LHCb's real-time alignment and calibration strategy

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on behalf of LHCb Collaboration

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Outline

- Run1 strategy
- What did we learn?
- Run2 strategy
- Alignment method and automatic procedure
- Plan for upgrade strategy
- Conclusion

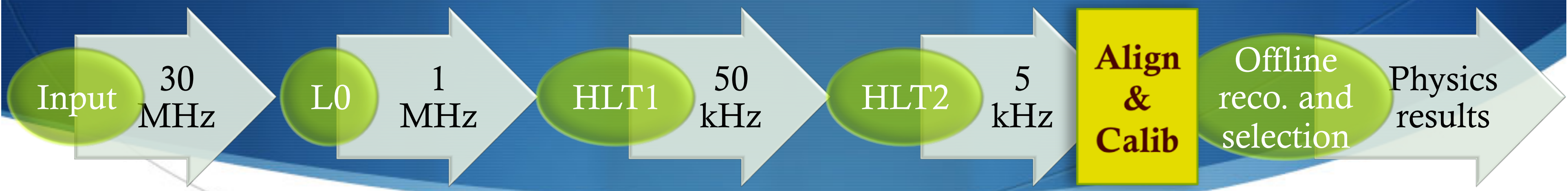
Requirement for physics

→ the smallest statistical and systematic errors

- Best performance
  - Proper PID calibration and alignment are an essential element to get the best performance
- Highest efficiency
  - Minimization of the differences on online and offline reconstruction would allow to improve efficiency
  - Having better performance at the trigger would allow to optimize the selection thus higher efficiency
- Stability over data taking
  - Any time dependency on the detector performance could reflect in larger error in physics results

Run1 strategy

Run1 strategy



- Run HLT and offline with different alignment and calibration
  - HLT calibration/alignment quality improved during the years
- Simplified reconstruction in HLT wrt offline reconstruction:
  - Only 1 PR in forward spectrometer, simplified material description, 1 kalman fit iteration
- 1st early processing of the data with preliminary alignment and calibration
  - For first physics results
- Improved alignment and calibration provided for the end of the year reprocessing data
  - For most of the physics analyses
- Final alignment and calibration for the data used for reprocessing during long TS

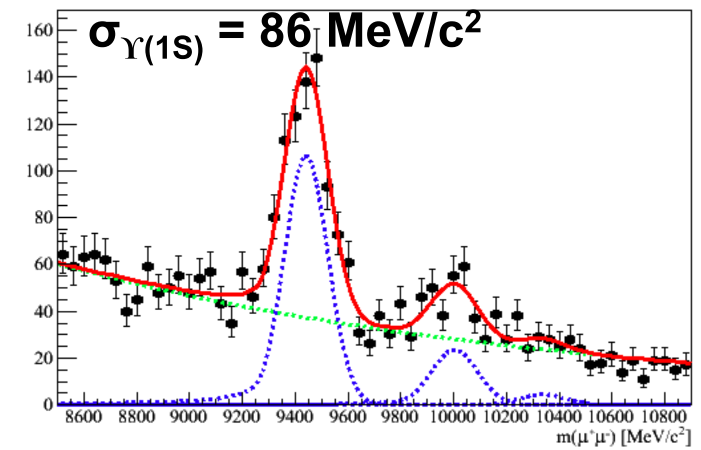
Effect of alignment and calibration on physics performance

Improvements on physics performance

evaluated with offline reconstruction

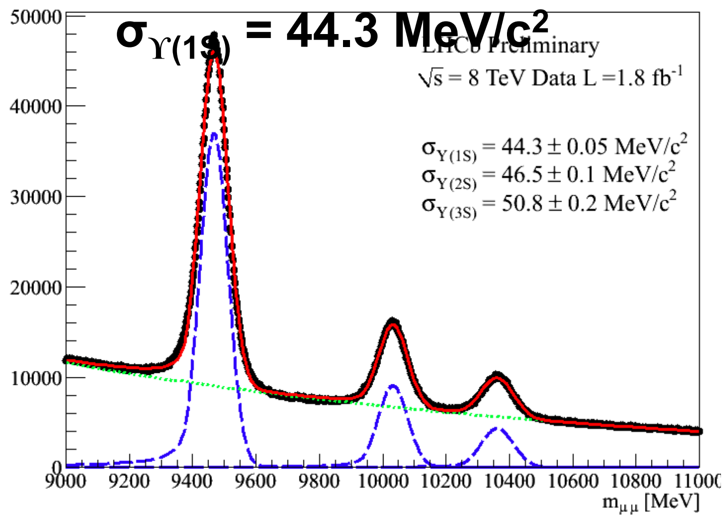
First alignment

$\sigma_{\Upsilon(1S)}$ = 86 MeV/c^2

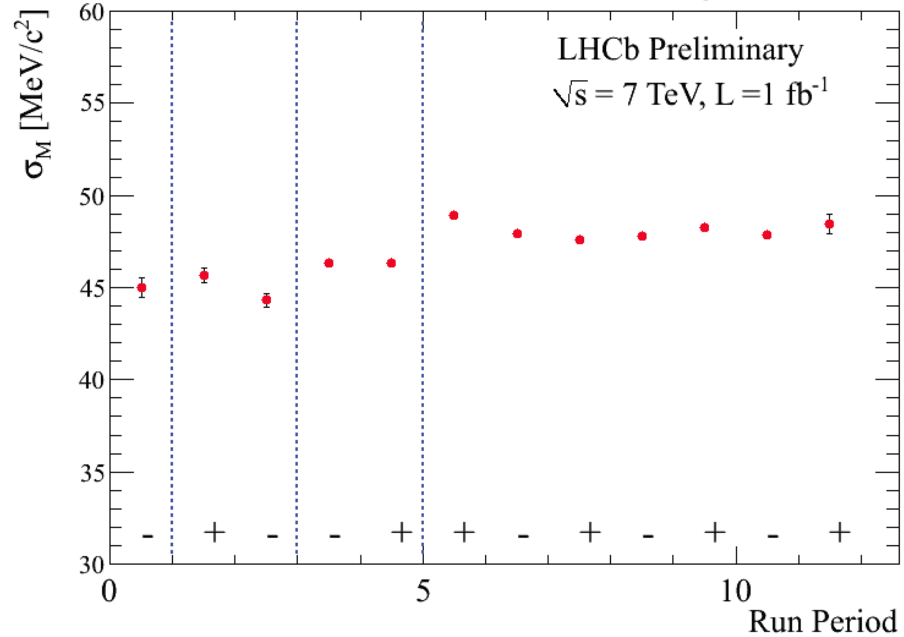


Latest alignment

$\sigma_{\Upsilon(1S)}$ = 44.3 MeV/c^2



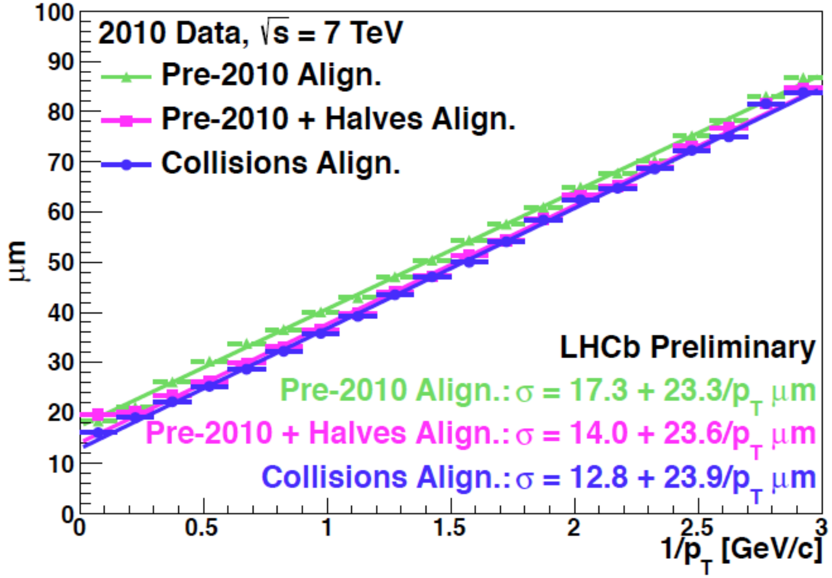
Stability of Υ mass resolution over time with some "intermediate" alignment



Improvements on physics performance
evaluated with offline reconstruction

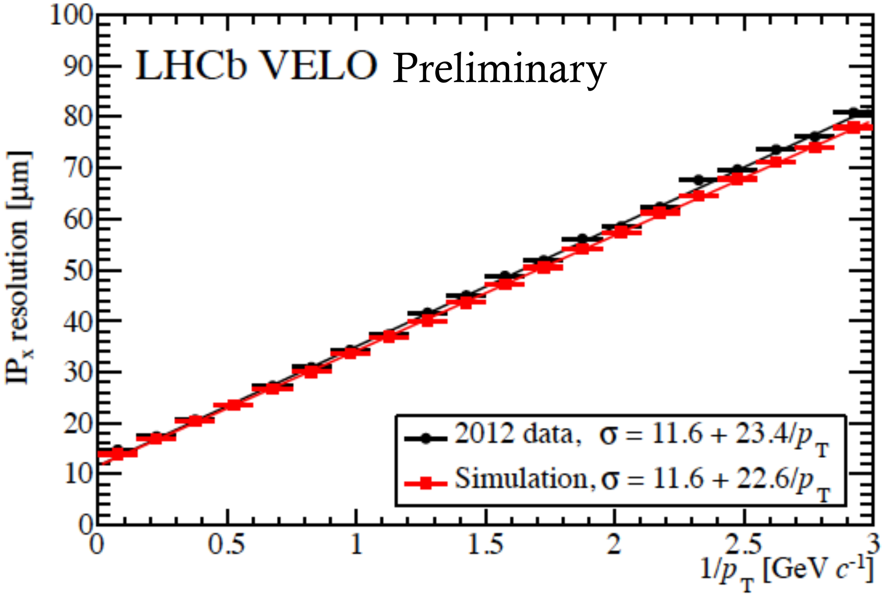
First full alignment

σ_{IP}(high p_t)=14.0 μm



Latest alignment

σ_{IP}(high p_t)=11.6 μm



What did we learn from Run1 experience?

Run1 strategy → Run2 strategy

- Using the latest alignment
  - Gain in time stability
  - Improvement of mass and IP resolution
- These improvements could also affect the HLT performance as selection based on χ^2, momentum and IP

→ Evaluate the alignment and PID calibration before the HLT selection

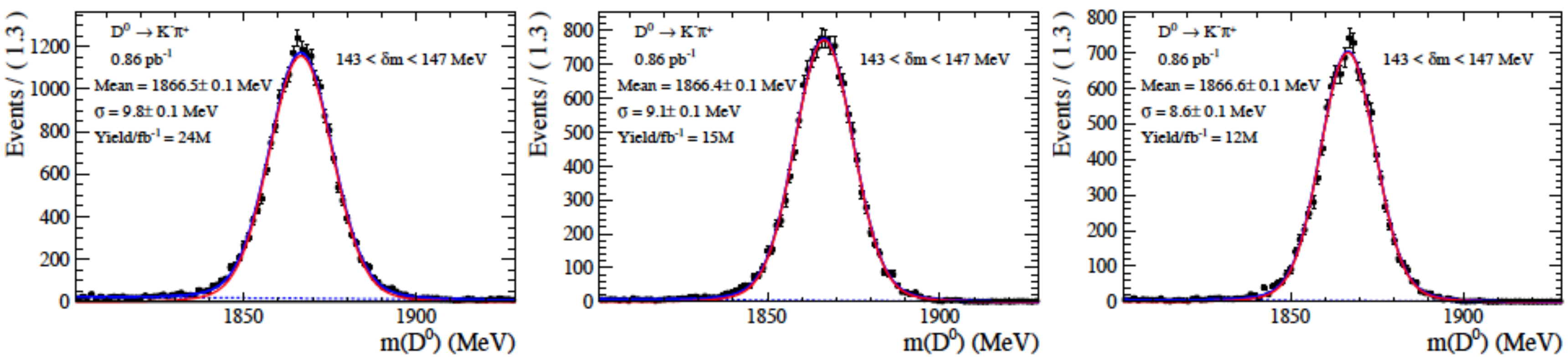
→ Allowing tighter criteria at HLT

PID importance

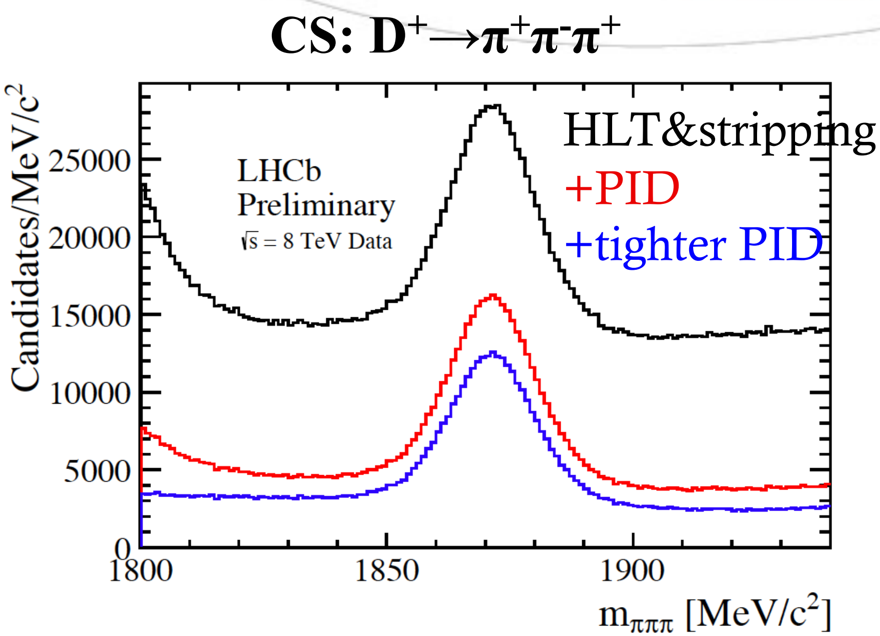
- Applying PID selection ➔ improve purity and mass resolution
- Improve performance of HLT selection, in particular in case of tighter selection
  - E.g. performance of exclusive selections of charm candidates

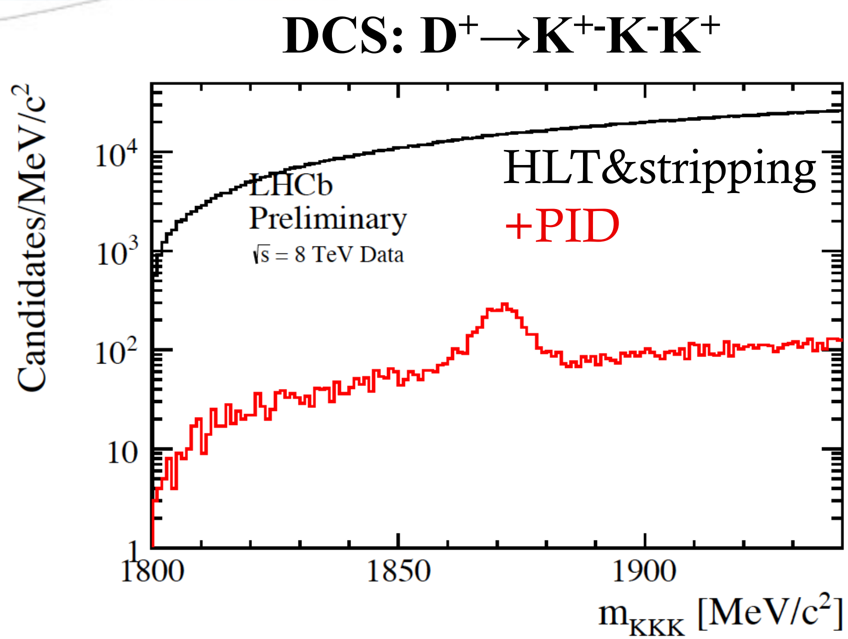
$D^0 \to K^- \pi^+$ invariant mass

Online: σ =9.8MeV | Online + PID σ =9.1MeV | Offline σ =8.6MeV



PID importance

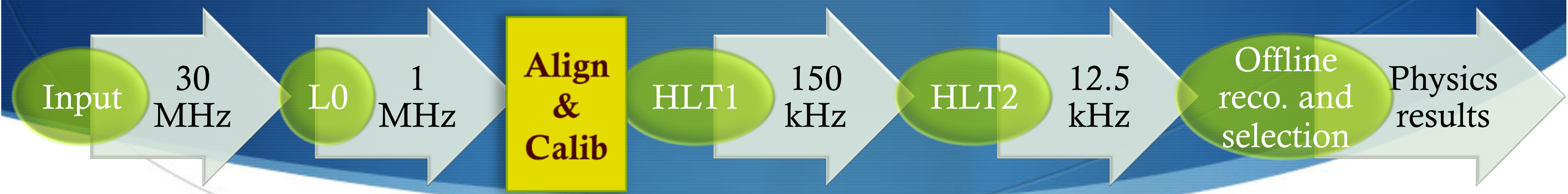




- PID requirements allowing exclusive selection and optimization the rate scaling for the CF modes (control channels in several measurements)

Run 2 strategy

Run2 strategy



- Evaluate the track based alignment and PID calibration before HLT
- Minimization of the online and offline differences
- Include selection based on PID in HLT2
- Run HLT and offline with same alignment and calibration
  - Used for all physics results during run2
- Reprocessing of the data foreseen only at the end of Run2

→Need an automatic procedure!

Alignment Method and Automatic procedure

Alignment

NIM A600 (2009) 471, NIM A472 (2013) 48

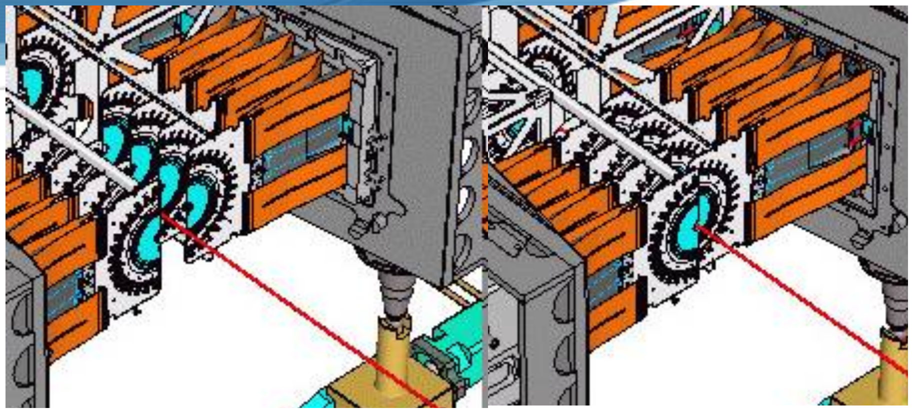
- Standard method based on kalman filter
  - Taken into account multiple scattering and energy loss corrections
  - Using the magnetic field map
- Possibility to apply mass and vertex constraints (in addition to std constraint, e.g. fixing elements or average position)
- Same algorithm for all the sub-detectors ➔ opportunity to have the alignment in one go:
  - internal alignment of elements within the same sub-detector
  - global alignment between the sub-detectors
- Possibility to parallelize the jobs on several CPU

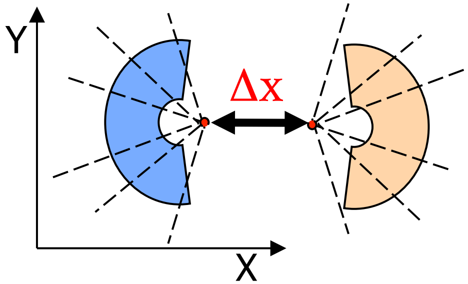
VELO alignment

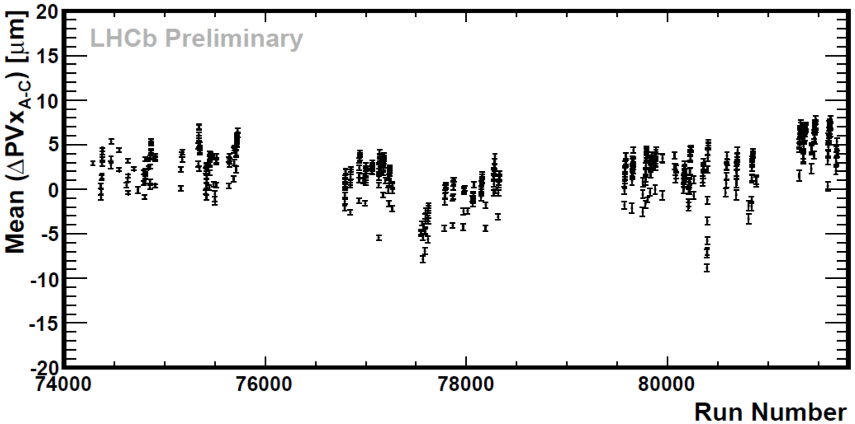
- VELO centred around the beam for each fill when the beam declared stable
- Stability of 2 half alignment by PV method:
  - within ± 5 μm for Tx
  - within ± 2 μm for Ty

➡ Alignment to be determined at the begin of each fill

Fully open   Closed pos.





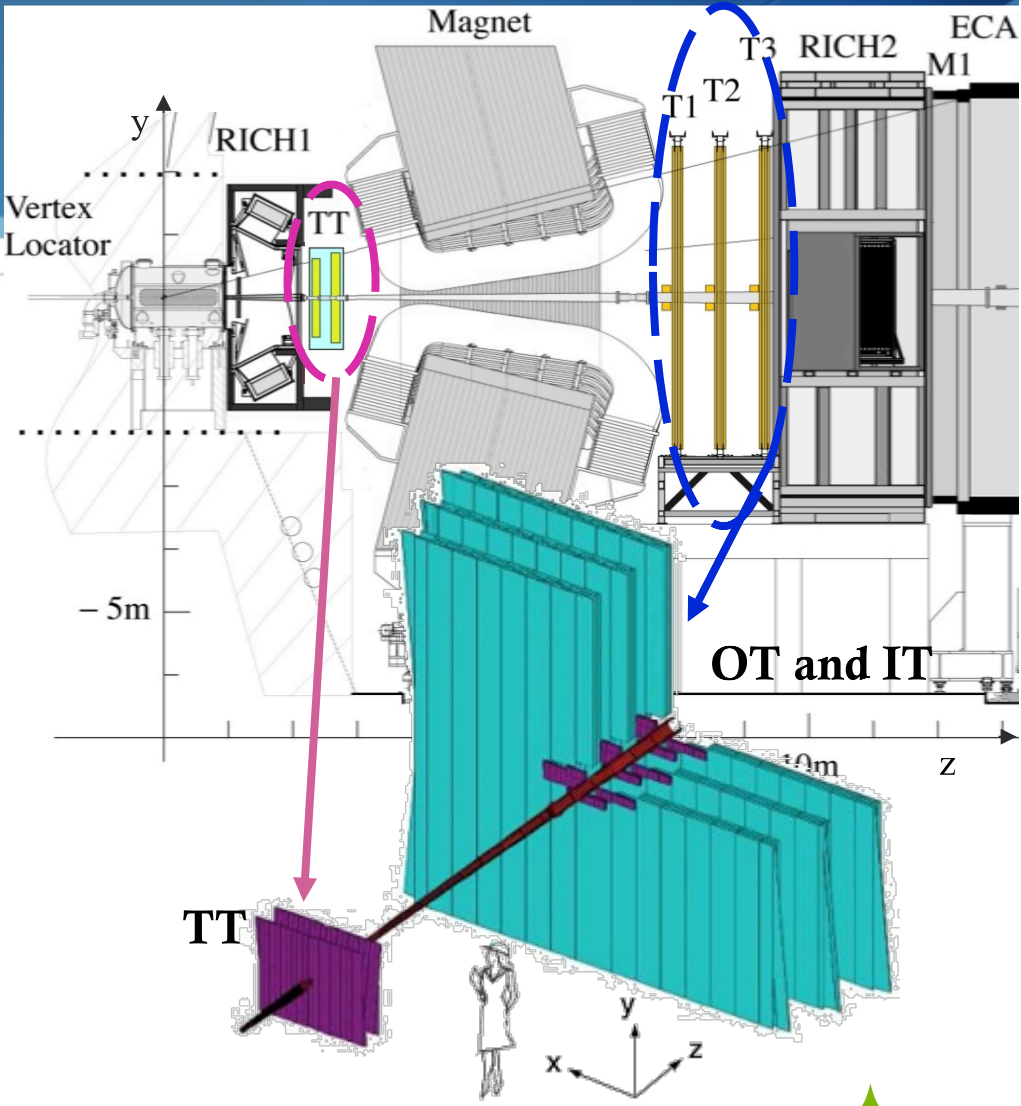


Tracker alignment

- Run independently from the VELO alignment (VELO used as constraint)
- Tracker system align wrt VELO using mass constraint (J/ψ, D^0 mass)
- Preliminary studies show time variation over a period of about 2 weeks, partially due to magnet polarity switch

➡ Alignment needs to be updated when variation are above a certain threshold

- This would trigger the need to check the RICH alignment that relies on the reconstructed tracks



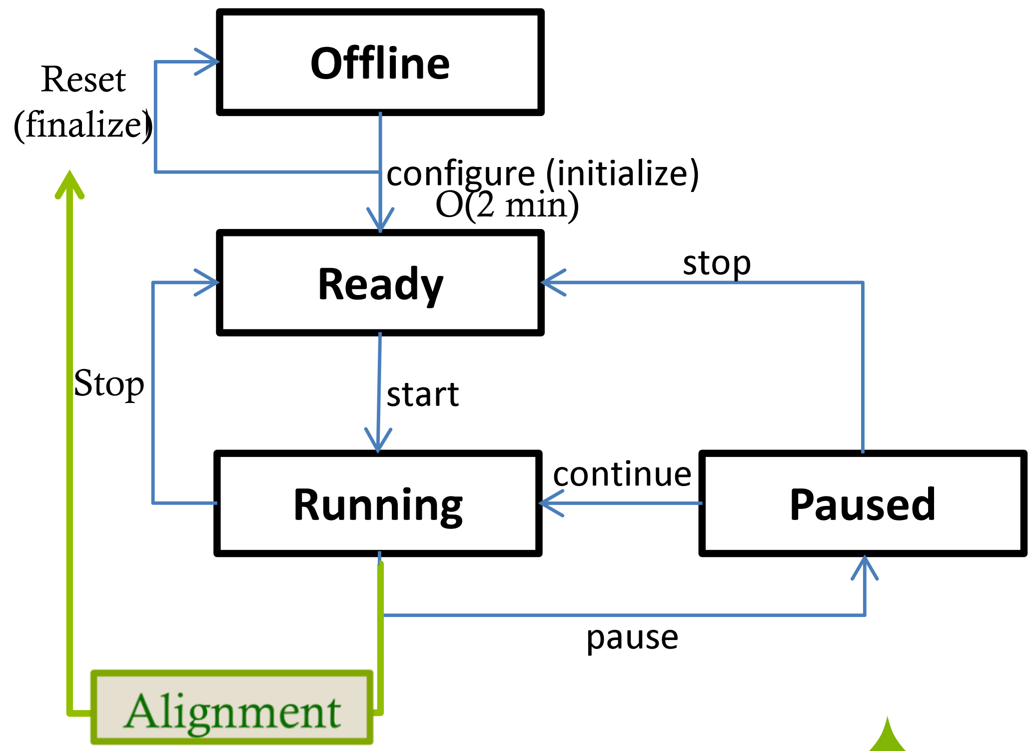
Automatic procedure

Procedure

- Collect enough data
  - Dedicated selection for each alignment
- Run the alignment
- Compare old/new alignment
- Update the alignment constants if needed

Job configuration

parallelization on several nodes



Online Alignment

- VELO alignment at begin of each fill
  - Split on 1500 nodes for the track reconstruction
  - χ^2 minimization in one single node
  - Update immediately if needed
  - Expected to be updated often but not for each fill
- Tracker alignment as soon as enough data
  - data collected in about 1 hour
  - Few dedicated CPU
  - Update as possible
  - To be update each ~2 weeks

Number of alignment constants	
VELO	86
TT	135
IT	64
OT	496

Required Time on 8 CPU	
VELO	20 min
Tracker (TT,IT,OT)	60 min

RICH alignment

- Calculate mirror alignment constants on fill by fill basis
  - Probably only change after technical stop and magnet polarity switch
- Preselected 50k events to have full coverage of the detector
- Alignment evaluated by fitting the displacement of Cherenkov rings wrt tracks versus phi
- Depends on HPD and refractive index calibration evaluated on run by run basis
- Can be done after HLT1 as it is used only at HLT2

Number of constants	
Mirror	1090
HPD	1940
Refractive index	2

Plan for the Upgrade Strategy

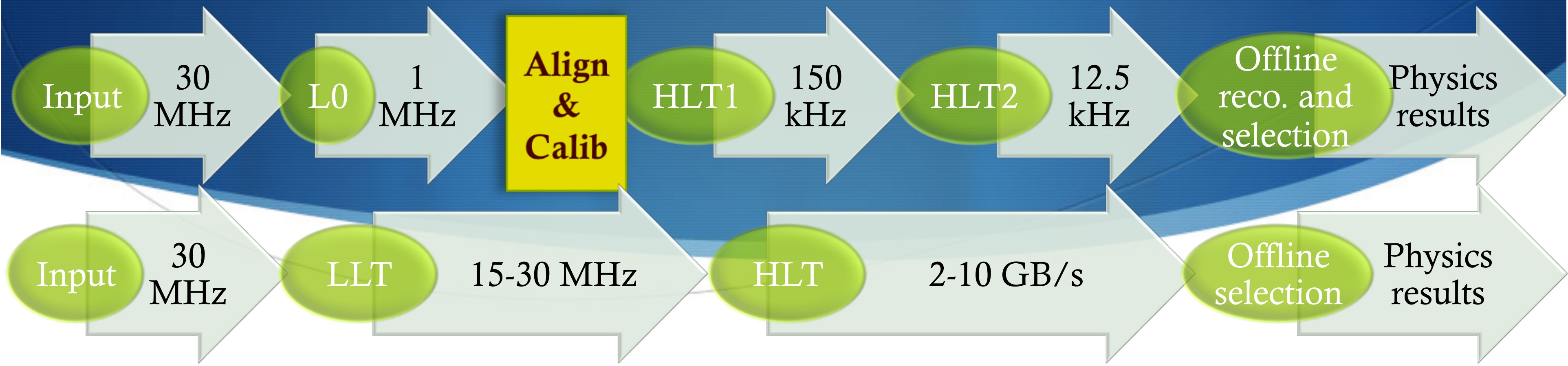
Upgrade strategy

- Full software trigger!
- HLT reconstruction should be the offline reconstruction
- Idea to save directly tracks
- Alignment and PID calibration need to be done directly online

➔ **Optimization of the resources to reach the best physics performance**

- Less data to save on disk
- Maximize efficiency
- No systematic due to different reconstruction and calibration between online-offline

Conclusion



- Run2 strategy:
  - Alignment and PID calibration evaluated before HLT
  - Include PID in selection criteria
  - Minimize the differences in track reconstruction
- Upgrade
  - Full software trigger
  - Same reconstruction in trigger and offline
  - Need to have the best alignment and PID calibration online

➔ **Optimization of the resources to reach the best physics performance**

Backup

RICH calibration

- Implemented as an online analysis task, evaluated run by run
  - RICH refractive index and HPD image
- Based on histograms ➔ required time O(1 min)
- Work flow:
  1. Take the last file of one run automatically (triggered by either when End-of-Run ("EOR") in the file name or run number in the file name changed)
  2. Run ref index job
  3. Run HPD image job
  4. Give signal to online that the calibration is done for this run