ALICE dHLT : Perspectives for Physics

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Outline

- Relevant muonic signals in the dimuon spectrometer
- Quick Update on dHLT Status
- Reminder : dHLT Design and Algorithms
- Baseline performances of L0 and dHLT
- Physics possibilities with dHLT extensions

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Physics with the dimuon spectrometer

- The spectrometer designed to measure heavy quarkonia via the dimuon channel (Also sensitive to heavy flavour via single muon decay)
- In general, “signal” is considered to be heavy quarkonia (J/Psi and Upsilon families), while background is considered to be high-pT muons from other sources :
  - charm (D 0 , D 0 , D ± , D s , Λ±)
  - beauty (B 0 , B 0 , B ± , B 0 , B s , Λ0 , Λ0) and
  - hadron decay
- Although these are important and interesting to study in their own right, we will focus on the heavy quarkonia for now...

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The dimuon spectrometer trigger

ALICE-INT-2006-0002 version 1.0

- L0 trigger designed with these sources in mind :
  - 6 trigger signals delivered to ALICE CTP < 800 ns after interaction, at 40 MHz frequency:
    - At least one single muon above low (high) pT cut, (single muon low (high) pT)
    - At least two muons with opposite signs, each of them above low (high) pT cut, (unlike-sign dimuon low (high) pT)
    - At least two muons with same signs, each of them above low (high) pT cut (like-sign dimuon low (high) pT)
- The choice of the low- (1 GeV/c) and high (2 GeV/c) pT cut represents a compromise between background rejection and signal detection efficiency in the mass regions of the J/Ψ and Υ resonances respectively
- But what if we could improve the background rejection without cutting out any of the rare signals ?
  - Refine the results of the L0 algorithm with a higher level of processing

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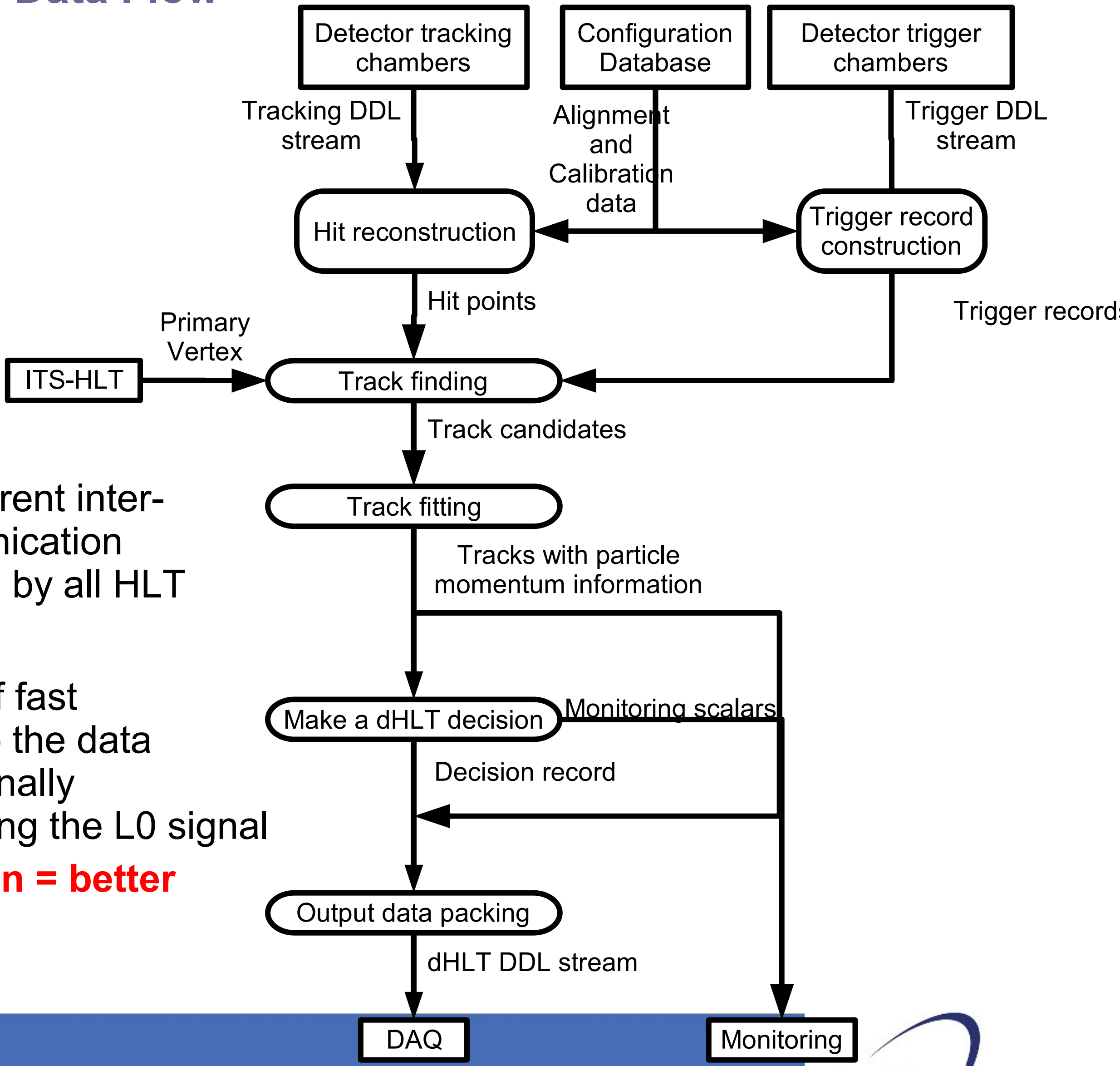
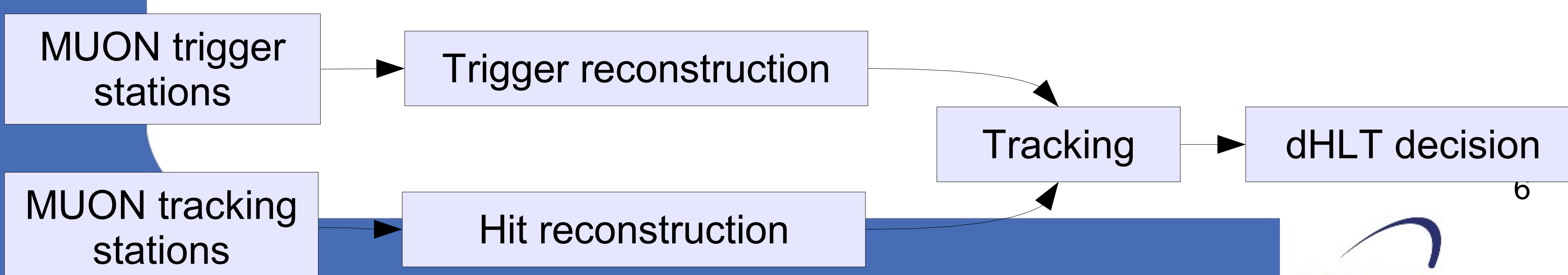
dHLT Design and Data Flow



- ***Architecture :***
  - Network-transparent inter-process communication framework, used by all HLT
- ***Principle :***
  - include a level of fast reconstruction to the data stream, before finally accepting/rejecting the L0 signal
  - **Better resolution = better selectivity !**

The algorithms in brief :

- Hit reconstruction performed on tracking stations 4 and 5. Algorithm applies a DC cut to all channels, then looks for 3 pad clusters on the bending and non-bending plane separately. The centre of gravity is calculated to give the reconstructed X and Y coordinate. X and Y is merged to give reconstructed hit.
- Trigger reconstruction is simply a data transformation from the DDL streams from trigger electronics. The X-Y bit patterns are converted into floating point coordinates in global coordinates.
- Tracking uses a track following algorithm which tracks back through the muon filter wall to stations 4 and 5. Circular regions of interest are used to search for and select reconstructed hit candidates forming part of a track. Pt is then estimated from the spatial information on the tracking chambers.



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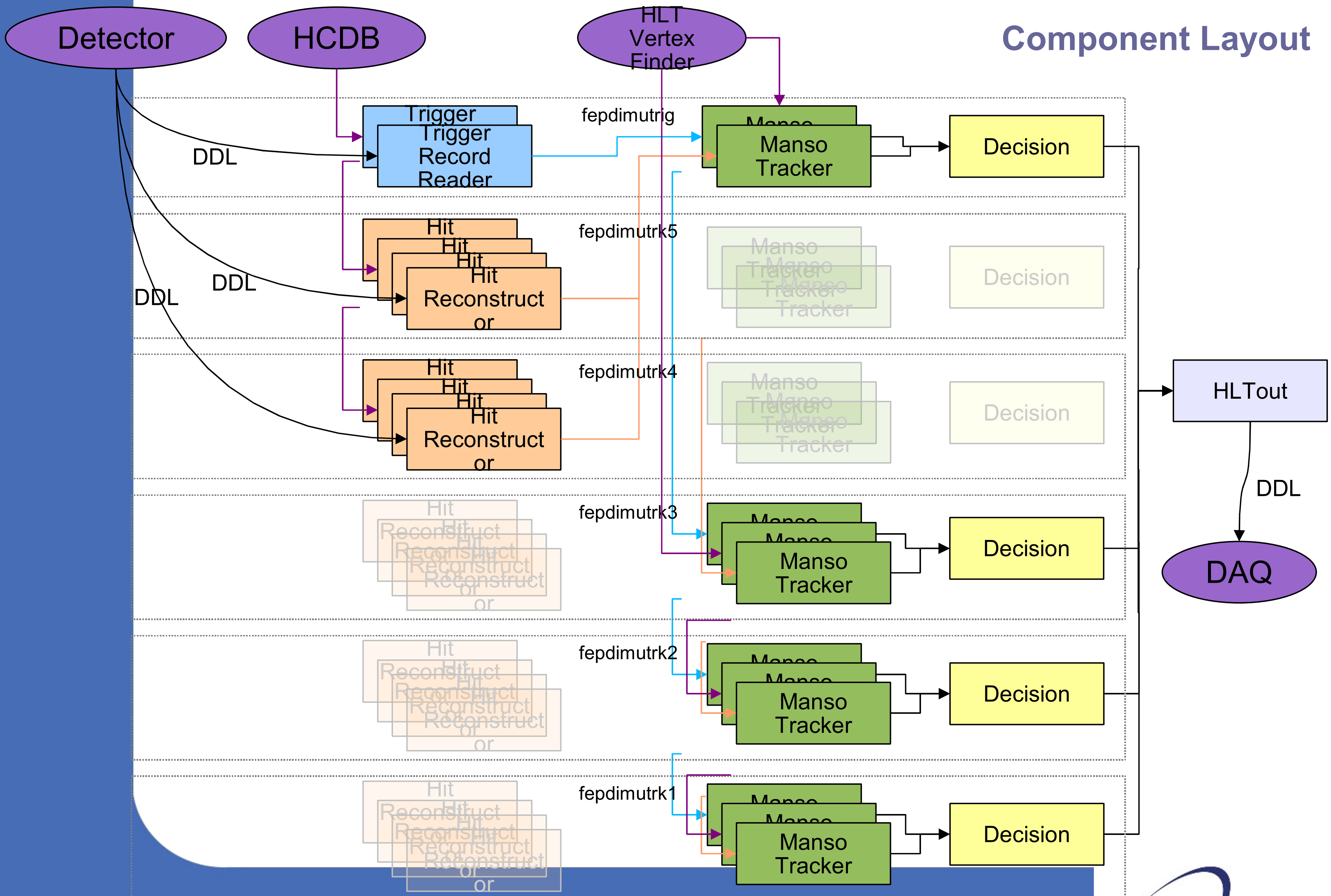
Component Layout



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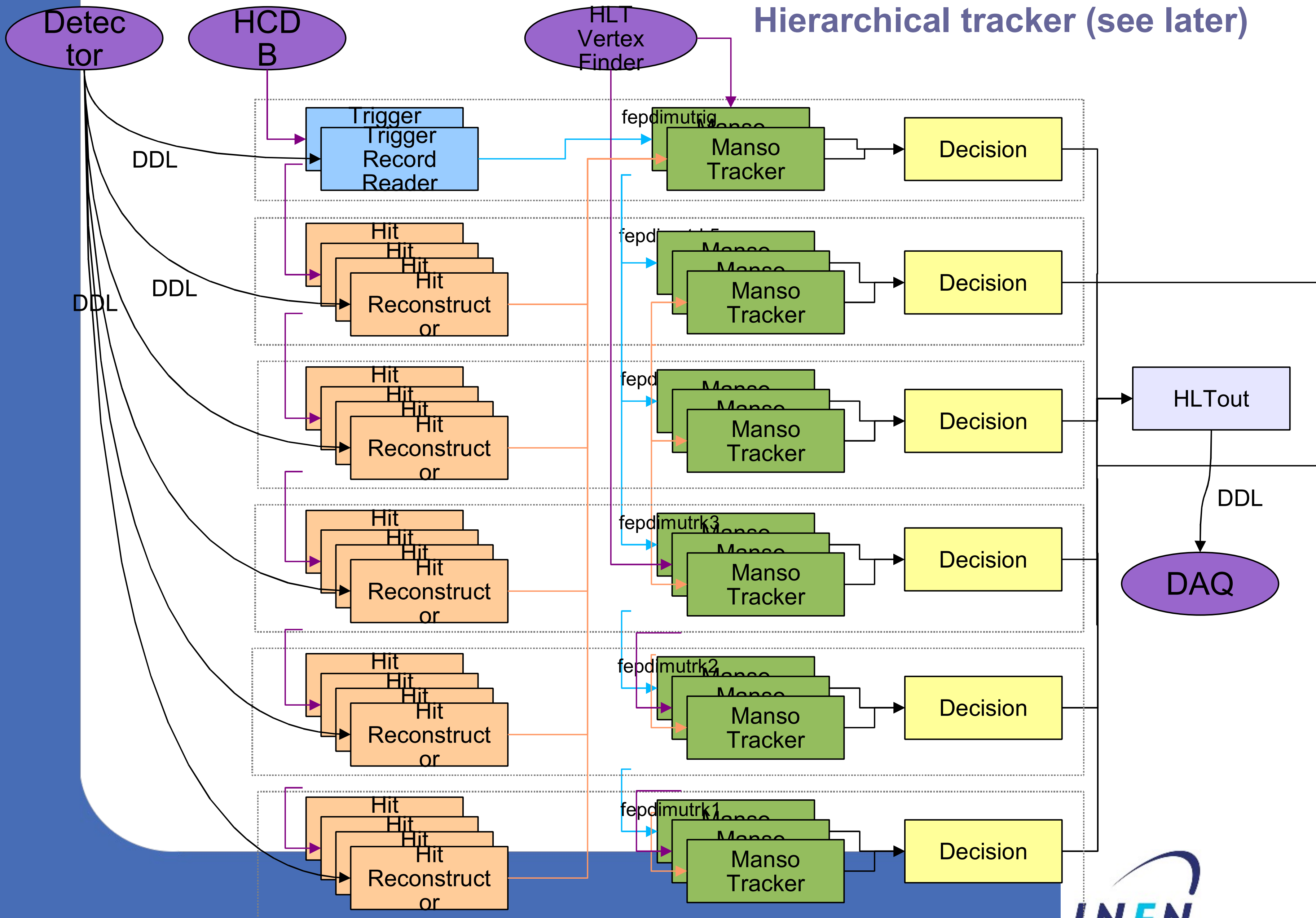
Expandable if Required : Hierarchical tracker (see later)



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dHLT Current Status :

- All components tested and performing according to design parameters – written up in **ALICE-INT-2007-022 v.1**
- Full stress tests have previously been performed in Cape Town and at CERN
- dHLT hardware is installed, waiting for fibres from the spectrometer (and other systems to HLT)
- Currently preparing for FDR and general commissioning...
  - dHLT development per se is frozen,
  - working on implementing all the missing interfaces (monitoring, calibration, etc)
  - Have to be ready for dimuon spectrometer and DAQ commissioning, whenever it will be.

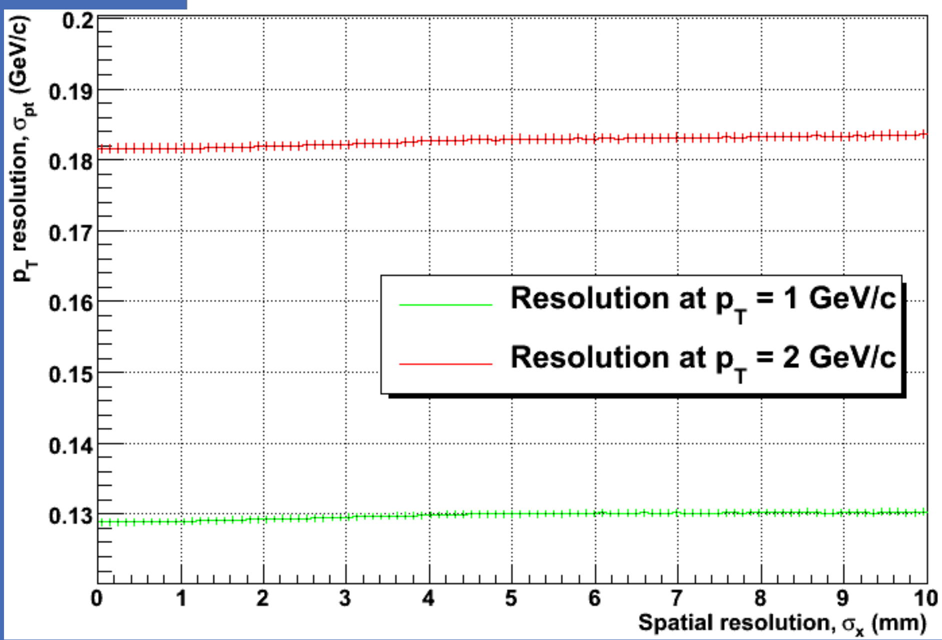
dHLT Performances at a Glance

Tracker resolution

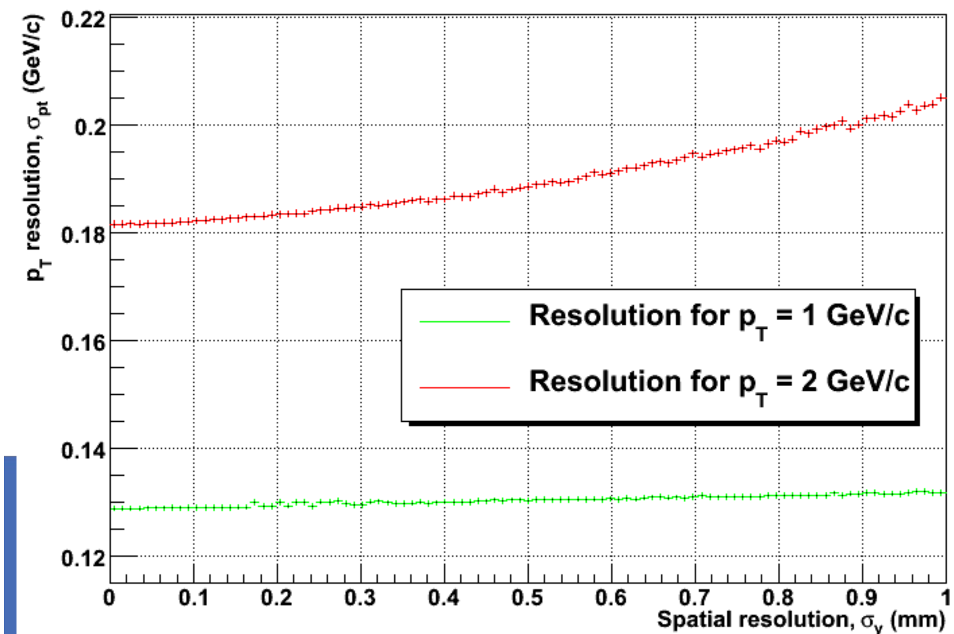
$$p_T = 0.3 \frac{q \int_0^L B(z)dz}{\theta_d} \cdot \frac{\sqrt{x_F^2 + y_F^2}}{z_F}$$

- The resolution at pT equals
  - 1 GeV/c is 0.13 ± 0.01 GeV/c, thats ~13% of pT,
  - 2 GeV/c is 0.18 ± 0.01 GeV/c, or ~10%.
- Resolution quite insensitive to spatial resolution in both bending and non-bending planes.
  - this is probably a good thing during those first, uncertain runs... There will probably be a lot of noise, but our tracker will be able to handle it !

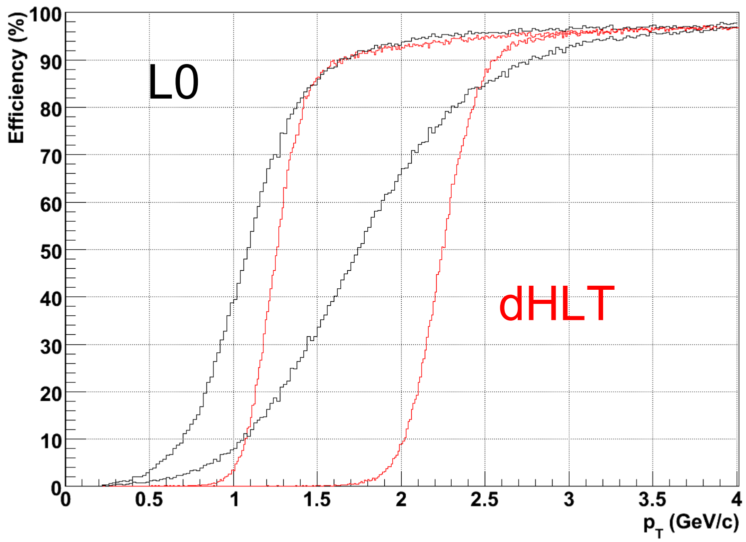
Non-bending (X) plane: 0.93 ± 0.08 mm

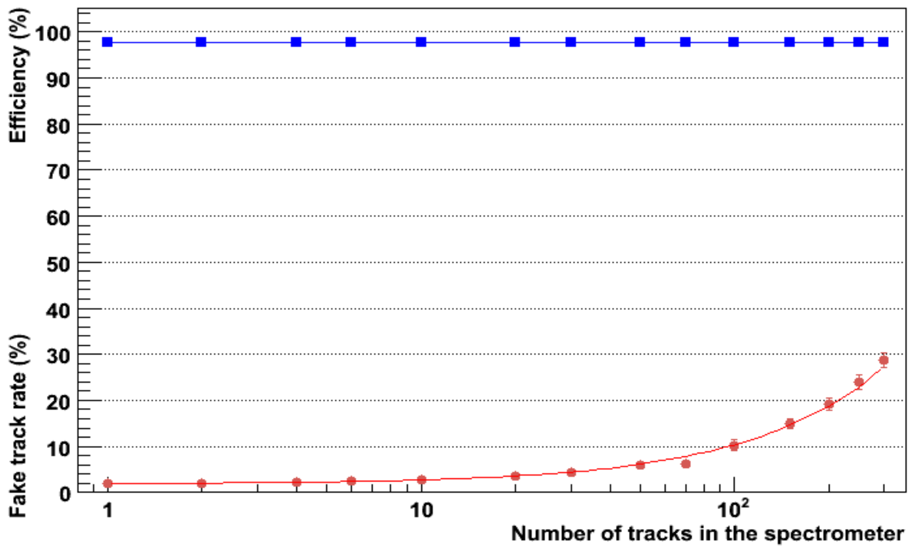


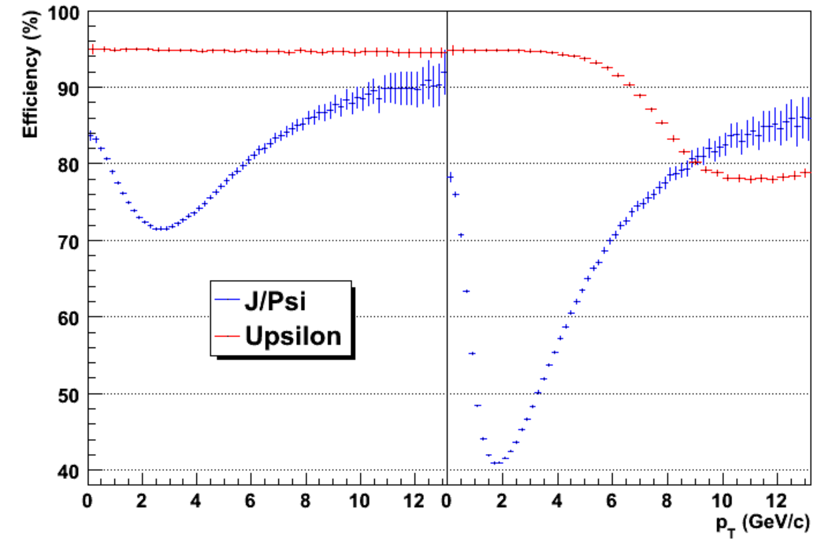
Bending (Y) plane: 48 ± 30 microns



dHLT Tracker : pT Cut Resolution/Fake Tracks/Detection Efficiency







- Sharper cut than L0
- Above 97% and flat for all numbers of tracks in the spectrometer.
- Fake hits (all tracks found that are not muons) grows quite rapidly for large numbers of tracks in the spectrometer, but acceptable for p+p runs.

Signal detection and backgound rejection – comparison with L0

- J/psi detection efficiency is 52.6% with a 1GeV/c Pt cut on L0 and 75.7% without the cut
- Upsilon detection efficiency is 91.3% with a 2 GeV/c Pt cut on L0 and 94.8% without the cut.
- Background rejection for nominal central events is about 4 to 5 times better than L0 alone for the 1GeV/c Pt cut and about 2 times better for the 2GeV/c Pt cut.

pT cut (GeV/c)	HIJING central event rejection (%)	
	dHLT	L0
1.	13.	3.
2.	76.	40.

Particle	pT cut (GeV/c)	Detection efficiency (%)	
		dHLT	L0
J/ψ	1.	52.6	71.
Y	1.	94.8	97.
Y	2.	91.3	88.

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Trigger rates

ALICE-INT-2006-0002

		ϕ	J/Ψ	Ψ'	Υ	Υ'	Υ''
	$\sigma_{pp}^{[Q\bar{Q}]}$ (μb)	120000	54.1	7.8	1.13	0.52	0.23
p-p $\sqrt{s_{NN}}$ = 14 TeV	f_{trig}^{all-pt} ($\times 10^{-3}$ Hz)	1350	430	7.9	3.8	0.96	0.57
	f_{trig}^{l-pt} ($\times 10^{-3}$ Hz)	310	340	6.9	3.8	0.96	0.57
	f_{trig}^{h-pt} ($\times 10^{-3}$ Hz)	43	100	2.4	3.5	0.88	0.53

	f^{coll} (Hz)	f_{trig}^{all-pt} (Hz)	f_{trig}^{l-pt} (Hz)	f_{trig}^{h-pt} (Hz)
Pb-Pb , single muons	$4\ 10^3$	1700	1100	450
Pb-Pb , unlike-sign dimuons		930	330	65
Ar-Ar , single muons	$1.5\ 10^5$	26000	10000	3000
Ar-Ar , unlike-sign dimuons		4500	630	73
p-p , single muons	$2\ 10^5$	1850	510	225
p-p , unlike-sign dimuons		27 (±10)	10 (±5)	5 (±3)

Table 16: Trigger rates for Pb-Pb, Ar-Ar and p-p minimum bias collisions, for single muons and unlike-sign dimuons, and for all-pt, l-pt and h-pt cuts.

Trigger Rates (2) – What can we do with the dHLT ?

- dHLT can handle ~1.7 kHz on current architecture for 150 single muons per event
  - compare with expected max. multiplicity of single muons on trigger stations - 6.25
- However, spectrometer can only be read out max ~ 1.2 kHz to avoid dead-time effects.
- Nonetheless, we can in principle have only all-pT L0 signals, saturate the trigger rate and still respect bandwidth constraints, rejecting almost all background.

ALICE-INT-2006-0002

		pions, kaons	charm	beauty	Total
Pb-Pb **b < 5 fm**	m_{μ}^{all-pt}	4.84	1.23	0.16	6.25
	m_{μ}^{l-pt}	1.50	0.47	0.11	2.09
	m_{μ}^{h-pt}	0.42	0.13	0.05	0.64

Systematic Studies :

- We have shown that we have a fast, high-res online processing system - can make more accurate and therefore more selective cut.
- But what are we really selecting when we make the pT cut ? Have to perform systematic studies, to determine
  - Bias introduced with the various dHLT cuts
  - S/B as a function of pT and multiplicity, in order to optimise pT cuts.
  - Acceptance as a function of search region on tracking stations
- Define “very rare” topologies, which could override any processing underway to prioritise trigger signals (e.g. very high pT single muons from Z)
- Etc – work ongoing (but takes a second place to commissioning at this point)

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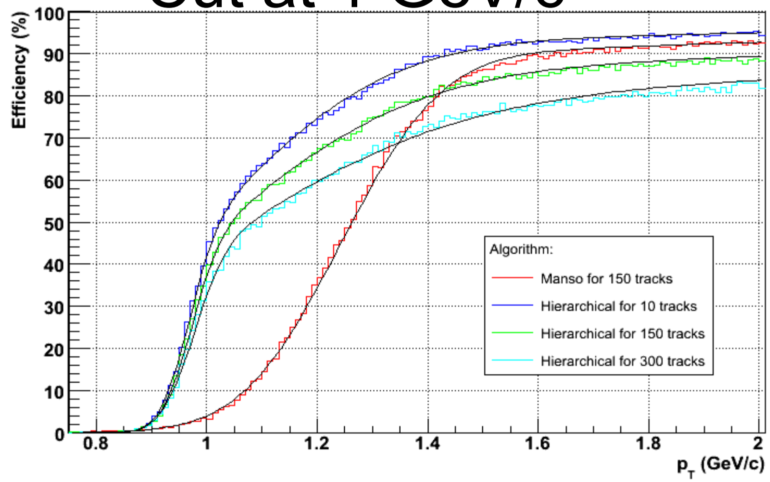
Extensions to dHLT to study these signals better

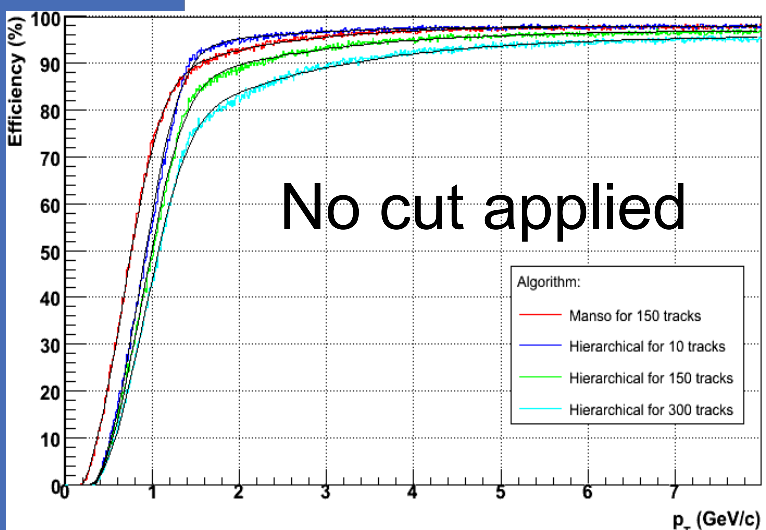
- Since the dHLT is based on a modular architecture, algorithms can be swapped in and out, at any level, provided they respect basic interfaces
- In particular, we have developed a hierarchical tracker, using input from all spectrometer DDLs, and performing tracklet and track finding in parallel at every level
  - Advantages :
    - Can perform a Branson and energy-loss corrections (more points as input)
    - Can provide a fit quality (Manso algo only uses 2 points)
    - Much sharper pT resolution, depends on hit-rec resolution
    - Hence sharper mass resolution...
  - Disadvantages :
    - Not properly tested in a systematic way (has to wait until after first run)
    - More processing time needed than Manso (but not as much as you might think – it's a parallel algorithm. And if besides, CPU's are not really the problem
    - Requires more input (DDLs from all stations, and hence hit rec on all stations – non trivial due to hardware of the detectors.)
    - Requires ITS Vertex position (can be given by ITS-HLT though...)

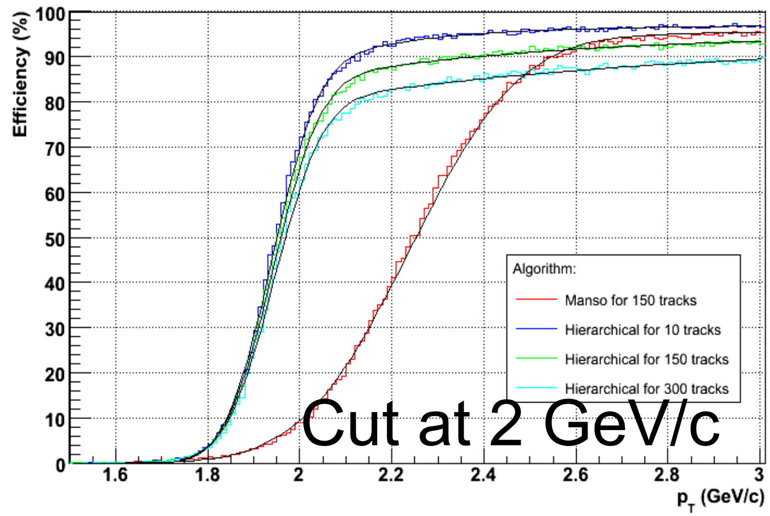
Hierarchical Tracker pT cut resolution :

- Note – pT resolution much sharper even than Manso algorithm

Cut at 1 GeV/c





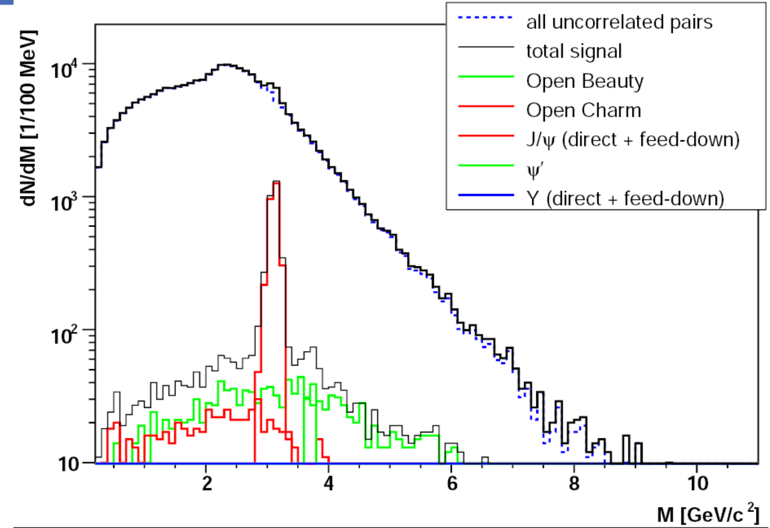


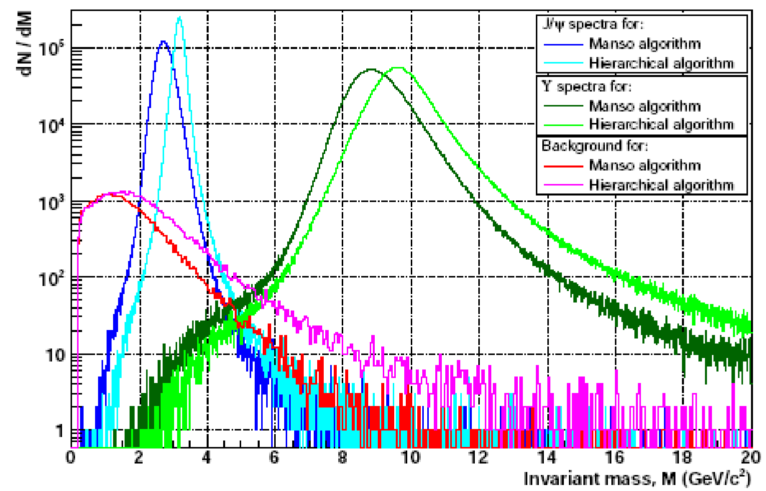
Invariant Mass Resolution

- What resolution can we expect from the online tracking algorithms ?

	Invariant mass resolution (GeV/c^2)	
	J/psi	Upsilon
L0	0.62	2.24
Manso	0.266	0.94
Hierarchical	0.183	1.04

- These numbers are somewhat realistic (obtained from very large samples) but...
- We can think about opening the possibility of implementing an invariant mass trigger.
  - Depends on how much extra processing time is required
  - If we can be sure to select properly





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Conclusions

- dHLT components are fully designed and almost completely implemented (some external interfaces missing)
- Full Project Review published as Internal Note (Nov. 2007), contains full performance parameters of all algorithms studied so far.
- dHLT can provide higher resolution and hence selectivity of muon tracks, online, using seeds from L0
- Using dHLT as a filter on L0 ApT triggering can retain almost all the signal and reject almost all of the background (depending on colliding system)
- Several systematic MC studies have to be performed to ensure that the dHLT is really performing as we think it should.
- Some very interesting possibilities for sophisticated event topology selection using more sophisticated tracking algorithm.
- Work in progress !
- Thanks to A. Szostak (INFN, CA), I. Das (Kolkata), HLT team (Heidelberg and CERN) and C. Cicalo (dHLT Co-ordinator, INFN, CA)