphi^0 + f^i(p_T) \qquad \alpha^j = f^j(p_T)$$

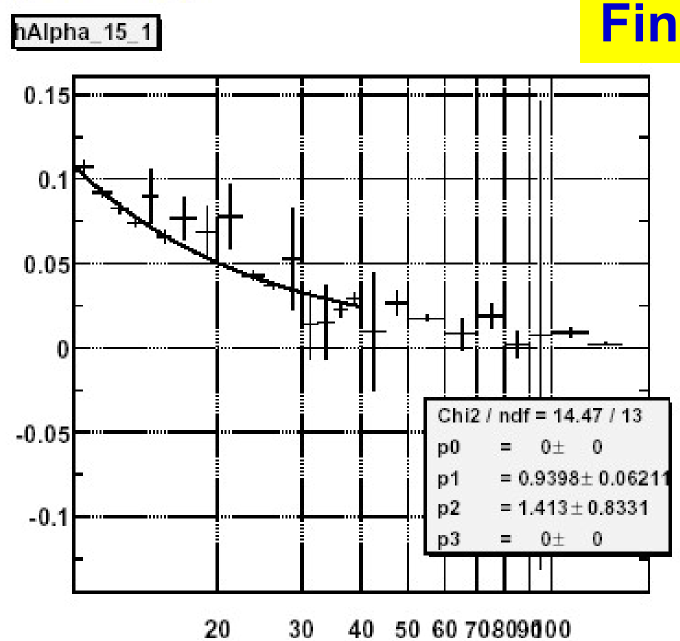
$$\chi^2_\varphi = \Sigma_i(\varphi^i - \varphi^0 - \mathrm{charge}\cdot f^i_\varphi(p_T))^2 \qquad \chi^2_\alpha = \Sigma_j(\alpha^j - \mathrm{charge}\cdot f^j_\alpha(p_T))^2$$

look for p_T, charge, φ^0 that gives minimal χ^2_α, χ^2_φ

and combined $\chi^2_\alpha + \chi^2_\varphi$ (in p_T range 5-L1)

Fast fit of track parameters to L2 segments (a là L1 Track-Finders)





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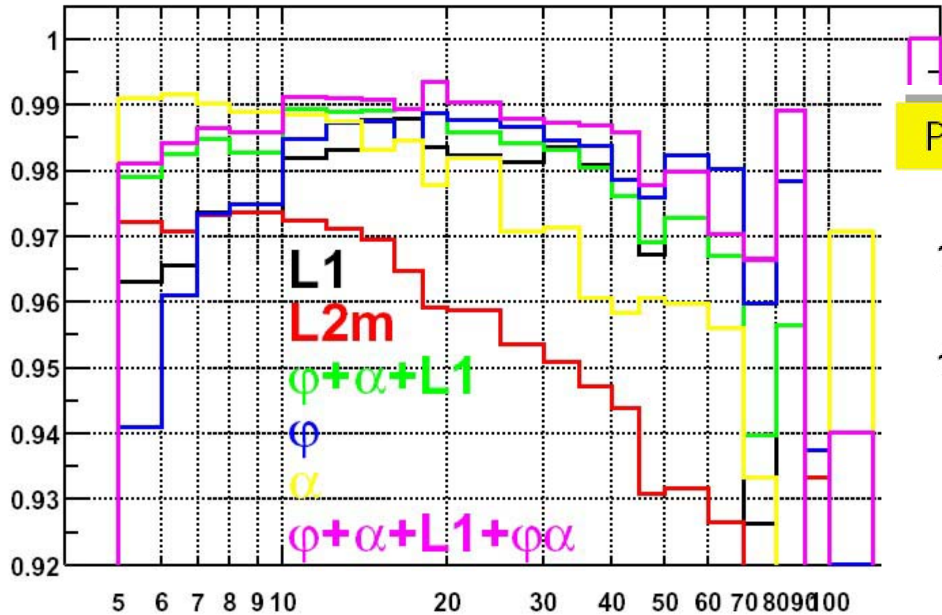
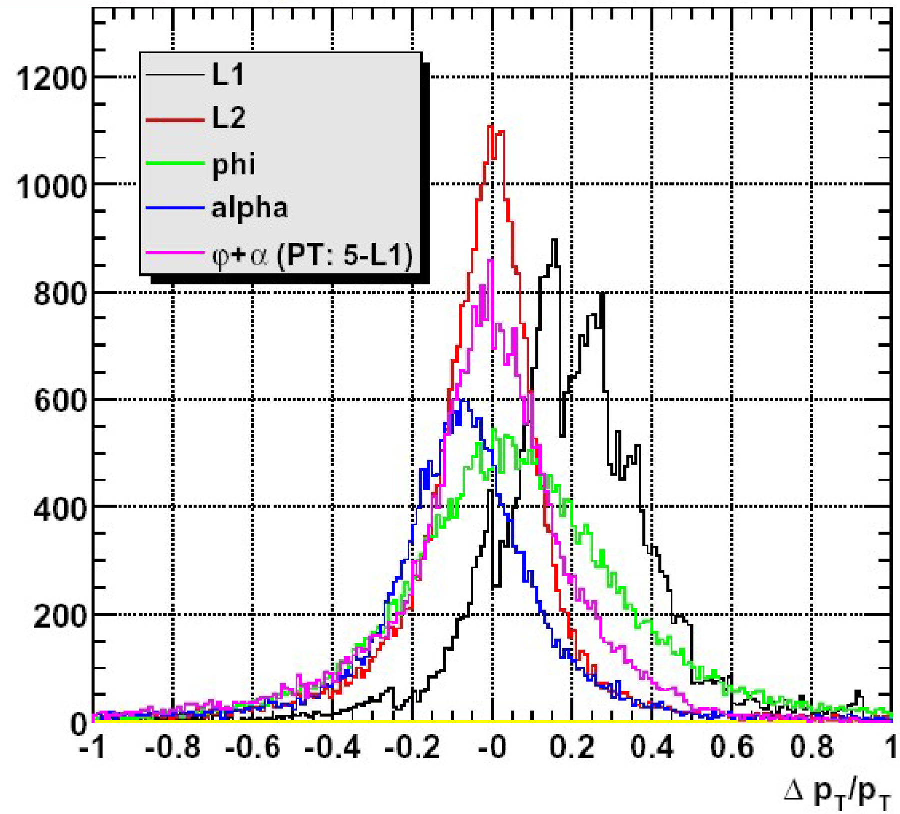
Assignment of Parameters

CHARGE assignment



p_T resolution similar to standard L2

PT assignment



Fast L2 (and even L1 !) has higher probability of getting charge correct over std. L2

Fast Seed Selection in Tracker

Seed selection

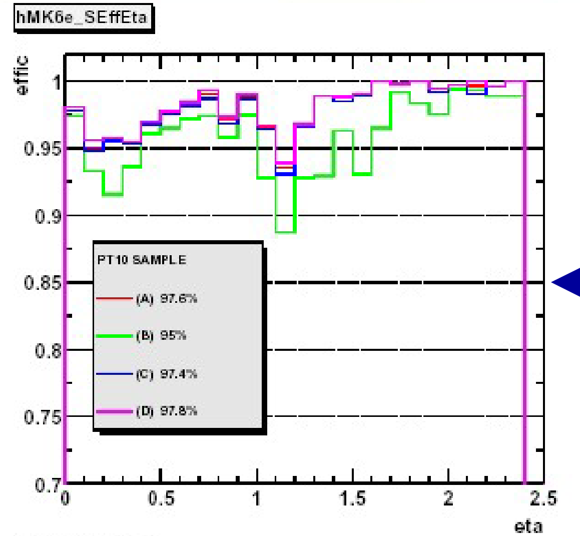
Seed consists of 2 pixel hits. It should pass the following selection:

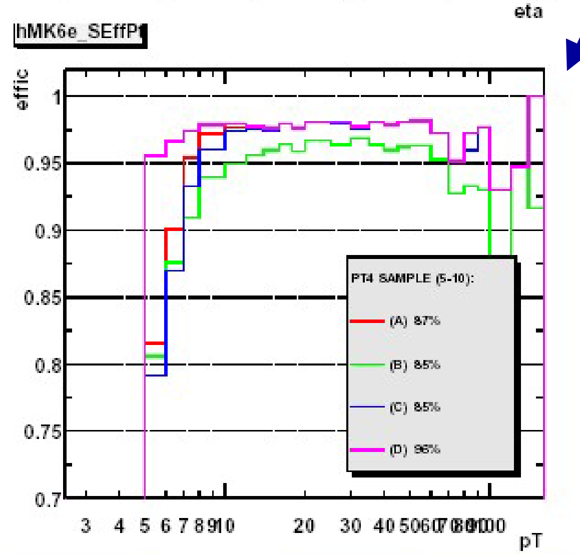
(B) $|\Delta\eta| < 0.05$ AND $|\Delta\phi| < 0.12$

(C) $|\Delta\eta| < 0.03$ AND $|\Delta\phi| < 0.25$
OR $|\Delta\eta| < 0.05$ AND $|\Delta\phi| < 0.07$

(A) $|\Delta\eta| < 0.03$ AND $|\Delta\phi| < 0.25$
OR $|\Delta\eta| < 0.05$ AND $|\Delta\phi| < 0.12$

(D) $|\Delta\eta| < 0.03$ AND $|\Delta\phi| < 0.25$
OR $|\Delta\eta| < 0.1$ AND $|\Delta\phi| < 0.12$





Efficiency

M. Konecki

PRS/μ meeting, CPT WEEK, 16 April 2002

Possible Scenarios

Clearly there is room to optimize speed and efficiency in L2 and L3 algorithms

Possibilities exist to improve code organization, simplify segment selection and improve propagation procedure

Ultimately we will settle on a choice (or choices) that minimize execution time, maximize efficiency, and minimize backgrounds

2002 Muon Production Status

	Dataset Name	Events	Sim	Hits	Digis
	mu02_MB1mu_pt1	279358	✓	150000	✓
	mu02_MB1mu_pt4	404992	✓	250000	✓
	mu02_MB1mu_pt10	110513	✓	85000	✓
	mu02_tt1mu	20000	✓	✓	starting
	mu02_W1mu	50000	✓	✓	✓
	mu02_Z1mu	50000	✓	✓	✓
UF	mu02_drellyan_above_z	20000	✓	✓	✓
UF	mu02_z_peak_mumu	20000	✓	✓	✓
	mu02_gg_bbh200_2tau_mue	10000	✓	✓	starting
	mu02_gg_bbh200_2tau_muX	10000	✓	✓	starting
	mu02_gg_bbh500_2tau_mue	10000	✓	✓	starting
	mu02_gg_bbh500_2tau_muX	10000	✓	✓	starting
	mu02_gg_h200_2tau_muX	20000	✓	✓	starting
	mu02_hxxx_WW2mu m_H= 120,140,160.180,200	10000	✓	✓	✓
	mu02_hxxx_ZZ4mu m_H= 130,150,200,300	10000	✓	✓	✓
		1074863			

($L=10^{34}$)

low lumi still to be done

- Simulation
- Hitformatting finished

- Digitization high L almost finished

- Crashes occur for 15% of high-lumi jobs

User Access to Muon Samples

- **Samples produced by INFN and Florida will be copied to CERN**
  - ➔ They are also available at the production sites with a limited number of visitor accounts for analysis (<20 for Legnaro)
- **We also have agreement with that Fermilab will host muon databases**
  - ➔ Will try to have all or most of the PRS/Muon samples replicated at Fermilab for U.S. users
  - ➔ Fermilab is purchasing a dedicated server + 1.5 TB disk
  - ➔ Fermilab can issue accounts to users
    - ☐ But also you will need Kerberos or a "cryptocard"
  - ➔ Already we have several hundred GB available
    - ☐ Plan to copy 200 GB di-muon sample from Florida
  - ➔ What would U.S. users like to see there?
    - ☐ Might be useful to place cosmic ray and testbeam data there as well for validation studies

PRS/Muon Community

- Typical meetings have about 20 people (~8 via VRVS)
  - ➔ Okay, they are a bit long as they tend to be working meetings
- The group is short on muon "experts"
  - ➔ Only a small number of individuals can work on details of HLT code
- These few individuals take on too many tasks for timely completion and detailed validation
  - ➔ e.g. One INFN postdoc coordinates MC production, is Muon librarian, is principal author of L2 code, and plans to work on testbeam analysis…
- Some of this is just a chronic shortage of manpower, and the historical nature of some groups trying to do everything
- Group has suffered from some well-publicized bugs when not enough time was spent on validation
  - ➔ This is an area that new users can contribute. Try the code out on your favorite signal. Try to understand why the efficiencies are the way they are. Dig into the code.

U.S. PRS/Muon Community

U.S. muon analysis is still CERN-centric

- ➔ A couple individuals have even “emigrated” to Europe

But muon chamber construction and testing is U.S.-based

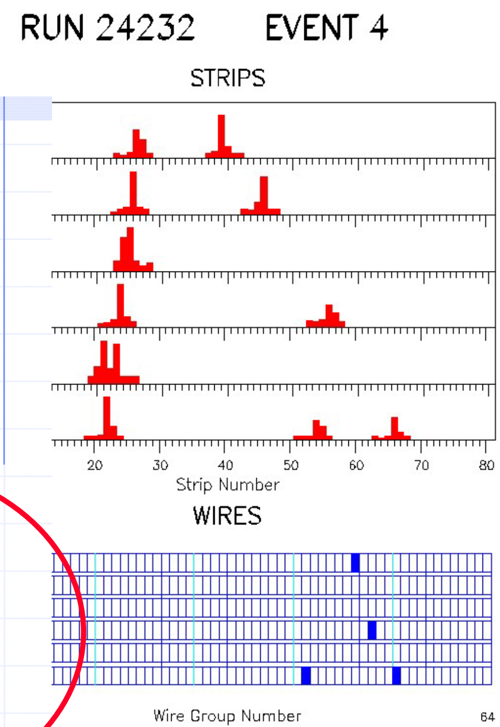
- ➔ Some mismatch between where the software developers are and where the people looking at data and writing firmware are

This is okay, but we have to work on communication, and invite people working on hardware to participate more in the PRS/Muon group

Examples of tasks that bridge the two communities:

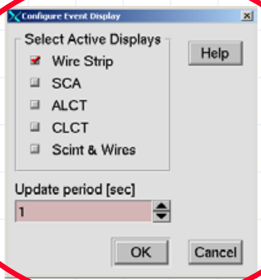
- ➔ Validation of the simulation against cosmic and testbeam data
- ➔ Validation of the algorithms with the actual electronic firmware for the L1 trigger and DAQ
- ➔ Integration of test-stand code with the CMS DAQ framework (XDAQ) and with ORCA (for storing data)
- ➔ Specification of calibration procedures
- ➔ CSC event display

Integration of CSC Display into IGUANA



Work in Progress

- 2D Viewers (XY, RZ, …);
- Interactive GEANT4; highlight overlaps in 3D;
- Interactive controls for reconstruction parameters and cuts (Maria Mennea, INFN);
- Annotations;
- CSC FAST event display integration;
- Document evaluation and recommend a performant graphics environment:
  - Preliminary: software (OS: redhat 6.2, 7.2; tools; compiler options; GL: native with NVIDIA; Xfree: 4.0.1 or higher) and hardware (CPU; memory: 250-500 MB; graphics card: NVIDIA Quadro2 Go).



Ianna.Osborne@cern.ch

http://iguana.web.cern.ch/iguana/

Getting Started with Muon Analysis

Nice tutorial written by R.Wilkinson for the ORCA training held last week in San Diego

- ➔ http://heppc16.ucsd.edu/cms_tutorial/agenda.html