Muon Isolation in ORCA and CMSSW

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Outline:

- Documentation
- ORCA - review
- CMSSW - to be discussed

Muon Isolation in DAQ TDR

C. Albajar, G. Wrochna,
Isolated Muon Trigger
CMS NOTE-2000/067
http://cmsdoc.cern.ch/documents/00/note00_067.pdf

N. Amapane, M. Fierro, M. Konecki,
High Level Trigger Algorithms for Muon Isolation
CMS NOTE-2002/040
http://cmsdoc.cern.ch/documents/02/note00_040.pdf

CMS DAQ TDR, v2 (CERN/LHCC 2002-026)
chapter 15.3.2, 15.3.3
http://cmsdoc.cern.ch/cms/TRIDAS/Temp/CMS_DAQ_TDR.pdf

S.Abdullin et al.,
Sensitivity of the Muon Isolation Cut Efficiency to the Underlying Event Uncertainties
CMS NOTE-2006/033

CMS PTDR v1 (CERN/LHCC 2006-001)
chapter 9.3, 9.4
http://cmsdoc.cern.ch/cms/cpt/tdr/ptdr1_final_colour.pdf

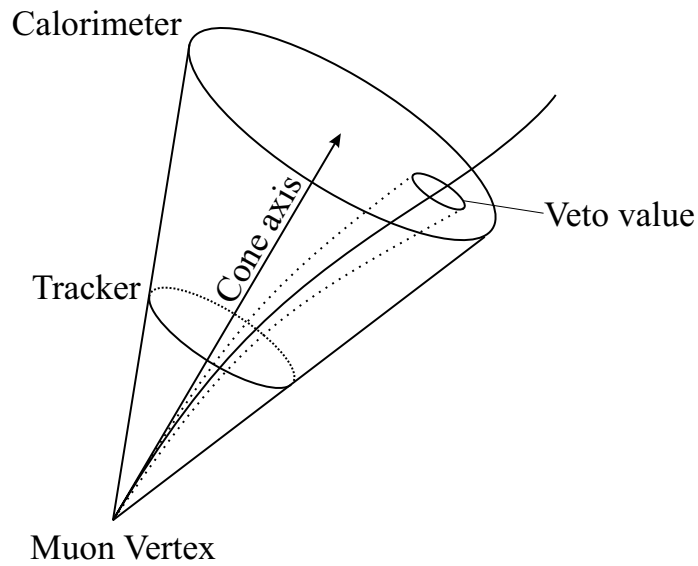
Muon Isolation in DAQ TDR

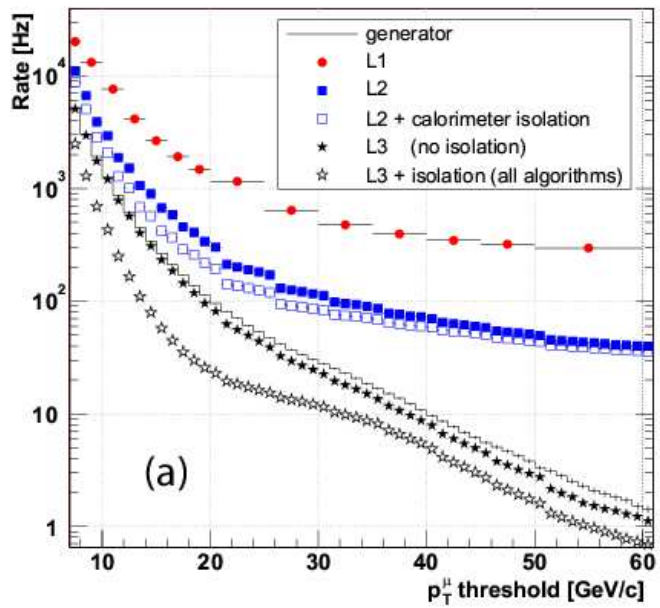
A tool to reject muons from K, π, b, c decays which are often a background for discovery physics.

Isolation is based on the comparison of $\sum E_T$ or $\sum p_T$ in a cone around the muon with the predefined threshold. Muon deposit is extracted (veto cone). Thresholds are η-dependent, optimized to obtain `nominal efficiency` for $W \rightarrow \mu$ events.

- Calorimeter Isolation
  E_T in calorimeter towers. $E_T = \alpha E_T^{ECAL} + E_T^{HCAL}$.
  Can be applied already at L2. **Sensitive to pile-up.**
- Tracker Isolation
  $\sum p_T$ of tracks around L3 muon. Tracks from Full Tracker reconstruction **(since `ORCA_62` regional seeding and conditional reco)**
- Pixel Isolation
  $\sum p_T$ of tracks around L3 muon.
  Tracks from `PixelReconstruction` (global). **Good timing.**

Pixel Isolation has similar but slightly worse performance than Tracker Isolation.
Only Calorimeter and Tracker Isolation used for muon selection for DAQ TDR (with nominal efficiency of 97%).
Cone size ≈ 0.2





Muon Isolation since DAQ TDR times

Muon Isolation algorithms were developed for High Level Trigger (DAQ-TDR). No algorithm development since then but changes to interfaces, repackaging etc.

ORCA status:

- web page documentation (with detailed description and examples):

  `http://cmsdoc.cern.ch/orca/ -> ReferenceManual -> MuonReco -> MuonIsolation`

  see also: ORCA directory of MuonReco/MuonIsolation/doc, test

- Two basic steps (as in DAQ-TDR):
  - deposit extraction - defined for Calo,Pixel,Tracker,
  - comparison with threshold - two isolators available : for "nominal efficiency" way and for "simple deposit comparison".
- Two levels of persisitency
- Two types of isolation variable on which one can cut:
  - nominal efficiency
  - $\Sigma\, p_T$ or $\Sigma\, E_T$.
- user has to care about configuration

Available MuonIsolation RecAlgorithms (ORCA_872)

for studies:

MuIsoByCaloEt
- Calorimeter isolation using ECAL and HCAL.
- The isolation variable is the weighted sum of ECAL and HCAL deposits.

MuIsoByCaloEff
- Calorimeter isolation using ECAL and HCAL.
- The isolation variable is Nominal Efficiency.

MuIsoByTrackerPt
- Tracker isolation.
- The isolation variable is the sum of pT of tracks in a cone around the muon.

MuIsoByTrackerEff
- Tracker isolation.
- The isolation variable is Nominal Efficiency.

MuIsoByPixelPt
- Pixel isolation.
- The isolation variable is the sum of pT of tracks reconstructed with the pixel detector only in a cone around the muon.

MuIsoByPixelEff
- Pixel isolation.
- The isolation variable is Nominal Efficiency.

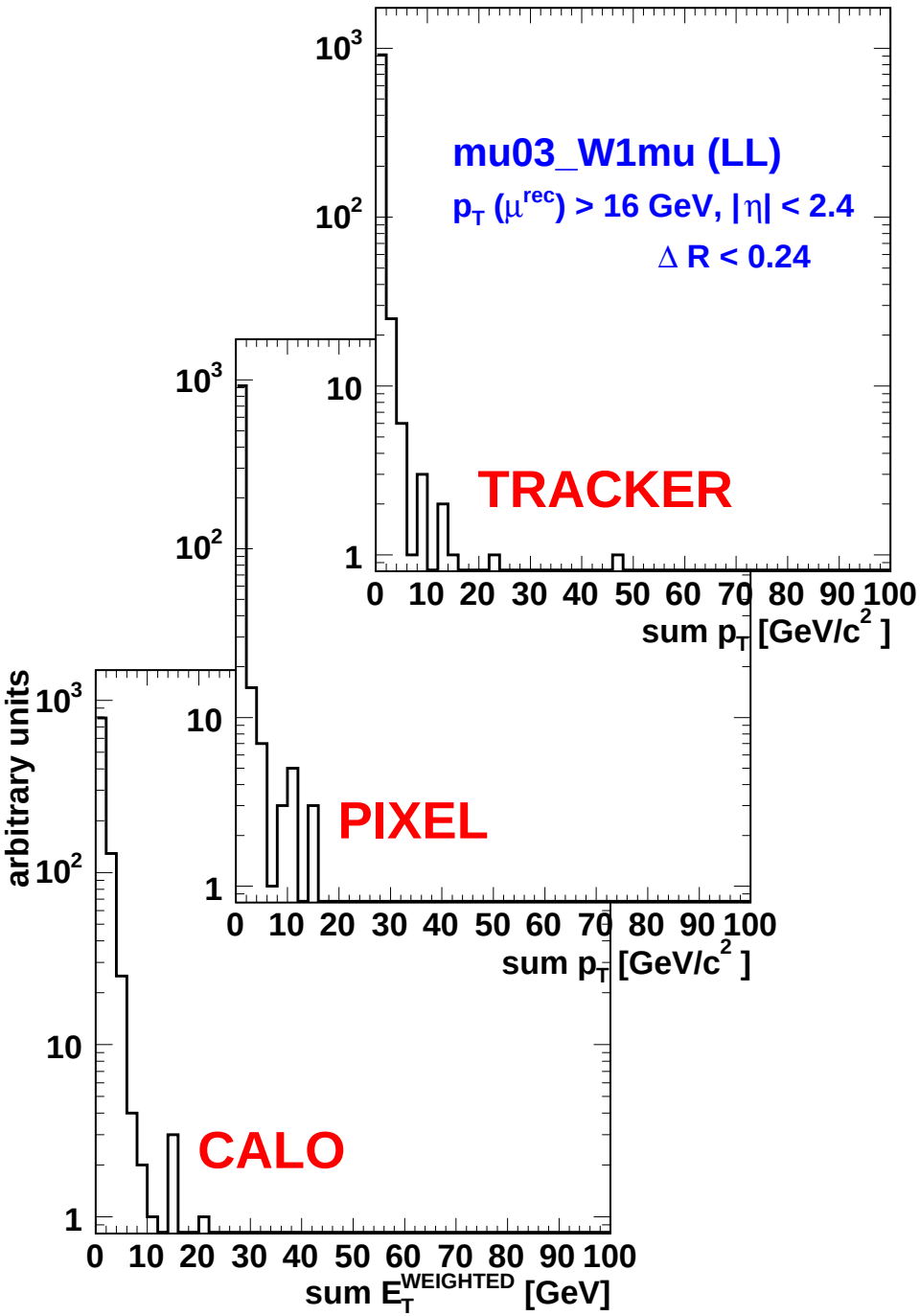
for HLT:

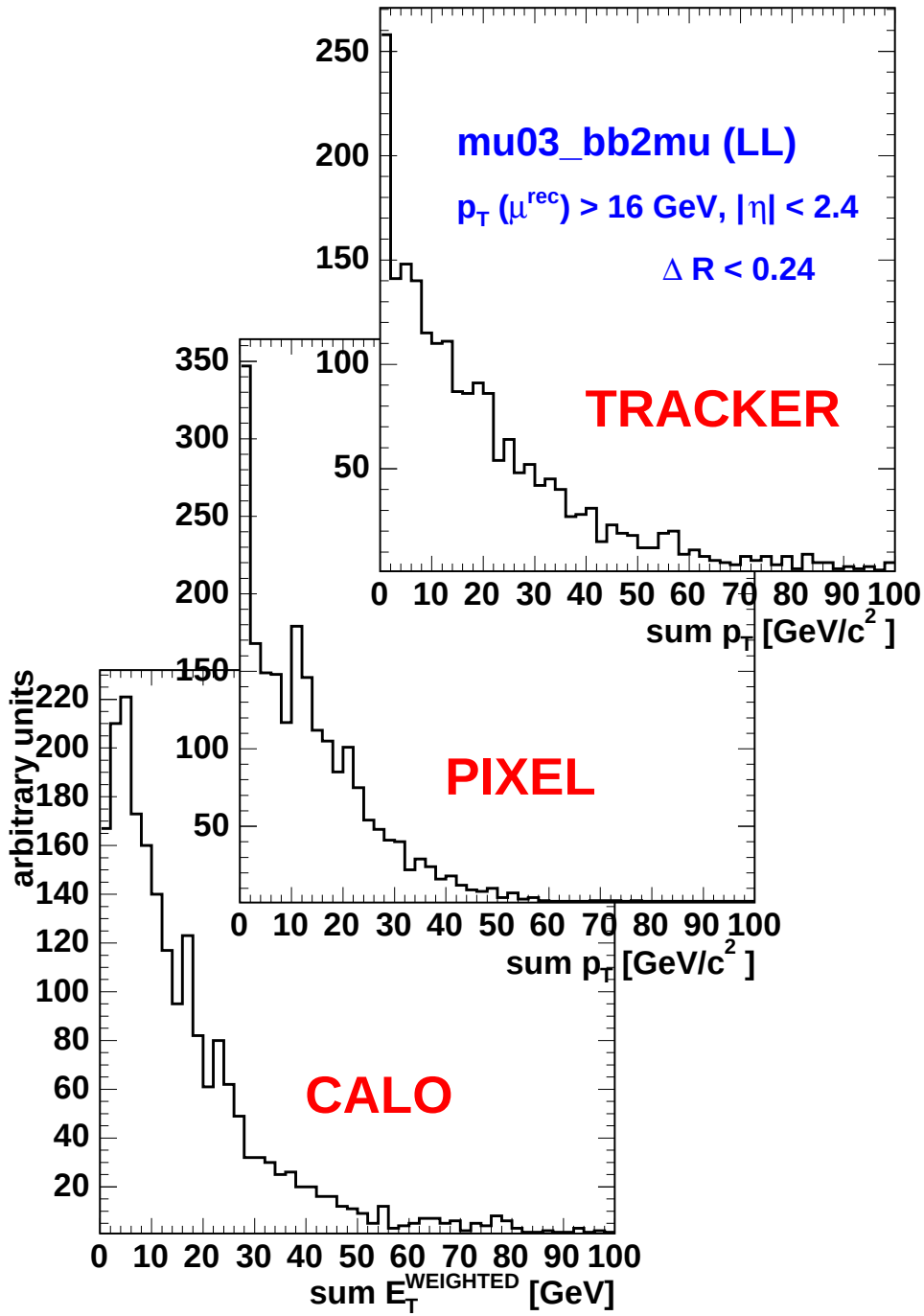
MuIsoL2ByCalo
Equivalent to MuIsoByCaloEff with fixed cuts and muon source (L2). CMS NOTE 2002-040.

MuIsoL3ByTracker
Equivalent to MuIsoByTrackerEff with fixed cuts and muon source (L3). CMS NOTE 2002-040.

The HLT algorithms will be applied by HLT before offline custimised user selection. Users are not supposed to modify the configuration of HLT algorithms.

Results (E_T, p_T deposits), ORCA_872

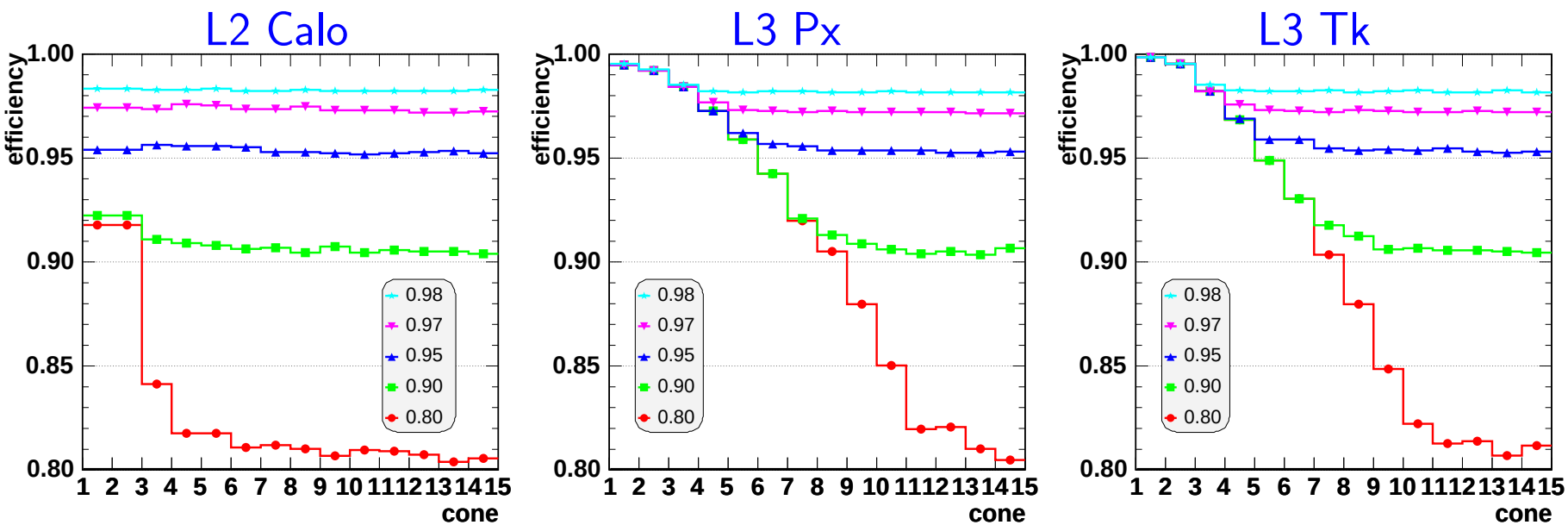




Update of HLT algorithms: Low luminosity, thresholds

- The isolation thresholds are fully defined by reference signal.
- For a predefined efficiency `eff_thr` the deposit variable `var_thr` is set in the way that deposit in the range [0, `var_thr` [ensures efficiency $\geq$ `eff_thr` for reference signal.
- for small cones it is not possible to set thresholds in flexible way – resulting efficiencies are higher

CONE	ΔR_{max}	*CONE*	ΔR_{max}
1	0.02	8	0.28
2	0.045	9	0.32
3	0.09	10	0.38
4	0.13	11	0.45
5	0.17	12	0.5
6	0.2	13	0.6
7	0.24	14	0.7



Update of HLT algorithms: Low luminosity case - Best cone definition

- the choice of cone which is used to obtain given nominal efficiency depends on the background sample (and can be configured in ORCA by steering cards)
- the best cones obtained with my reference background samples are quite different (bigger cones preferred)

CONE	ΔR_{max}	*CONE*	ΔR_{max}
1	0.02	8	0.28
2	0.045	9	0.32
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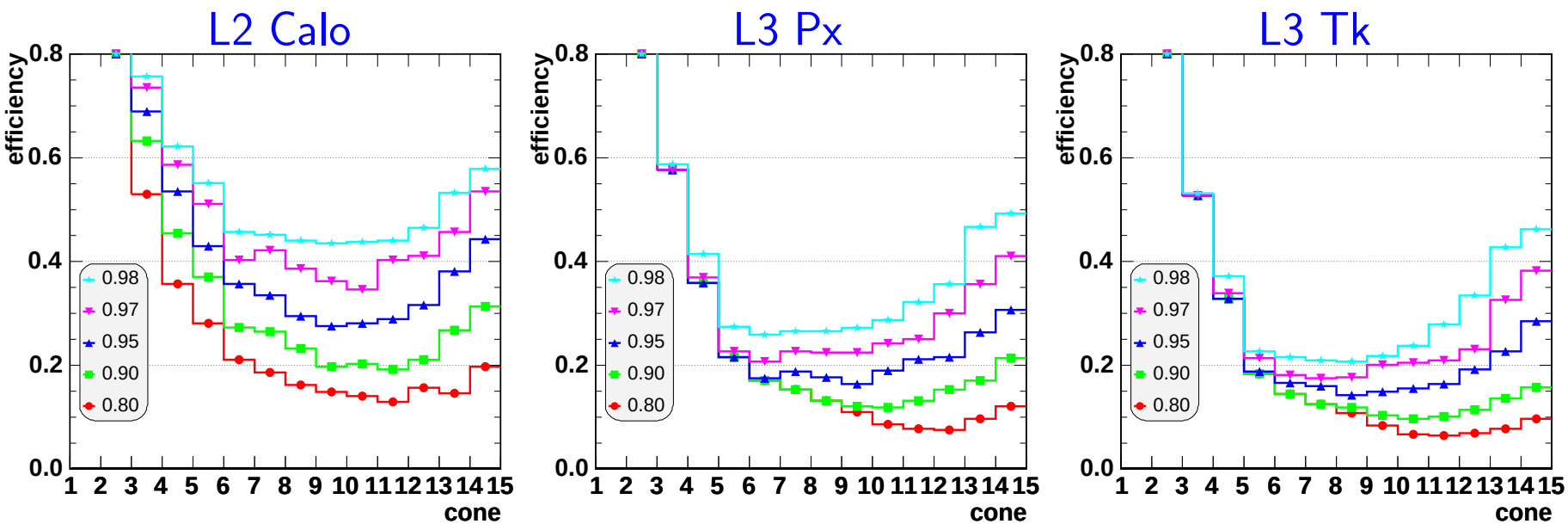
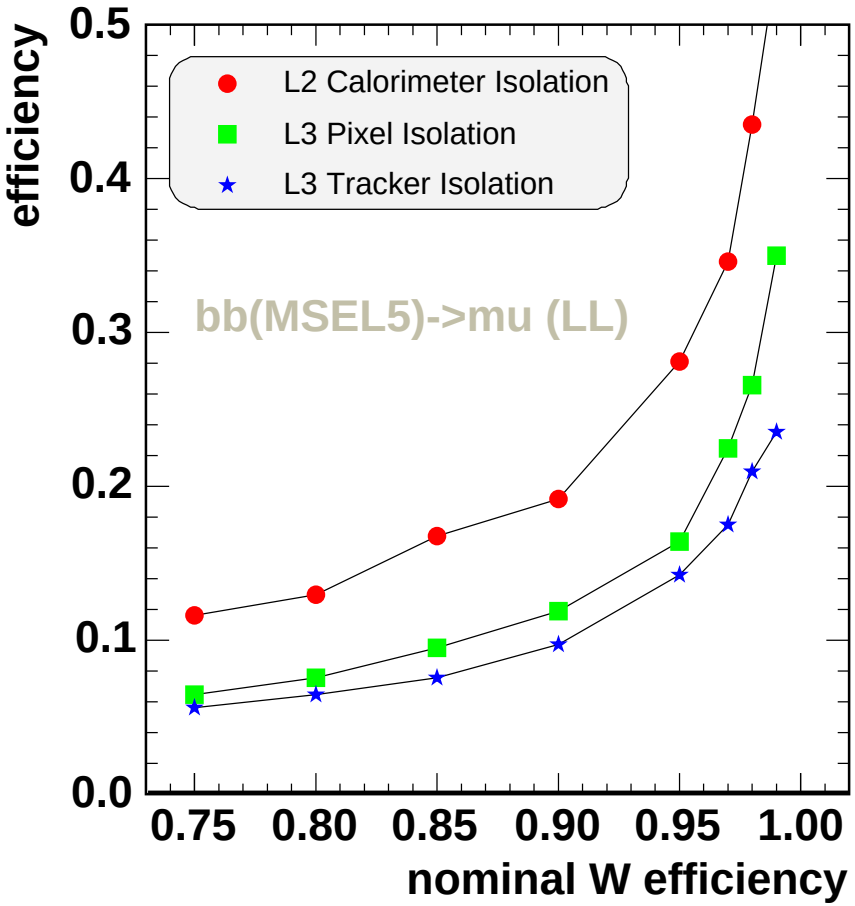
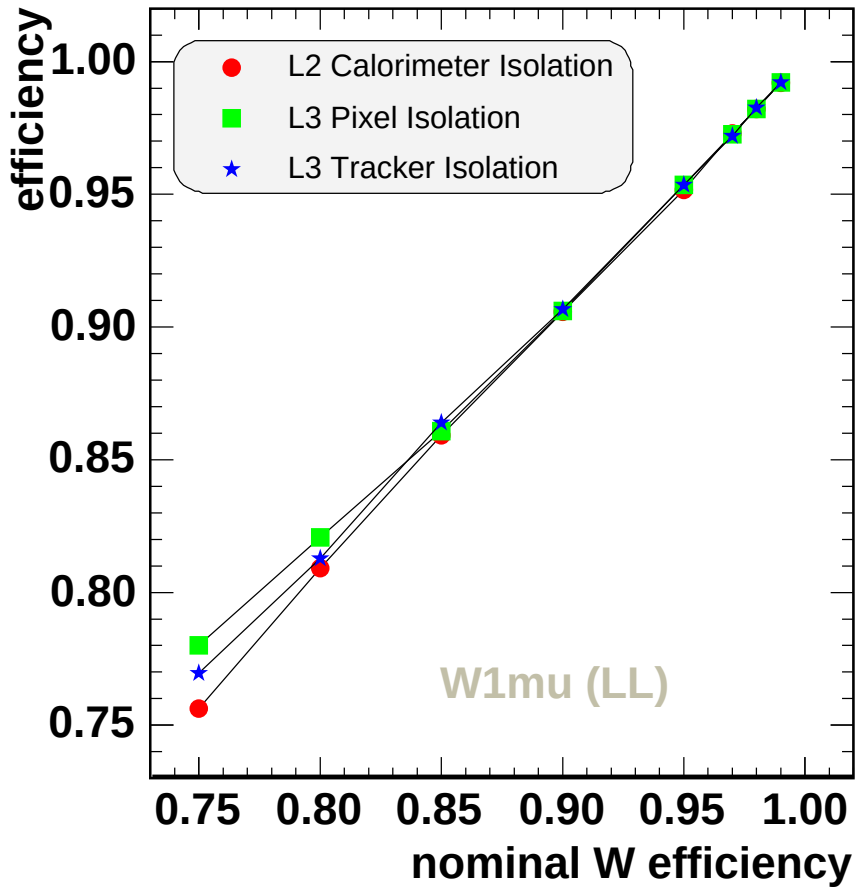


Update of HLT algorithms: Low luminosity case - final results



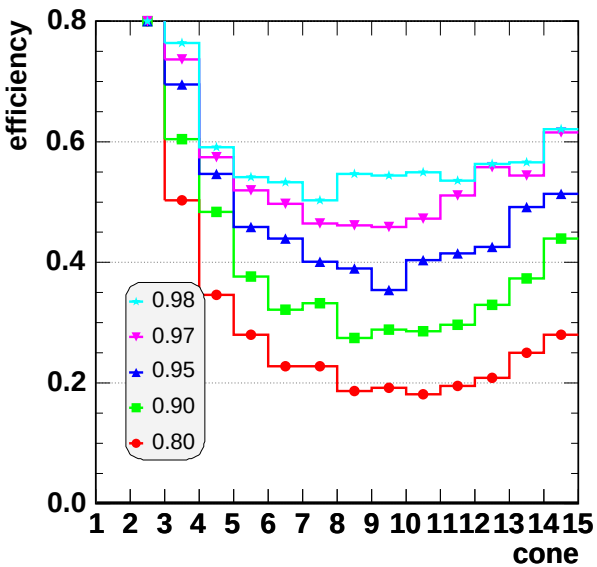


Update of HLT algorithms: High luminosity case

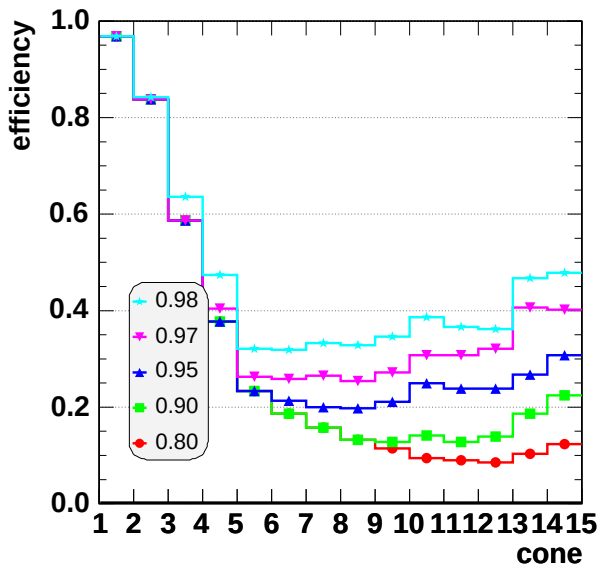
- The same procedure as for low lumi
- The same conclusions
- Low statistics!

CONE	ΔR_{max}	*CONE*	ΔR_{max}
1	0.02	8	0.28
2	0.045	9	0.32
3	0.09	10	0.38
4	0.13	11	0.45
5	0.17	12	0.5
6	0.2	13	0.6
7	0.24	14	0.7

L2 Calo



L3 Px



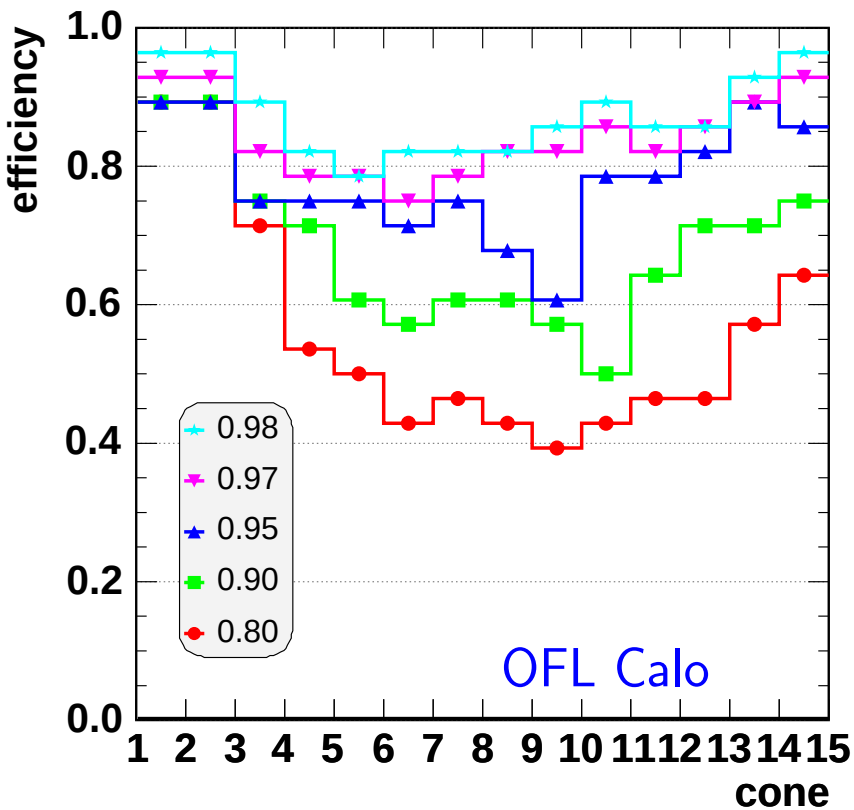
L3 Tk

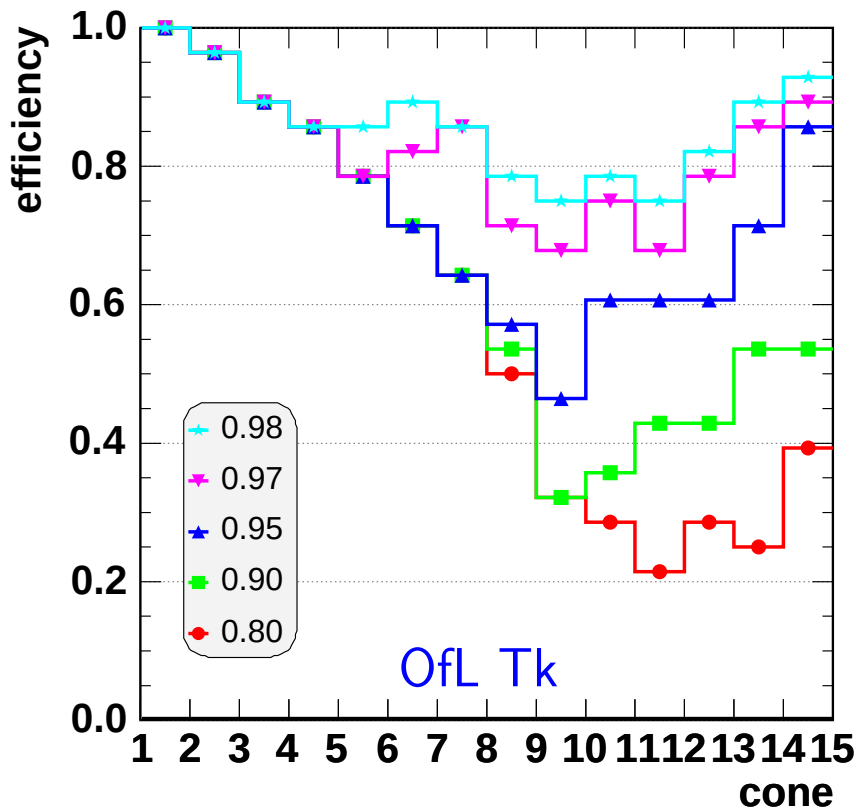
CPU killer!

Offline algorithms - Calo, tracker

- The HLT isolation Calo+Tracker @97% applied in cascade results in efficiency 0.95 for signal events
- After that it is still possible to use Tracker and Calo isolation separately with offline muons.
- The thresholds file (in order to get correct nominal efficiencies) is made with events passing HLT isolation only

WARNING: small statistics plots!





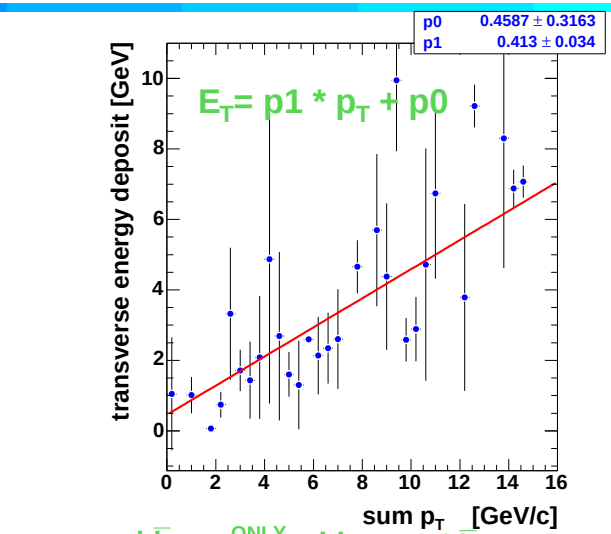
For offline signal efficiency 97% one can obtain 20-30% rejection of background

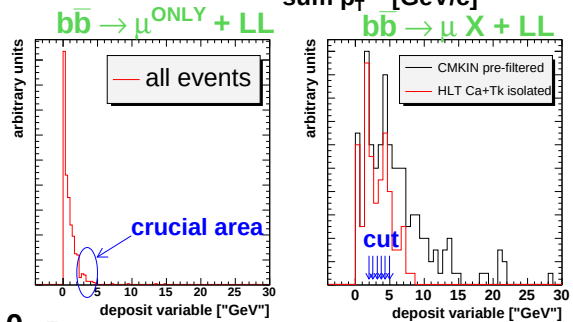
Offline algorithms - Combined

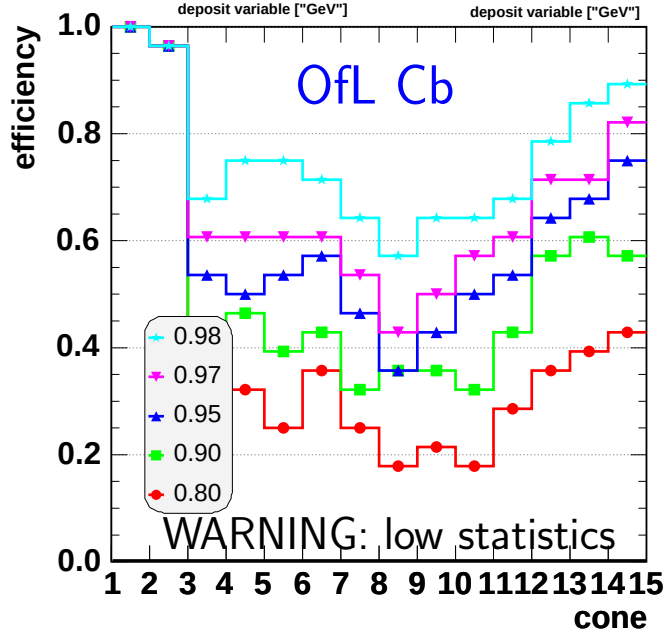
Offline algorithm should combine calorimeter and tracker information

- charged particle tracks measured by tracker with high accuracy,
- neutral particles are seen only in calorimeters,
- do the best to exclude background contributing to isolation cone

- Find all charged tracks from full interaction region,
- Tag muon deposit in calorimeters,
- Propagate charge particle tracks to calorimeters and extract their deposits,
- define deposit as $\Sigma\, p_T + \alpha\, \Sigma\, E_T$, where $\Sigma\, E_T$ is combined HCAL and ECAL deposit with subtracted charged particles deposits (and muon contribution ignored)

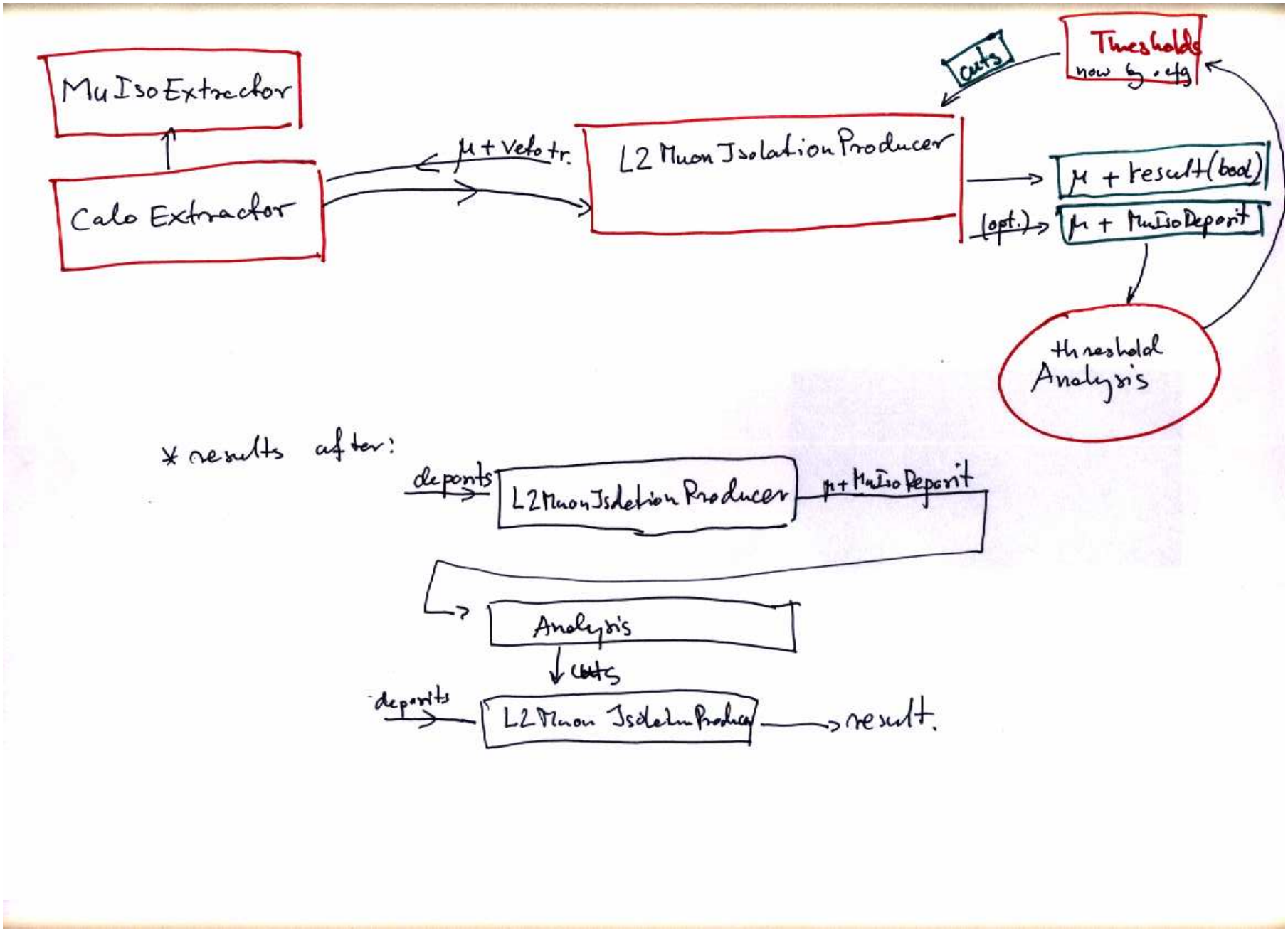




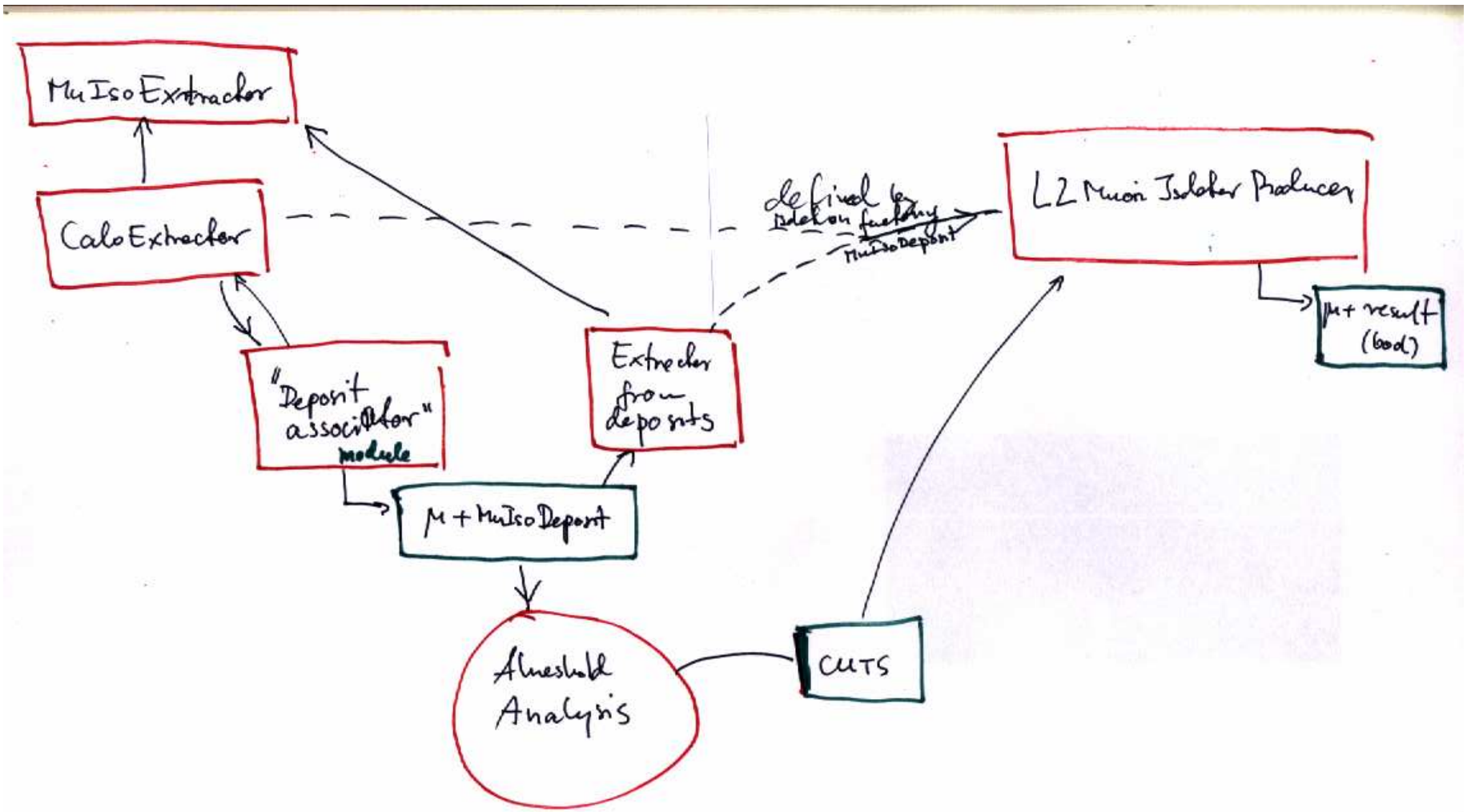


CMSSW - to start discussion on code architecture

CMSSW - current HLT design



CMSSW - optional HLT desing



* results after :

deposits → analysis → cuts

cuts + deposits → L2 Muon Isolation Producer → result.

CMSSW - optional Offline and User isolation desing