Tracking at High Level Trigger in CMS

Mia Tosi (Università degli Studi di Padova & INFN) on behalf of CMS collaboration

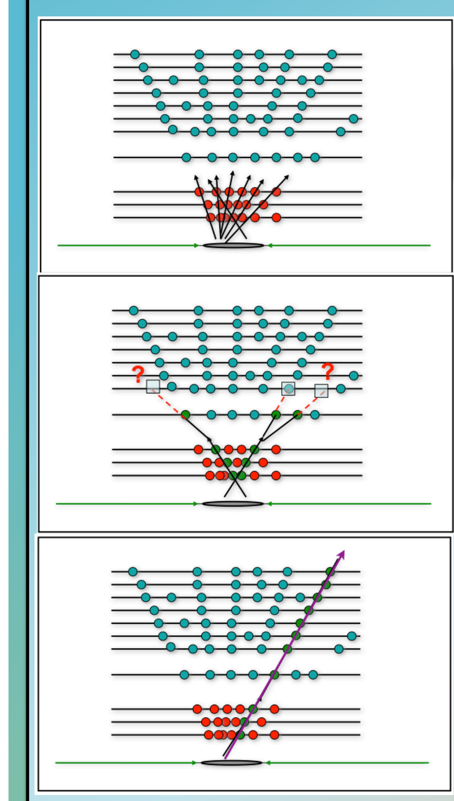
Run II of the LHC :
- **√s = 13 TeV**
- **bunch spacing = 25 ns**
- **luminosity up to 1.6x10^{34} cm^{-2}s^{-1} corresponding to pileup ~ 45** [in RunI pileup ~25]

a challenge for CMS High Level Trigger algorithms
- **event rates increase** (by a factor of 4 w.r.t. RunI)
  - **gain** in **signal efficiency** and **background rejection**
  - **improves physics objects performance** to match offline ones [b-tagging, lepton, object isolation, tau and jet/MET]
- **large hit combinatorics and timing increase @high PU**

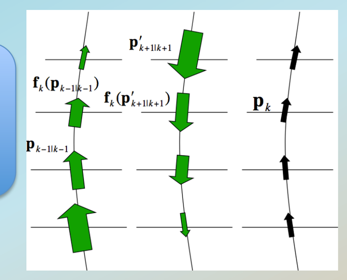
- **extend the usage of Particle Flow technique**
- **efficient and precise tracking**
  - **keep the same algorithm as offline but, drastically reduce tracking timing**

- **applying track reconstruction**
  - **at the end [after other requirements]**
  - **only in regions-of-interesting**
- **specialized track and vertex reconstruction**

track reconstruction: pattern recognition



SEEDING
- *starts from the pixel tracks or pixel/strip hits (triplets or pairs)*
- *seeds not compatible w/ the beamspot or PV are discarded*



TRAJECTORY BUILDING
- *each seed is propagated to successive layers, using **Kalman Filter** or **Gaussian Sum Filter** technique [allowing for missing hits in a layer]*
- *propagation continues until there are no more layers or there's more than 1 missing hit [**material effects** + **multiple scattering** taken into account]*

TRAJECTORY FITTING
- *more hits are added and the track parameters estimation is updated every time a new hit is found*
- *a final fit [Kalman Filter in-out+out-in] is performed to obtain the track parameters at the interaction point*

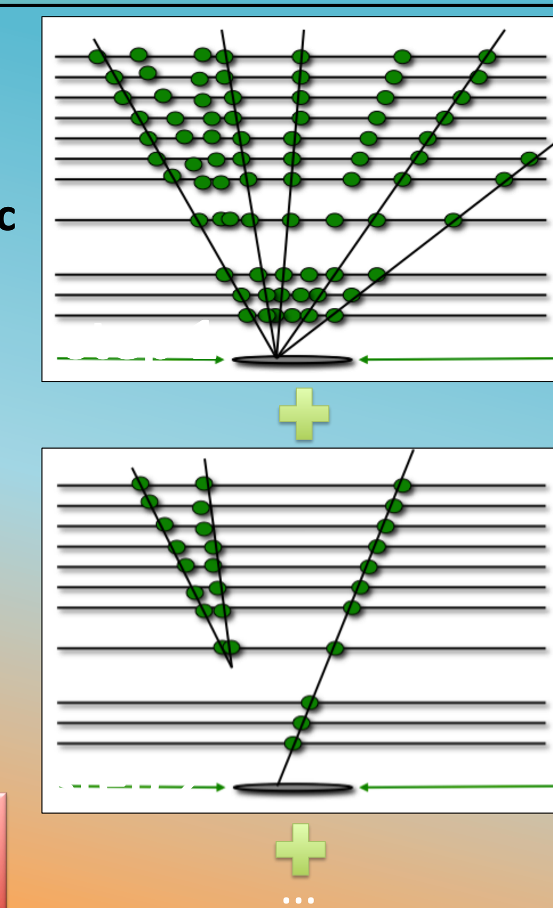
iterative tracking

track reconstruction procedure done **iteratively** where **each step** is meant for **reconstructing** a **specific subset of tracks** (prompt, low/high p_T, displaced, …)

1) reconstruct the most energetic tracks [starting from the high p_T seeds]
2) remove hits associated to found tracks
3) repeat the pattern recognition w/ looser set of cuts

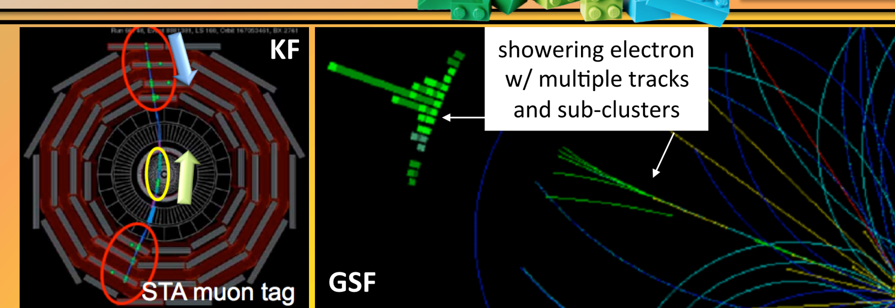
the **Iterative Tracking** reduces the combinatorics and improves both the efficiency and the fake rate
- **helps in reducing the event rate while keeping signal efficiency**

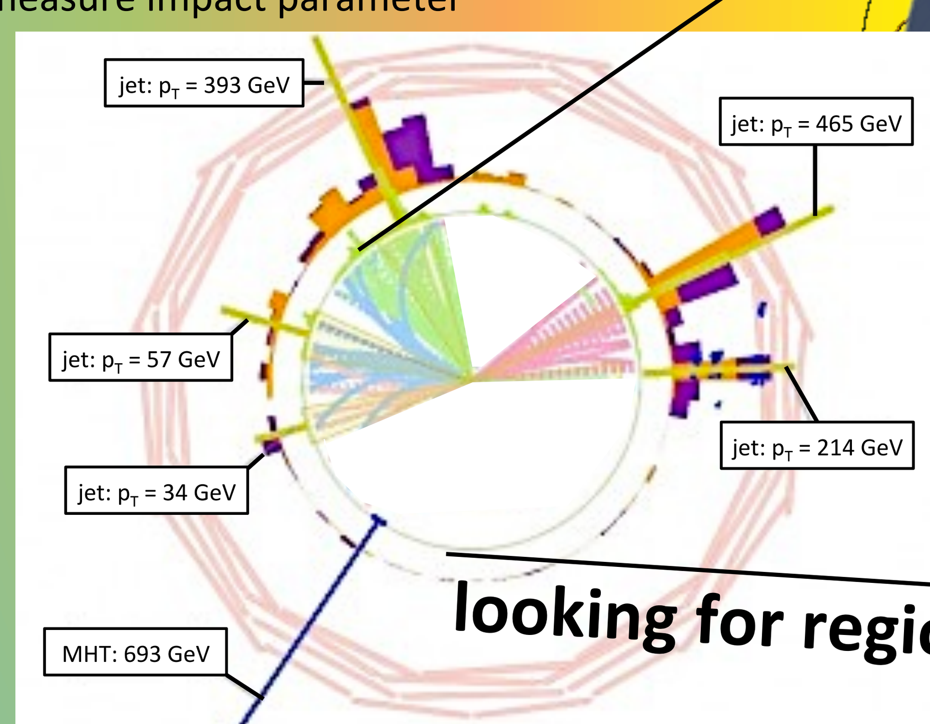
offline algorithms are too slow to be used online: **O(10 s)**
online version has to be much faster: **O(100 ms)**



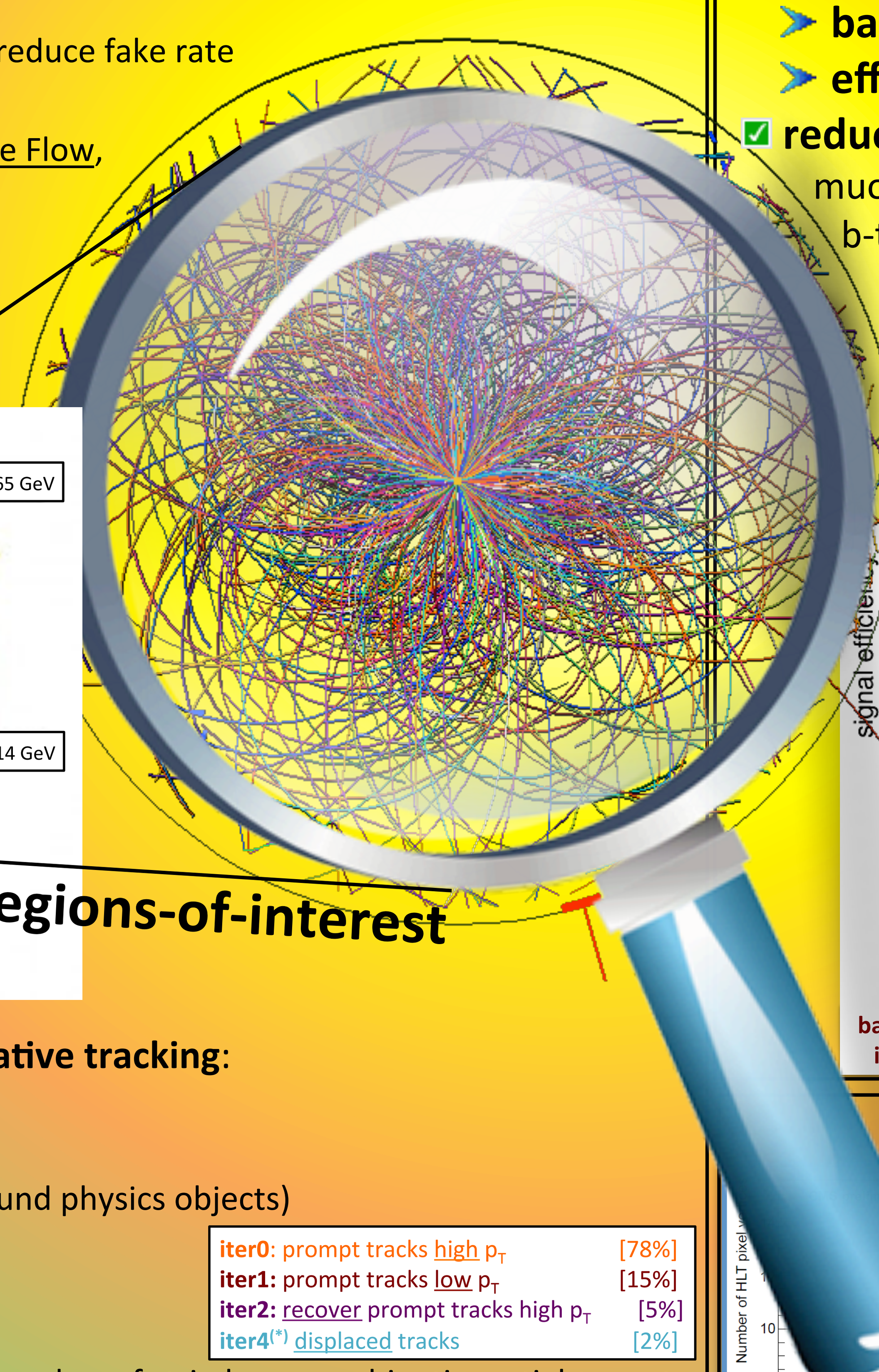
tracking at HLT

several use cases for tracking
- **leptons reconstruction**: Kalman Filter or Gaussian Sum Filter are used to improve p_T resolution of muons and electron
- **leptons isolation**: iterative tracking is used to improve efficiency and reduce fake rate
- **jet, tau and MET reconstruction:** iterative tracking is the key ingredient of the Particle Flow, which improves jet/MET resolution and it is extensivly used in tau reconstruction
- **b-tagging**: vertexing and iterative tracking are used to measure impact parameter





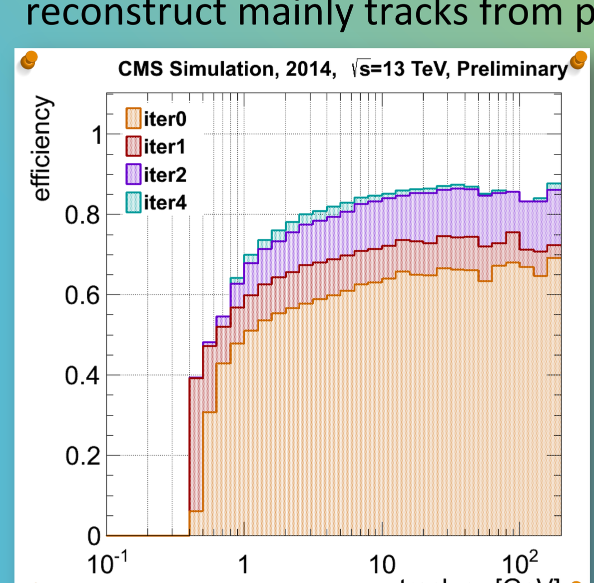
looking for regions-of-interest

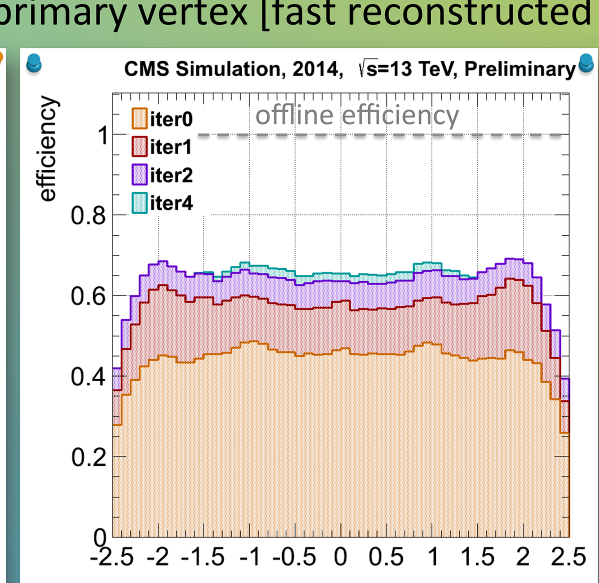


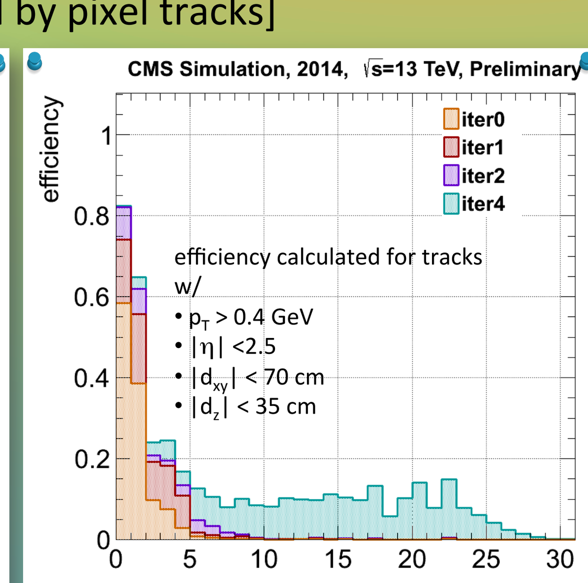
main **differences** between **HLT** and **offline iterative tracking**:
- strip clustering **OnDemand** ←→ !OnDemand
- **regional** ←→ global
  reconstruct tracks only w/in regions of interest (around physics objects)
- **less iterations**
  focus (almost) only on prompt tracks

iter0: prompt tracks high p_T	[78%]
iter1: prompt tracks low p_T	[15%]
iter2: recover prompt tracks high p_T	[5%]
iter4$^{(*)}$ displaced tracks	[2%]

- **seeding**
  pixel tracks used in iter0 [instead of pixel triplets], smaller number of strip layer combinations, tighter cut
  (*) iter4 in 2015 will be run only in a sub set of trigger paths where displaced tracks are needed
- **PV constraint**
  reconstruct mainly tracks from primary vertex [fast reconstructed by pixel tracks]





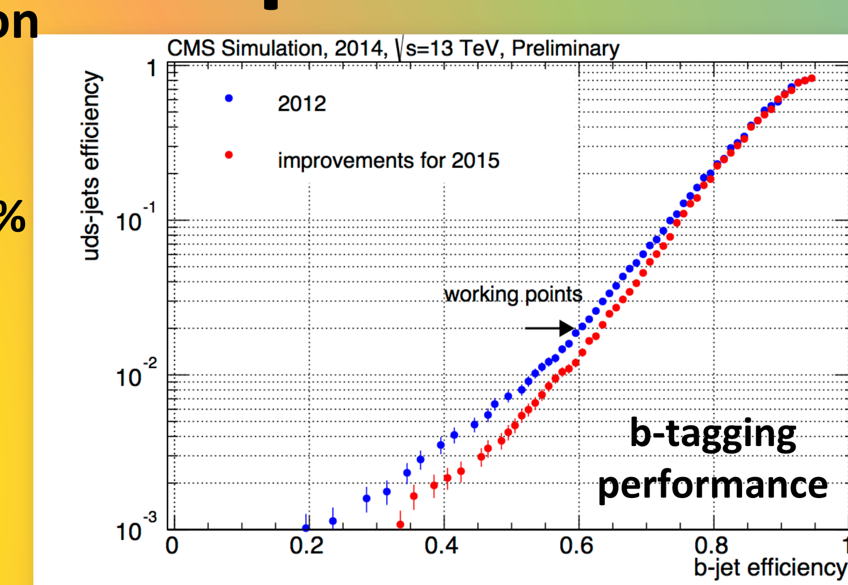


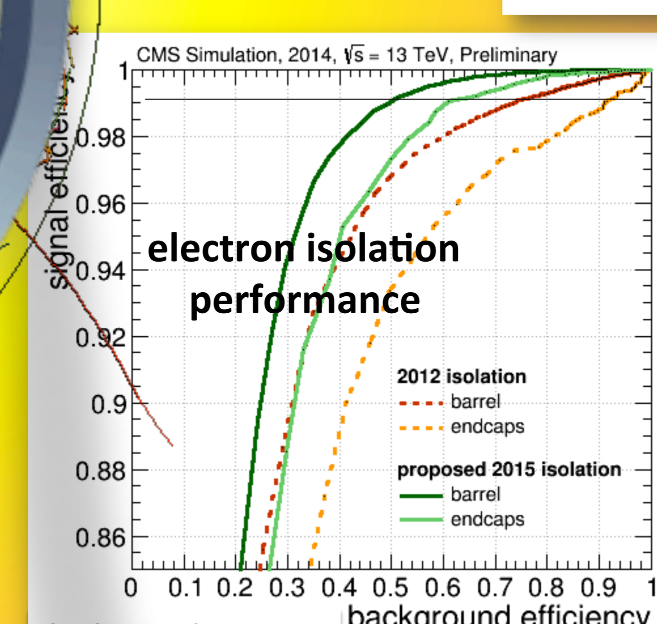
tracking is widely used at HLT
- ✓ **improves physics objects performance** [b-tagging, lepton, tau and jet/MET]
- ✓ **gain in signal efficiency** and **background rejection**
  - **keep rate under control**
  - **keep interesting events for physics analyses**
- ✓ **new HLT tracking configuration fits timing constraints**

mia.tosi@cern.ch

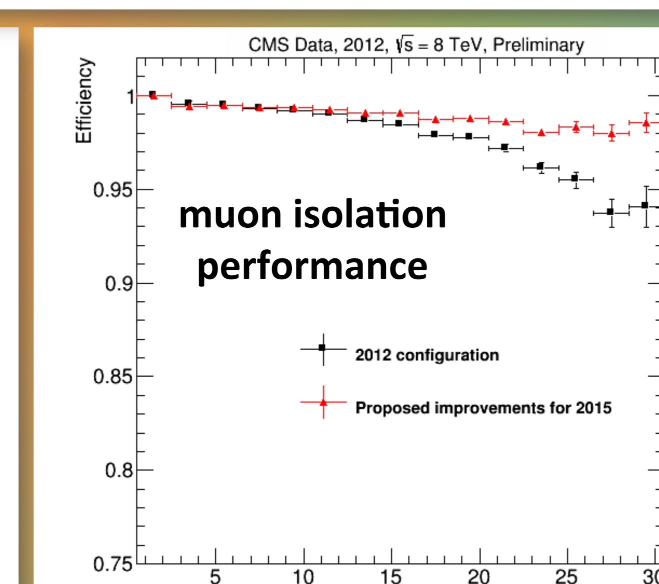
iterative tracking impact on physics object performance

iterative tracking
- ☑ **improves**
  - **signal efficiency**
  - **background rejection**
  - **efficiency vs PU**
- ☑ **reduces timing**
  muon isolation gain: **40%**
  b-tagging gain: **15%**



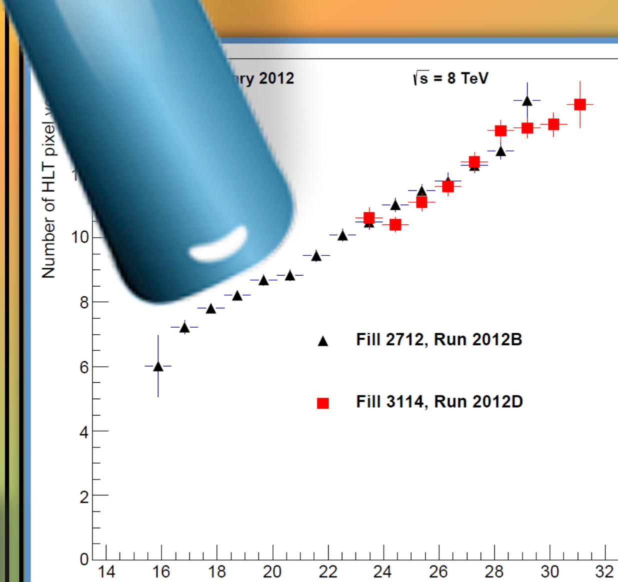


background rejection improves by ~30%



37.8% rate reduction

effect of pileup



- in RunII the number of cunsumers will increase
- with the increase of the luminosity
  ⚠ dramatic increase of combinatorics
- RunI tracking shows an increase of the timing [not linear]
- **new developments have been worked up in order to speed up the track reconstruction w.r.t. RunI and fit the HLT timing limits** [gain a factor ~4 @<PU> ~ 40]

pixelPV 1D (z)
- **fast** reconstruction algorithm : ~ O(1ms)
- **linearity** preserved during 2012 data taking
- separation along z ~O(0.1 mm)
- **robust performance** of the reconstruction **at HLT**