Alignment Calibrations

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- Note - these slides are preliminary as details have not been fully discussed and decided upon by tracking, DSC, and SRO working groups (and others). These are my personal thoughts as a starting point for a larger discussion

Alignment Strategy

- ePIC will have a challenge to align a large number of sensors in a large detector system spanning a large volume/area

- (As of now?) will use some combination of GeneralBrokenLines + Acts + Millepede2, where GBL/Acts will provide fit information and Millepede2 will perform global minimization

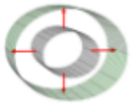
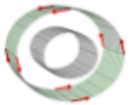
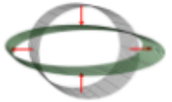
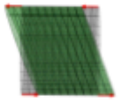
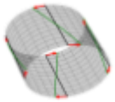
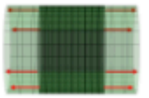
  - Common software tracking tools used by wide HEP/NP community

- Alignment will have to be performed in 6 DOF - 3 translation and 3 rotation per structure (barrel/disk, layer, stave, sensor…)

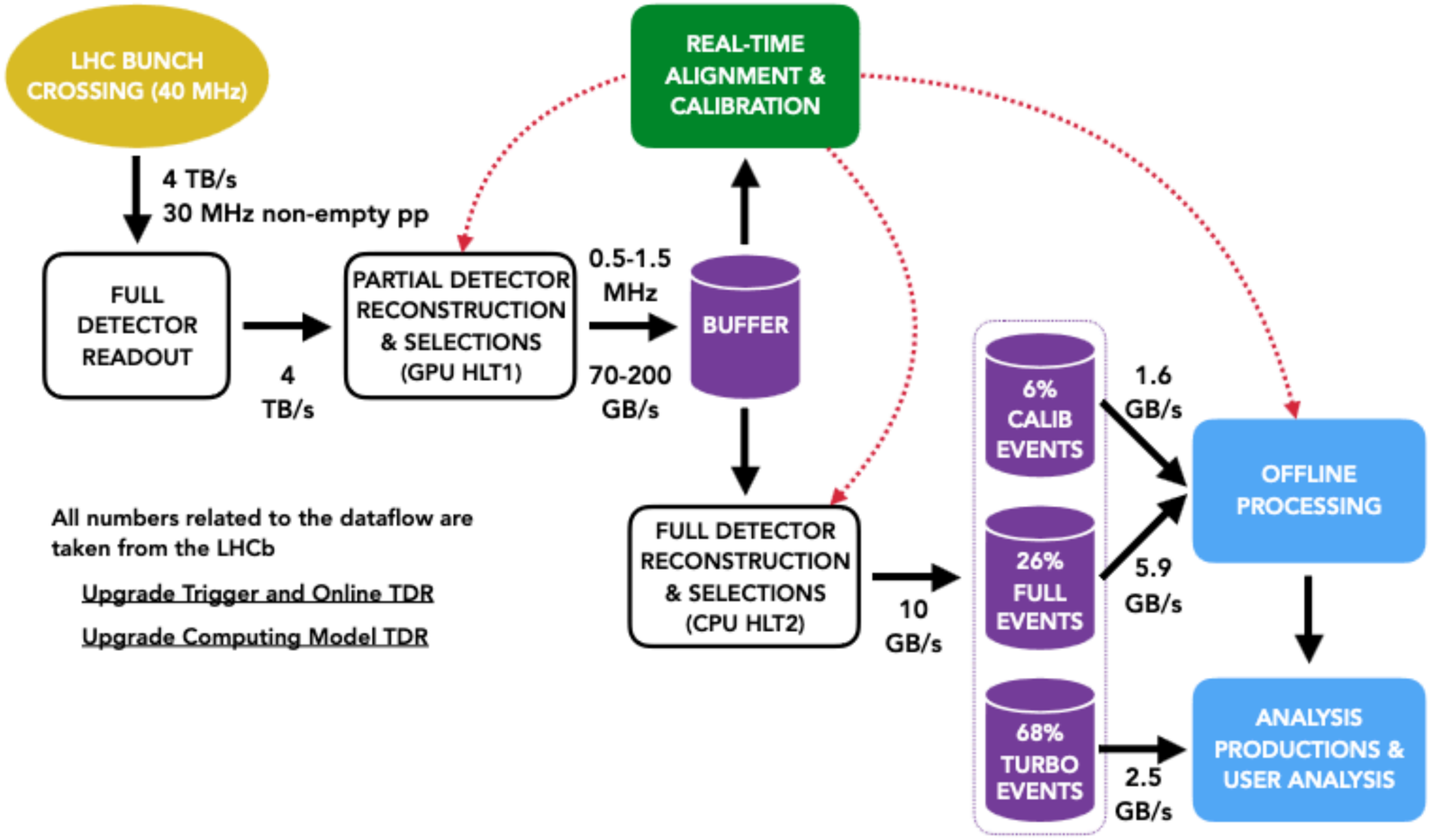
  - i.e. very large number of degrees of freedom when you consider all sensors

First Thoughts

- Will want to collect a wide variety of data to minimize “weak modes” as much as possible
  - Cosmics, low pileup beam data, magnet off/ on…
- LHC benefits from abundant, clean, and high mass resonance statistics (J/ψ, Z…) - ePIC won’t have that luxury
  - K^0_s will be a useful measuring stick
- In general strategy is to align larger structures first, then treat next smallest structure as perturbation
- S&C group has the goal of rapid data turnaround - essentially autonomous calibration on the time scale of a few weeks

	Δr	$r\Delta\phi$	Δz
r	**Radial expansion** $\Delta r = c_{scale} \cdot r$ 	**Curl** $r\Delta\phi = c_{scale} \cdot r + c_0$ 	**Telescope** $\Delta z = c_{scale} \cdot r$ 
ϕ	**Elliptical expansion** $\Delta r = c_{scale} \cdot \cos(2\phi) \cdot r$ 	**Clamshell** $\Delta\phi = c_{scale} \cdot \cos(\phi)$ 	**Skew** $\Delta z = c_{scale} \cdot \cos(\phi)$ 
z	**Bowing** $\Delta r = c_{scale} \cdot \lvert z \rvert$ 	**Twist** $r\Delta\phi = c_{scale} \cdot z$ 	**Z expansion** $\Delta z = c_{scale} \cdot z$ 

Alignment Workflow Model



- LHCb real time analysis model (also 100% streaming)

Survey Geometry

- When detectors are installed, survey will give some initial estimate of where the macro structures are located
- This will serve as our initial/ideal geometry (e.g. to input to simulation). Additional alignment corrections treated as perturbations
- Will be necessarily coarse - probably O(mm) but should give a good idea of where things are relative to each other
    - Often there is also machining survey geometry available, but this needs to be validated with tracks
- Following this we can use magnet off cosmics for initial estimate of large scale structure alignment
    - Turning a several T field on will move things around, so this will only be a starting point

Track Samples

- At any given time during taking, we will want
  - Cosmics trigger (?), or some way to identify cosmics events cleanly
  - Low luminosity and pile up beam conditions, where we can very easily identify tracks (i.e. few hits from out of time bunch crossings)
- Will be nice to have hot/dead channel maps and/or thresholds tuned to some degree already, although this isn't strictly necessary
- Need O(tens-hundreds) of tracks per structure to align
  - Experience with sPHENIX MVTX - For smallest scale (i.e. sensor) need O(100ks) tracks for 3 layers of mid rapidity silicon pixel, assuming completely homogeneous track distribution
- Laser system (?)
- ePIC will have challenge that we need to align many more detectors at very large distances to one another (e.g. forward disks to backward disks!). Estimates for track statistics may be higher because of this

Time Scales

- Calibrations will have to be applied to some interval of validity
- Certain alignment constants will be applicable for long time scales, others might not
  - e.g. the large scale structure determined from field off may be applicable for an entire run period, while smaller scale structure may need to be determined more frequently
- During commissioning, calibrations will steadily improve day-to-day, but during steady state running we will want periodic dedicated alignment calibration runs (cosmics, low/nominal luminosity)
  - Even if just for verification/validation purposes

Autonomous Calibration

- During commissioning we will need human intervention to the alignment, to be sure we understand what we are doing
- Goal is to have this fully automized, like the LHCb case
- The procedure is iterative and only “needs” human intervention to ensure that all weak modes are properly accounted for
    - Once we are in steady state and have had the experience to understand all weak modes, I expect this process to be fully automated

Storage of Calibrations

- Alignment is only relevant for reconstruction and analysis, to achieve optimal tracking performance
  - Not necessary early in DAQ process in (e.g.) time frame building
- We will want to store these in a conditions database, for which anyone can access the latest and greatest
  - e.g. give me the alignment calibrations for time frame X corresponding to data set Y
- Initially, calibrations will be iteratively improved
  - e.g. will not have 2 alignment calibrations that apply to the same time frame, one will be better than the other

Summary

- Alignment calibrations are iterative in nature
- Goal is to have this done autonomously once we are in steady state production
- Will need O(100ks) of tracks to reach 5 micron precision
  - Important to have a wide variety of tracks from cosmics, regular beam conditions, low luminosity beam conditions…
- Will need a robust conditions DB that can be continuously updated with the latest and greatest
- Don’t expect large needs from upstream DAQ process as these calibrations are primarily determined for reconstruction/analysis
  - Only need to be well integrated into the full online-to-offline workflow to ensure proper synchronization