Central Diffraction in ALICE in Run 3

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…and now for something completely different…

Plan of Talk

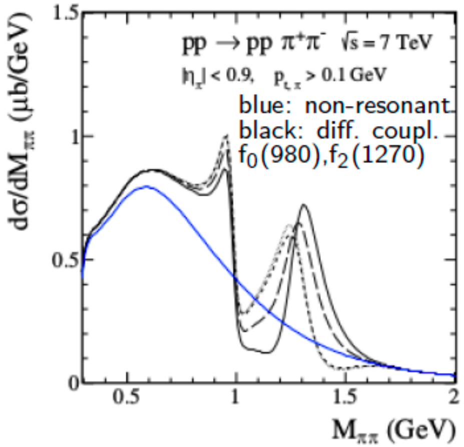
- Physics Motivation
- Continuous readout
- Data filtering strategies
- Detector layout
- First estimate of reconstruction efficiencies
- Projected interaction rates
- Conclusions

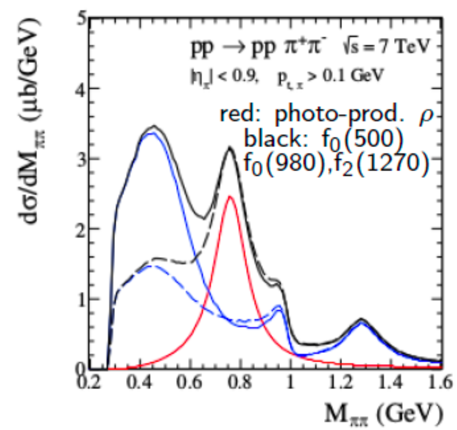
Physics Motivation

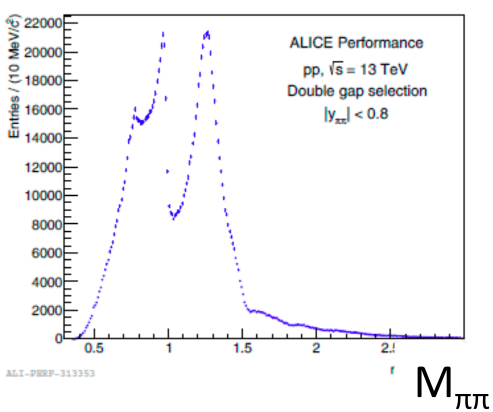
- A proposed physics programme for "double gap" physics was studied for the *Physics of the HL-LHC* report CERN-LPCC-2018-03 (Working Group 1)
- For ALICE, the main physics targets were
  - Glueball studies
  - The spin structure of the Pomeron
  - PWA of centrally produced meson systems
  - Production of heavy quarkonium states
- Runs 3 and 4 will bring enormously increased statistics. The run 2 integrated luminosity was ~8.2 pb^{-1}. After runs 3 and 4, we expect to collect considerably more, and in addition the data filtering from continuous readout will be 3-5 times more efficient than the run 2 trigger.

Predictions for main features of data

P.Lebiedowicz, O.Nachtmann, A.Szczurek, Phys.Rev.D98 (2018),014001.



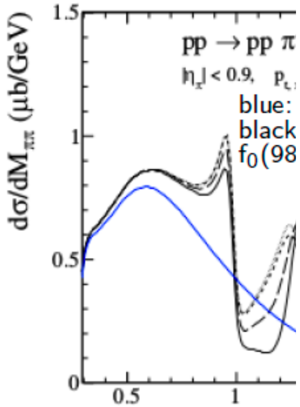




- Top plots show predictions from Lebiedowicz et al.
- Bottom plot shows ALICE performance data in pp collisions at 13 TeV
- Model reproduces main features of data, including resonant activity.

Predictions for main features of data

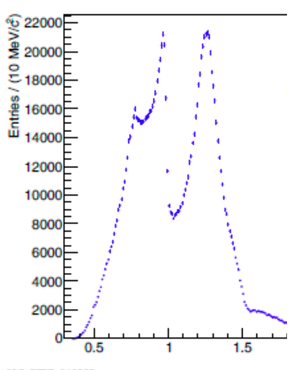
P.Lebiedowicz, C ... 018),014001.



Many glueball candidates with masses below 2 GeV could be produced in the central diffractive spectrum

particle	$I^G(J^{PC})$
$f_0(500)$ or σ was $f_0(600)$	$0^+(0^{++})$
$f_0(980)$	$0^+(0^{++})$
$f_2(1270)$	$0^+(2^{++})$
$f_0(1370)$	$0^+(0^{++})$
$f_0(1500)$	$0^+(0^{++})$
$f'_2(1525)$	$0^+(2^{++})$
$f_0(1710)$	$0^+(0^{++})$
$f_2(1950)$	$0^+(2^{++})$

Glue ball ? $J^{PC} = 2^{++}$



$M_{\pi\pi}$

from Lebiedowicz et al.

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tures of data, including

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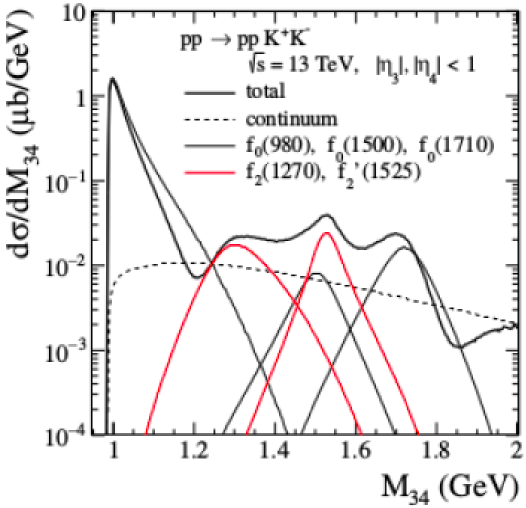
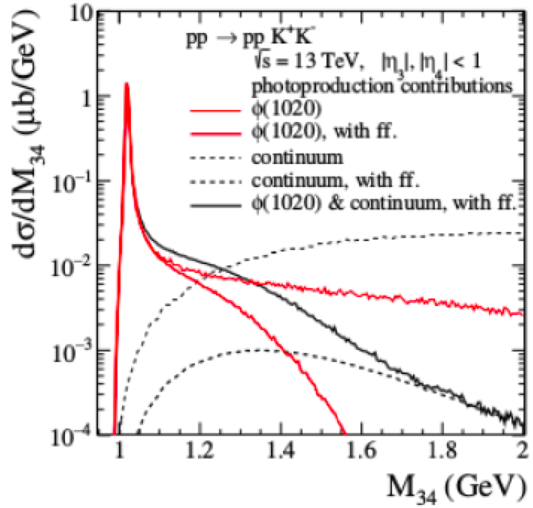
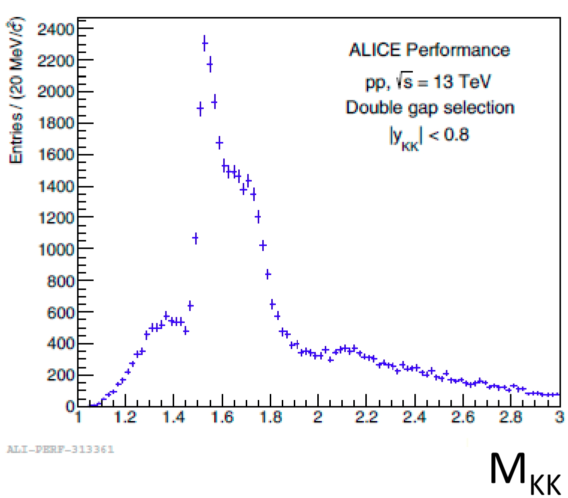
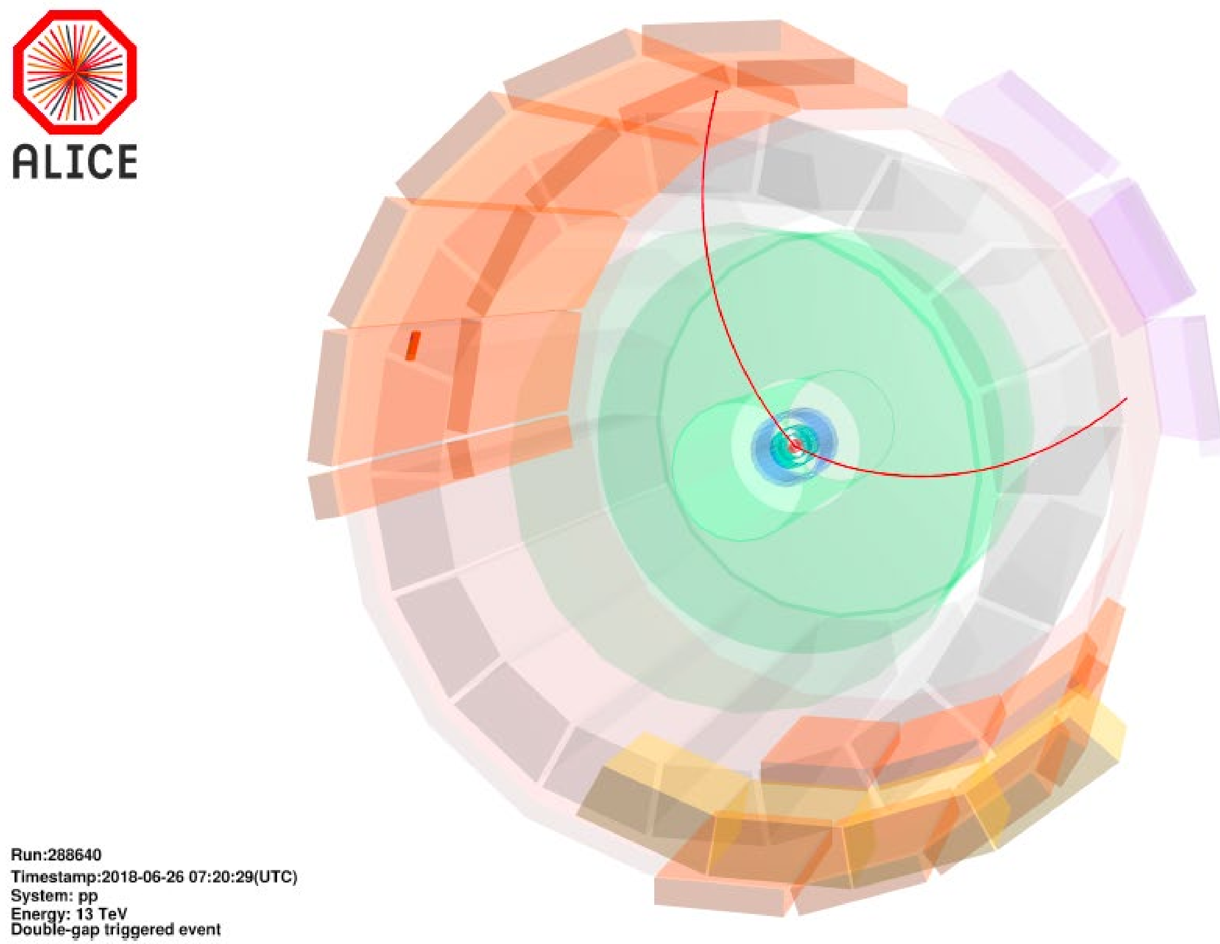






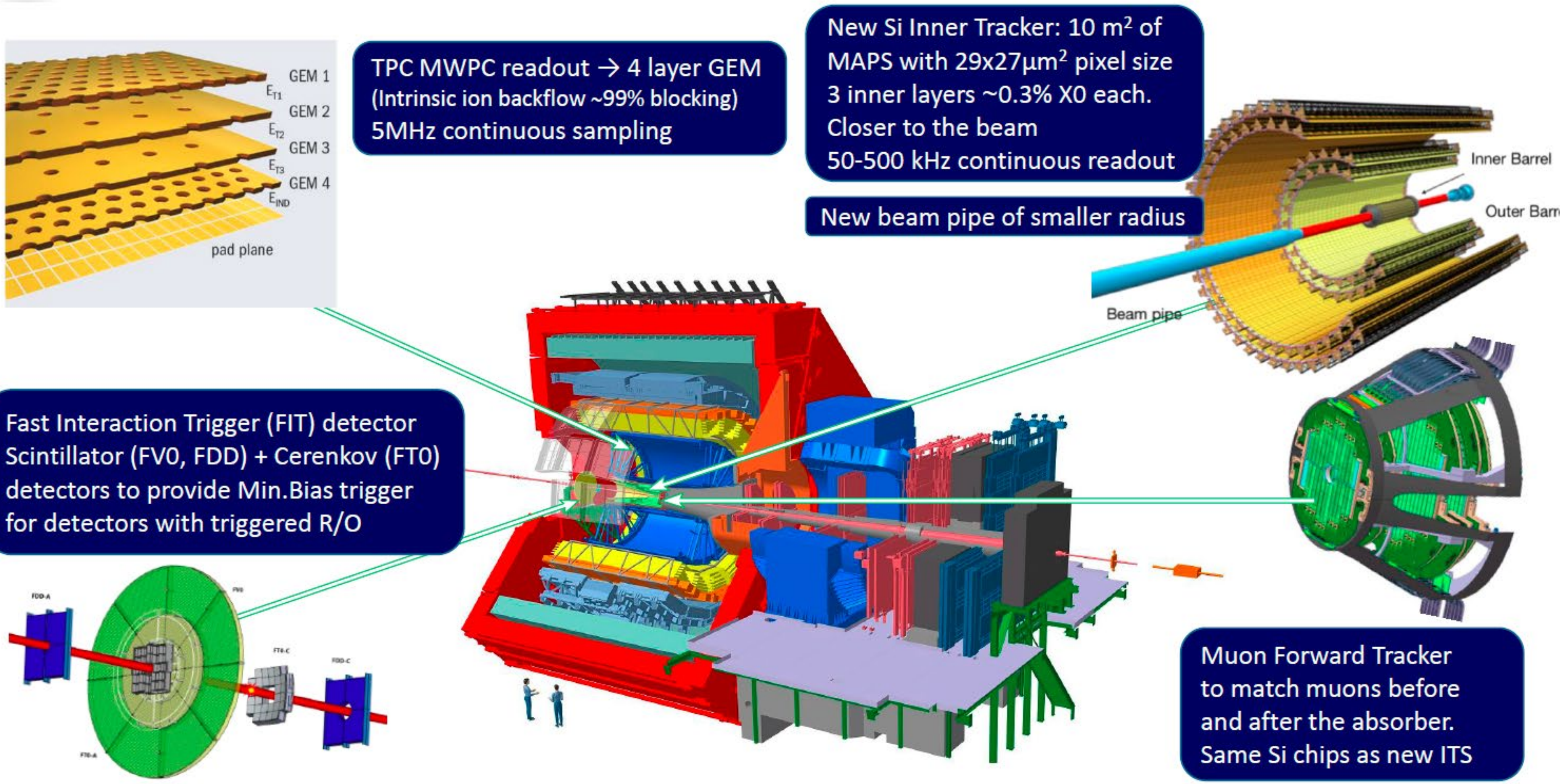
- Mass spectrum again shows a lot of resonant activity
- Data drop below ~1.4 GeV is a feature of the run 2 trigger. Should not occur with continuous readout.

Central Diffraction Event display

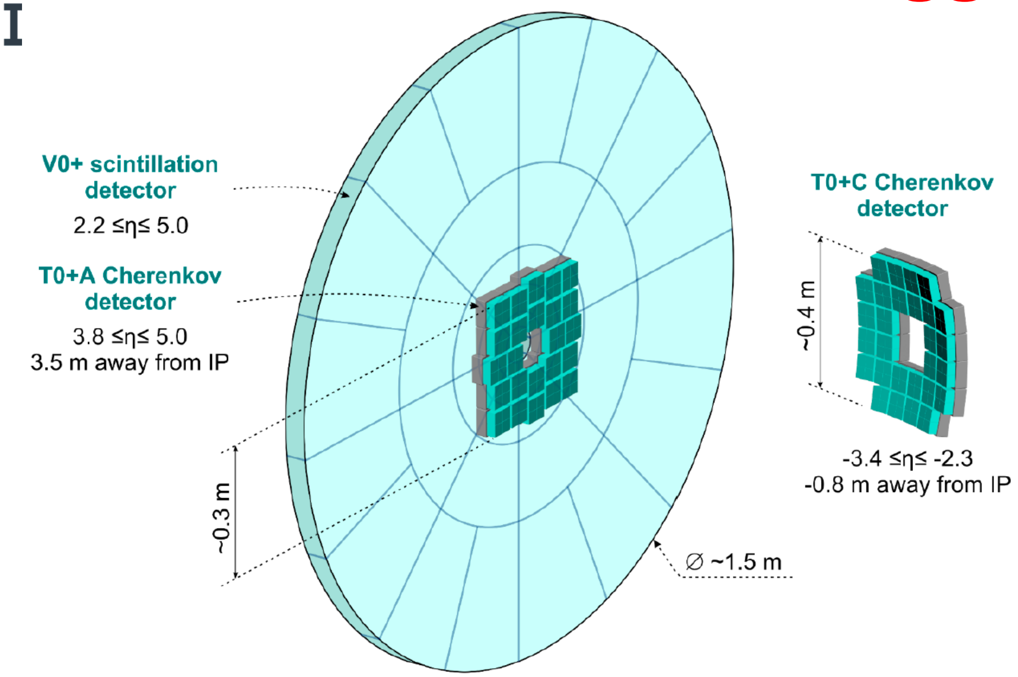


Run 3 hardware upgrade

https://indico.cern.ch/event/773049/contributions/3581368

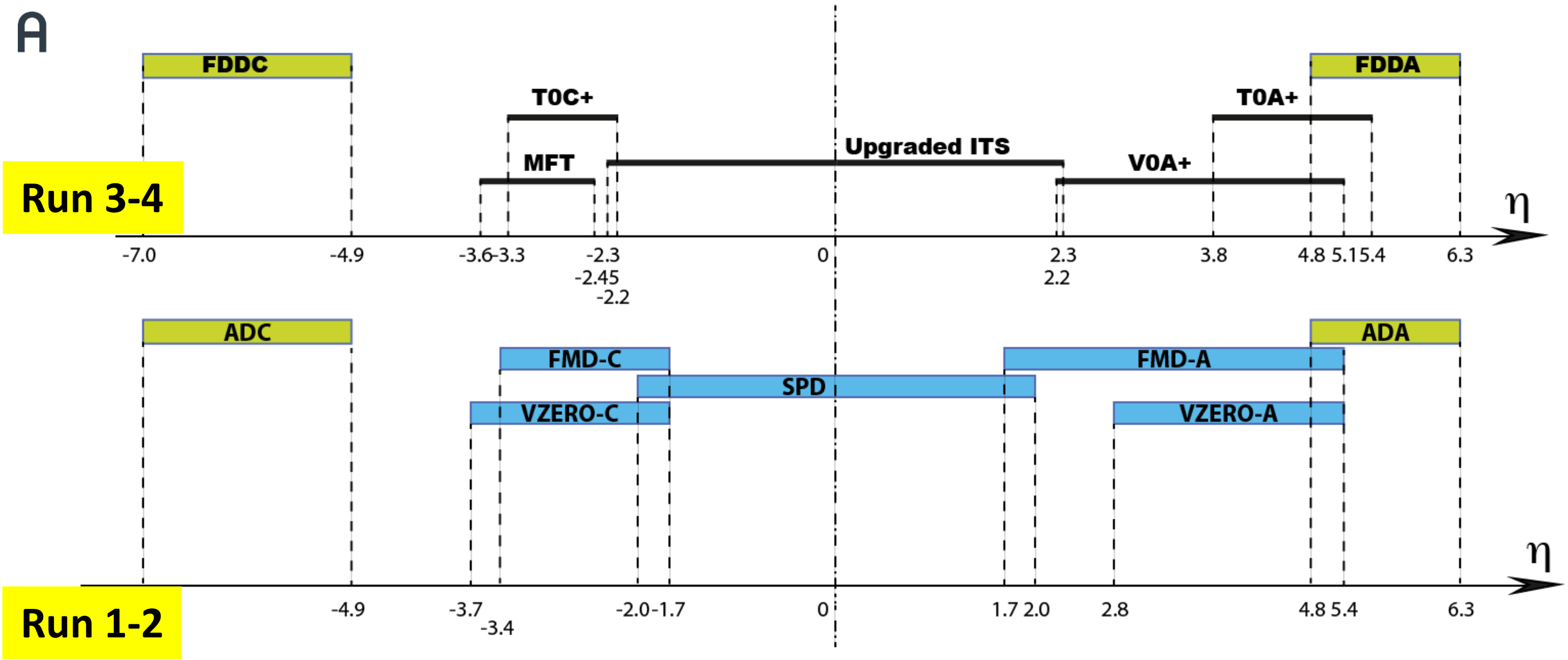


Fast Interaction Trigger Detector



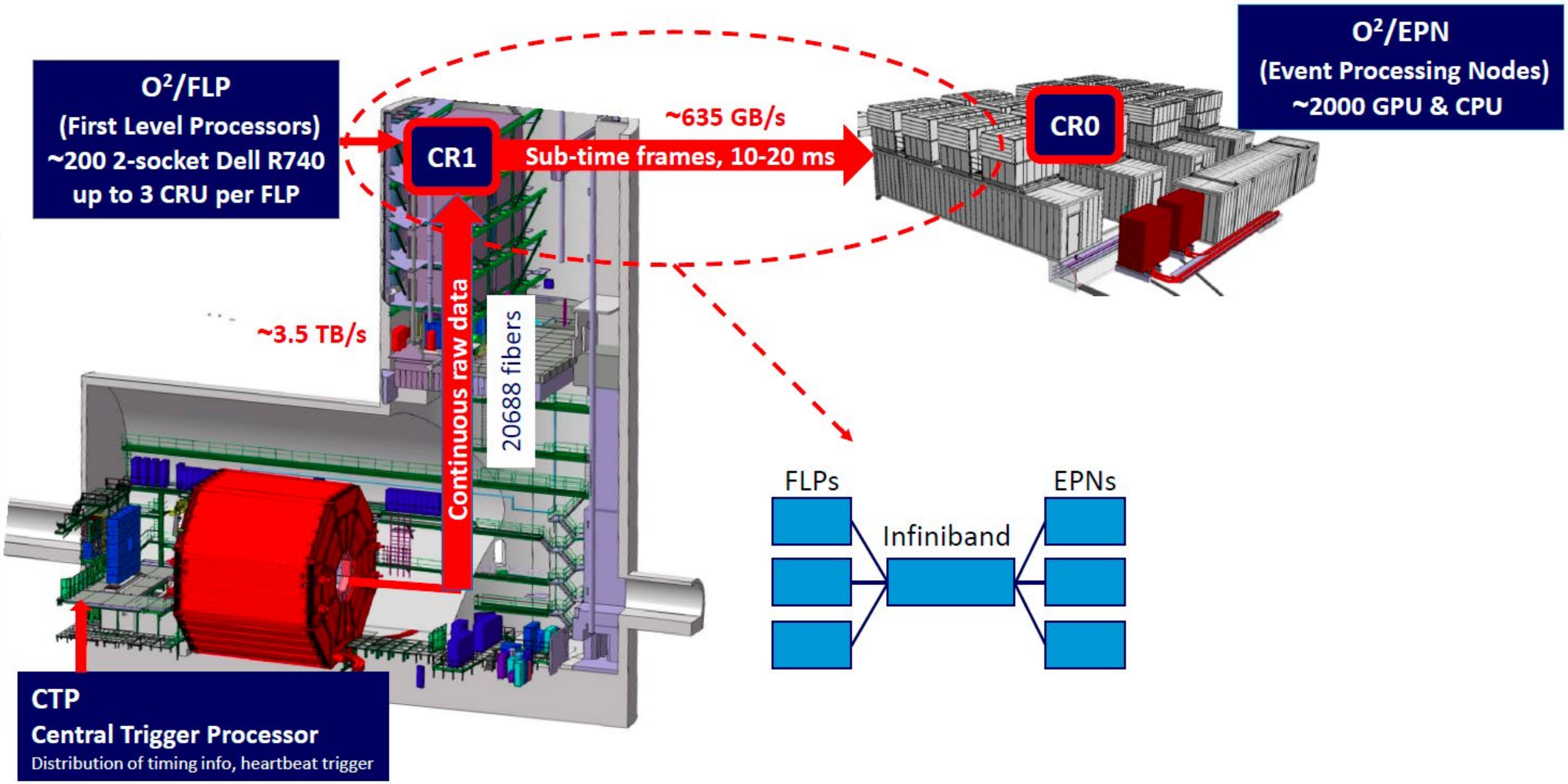
- Main design aims:
  - Accurate timing of interaction (σ ~ 30ps) (T0+A/C)
  - Measurement of forward multiplicity density (V0+)
  - High trigger efficiency.

Layout

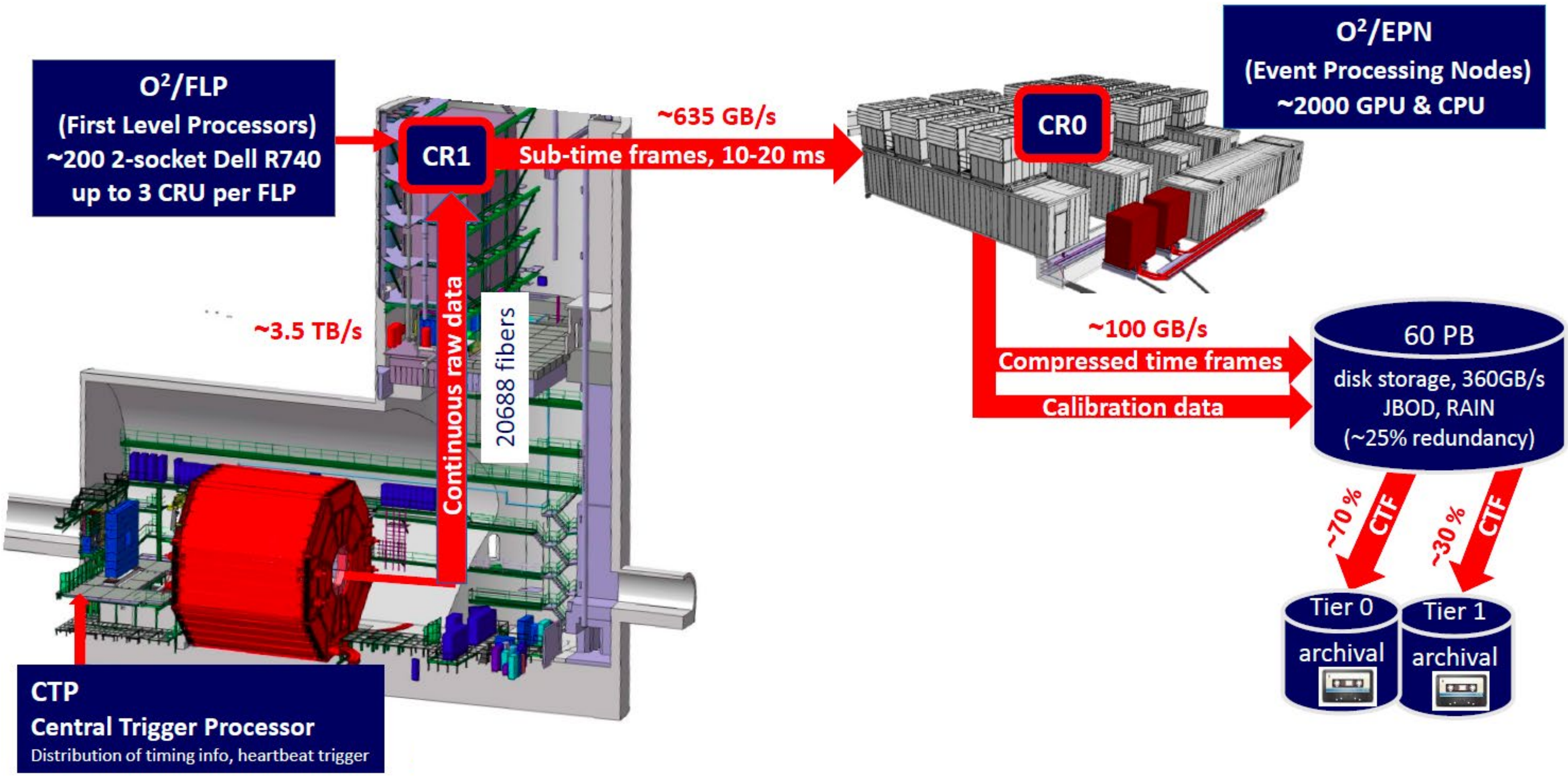


- In runs 1 and 2, VZERO, FMD and SPD were so arranged as to provide continuous rapidity cover in -3.7 < y < 5.4.
- They will be replaced by a new ITS, and a new Fast Interaction Trigger (FIT) consisting of upgraded V0 and T0 elements, adapted for continuous readout.
- In addition the Time of Flight (TOF) detector (|η|<0.8) can provide bunch-by-bunch hit information, and also form triggers for legacy non-continuous, triggered operation.

Continuous readout



Continuous readout



Continuous readout

- In run 3, ALICE intends to move to a new data-taking (and data-storage) paradigm which uses *continuous readout*.
- All data are read out, without any selection using a hardware trigger.
- Well suited to higher luminosity conditions, where otherwise there would be considerable overlap of events
- Nevertheless, the data are divided in time according to different intervals
- Basic interval is a *heartbeat*, a regular interval whose start and finish is marked by signals from the trigger system
- Although the length of a heartbeat is in principle arbitrary, current plan is that it should match the interval for one orbit
- Each heartbeat will contain several events, and it is the job of the reconstruction software to identify events of interest and reconstruct them

Continuous readout

- Good match to ALICE detectors. TPC has a drift time 0(100 μs)
- Interaction rate limited to ~1 MHz in pp collisions. For higher interaction rates, pile-up and space-charge buildup lead to space distortions in the TPC that become increasingly difficult to correct.
- We can impose a past-future protection to select events where there is no activity for a few bunch crossings on either side of our chosen interaction (carries a cost)

Finding events of interest

- In principle, the use of continuous readout means that we can find any interaction in the data stream, and reconstruct it.
- In practice, a completely unguided search in the data stream is very costly on data processing resources.
- Advantage in using some guides to identify interesting bunch crossings.
  - Leads us back in the direction of “triggered” physics, so should be used with some care.

Data filtering strategies

- Coping with the computing resources requirements lead us to two different (extreme) paradigms
  1. Use hardware information from triggering detectors as much as possible to filter events prior to reconstruction, then reconstruct and send to permanent media.
  2. Calibrate and reconstruct immediately and buffer data; only select events and write to permanent media once detailed analysis has been performed asynchronously.
- (1) is obviously less heavy on computing resources, but (2) allows much more flexibility for physics.
- Which route to take is currently under discussion for all Run 3 physics analyses.

Simulations

- In order to simulate the HB structure, we need to simulate realistic LHC filling schemes and pile-up rates.
- We have been given two scenarios considered to be "realistic"
  - BCMS: 2253 colliding bcs/orbit in ALICE =>μ = 3.9% at IR = 1MHz
  - BCMS+8b4e: 2048 colliding bcs/orbit in ALICE =>μ = 4.3% at IR = 1MHz

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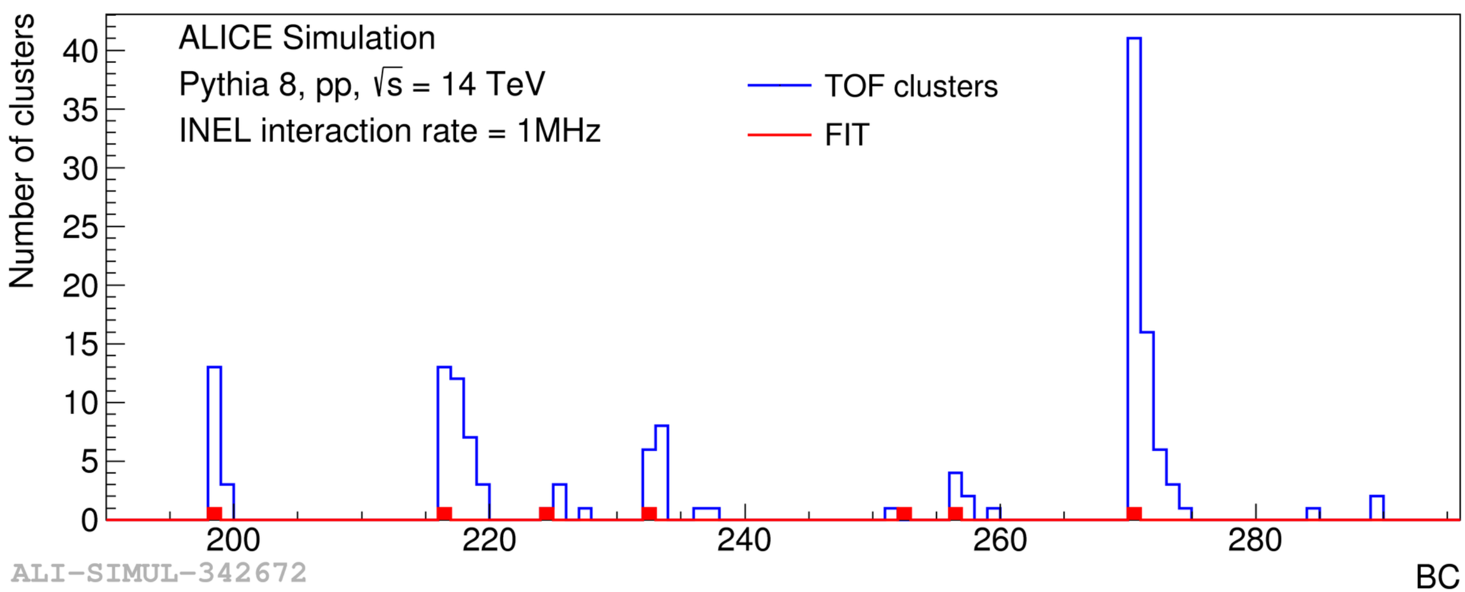
    - BCMS+8b4e: 2048 colliding bcs/orbit in ALICE => μ = 4.3% at IR = 1MHz
- Second filling scheme has been used to generate a file of simulation events separated into HB frames.
- Generates realistic background, provided rates for double gap events are also realistic.

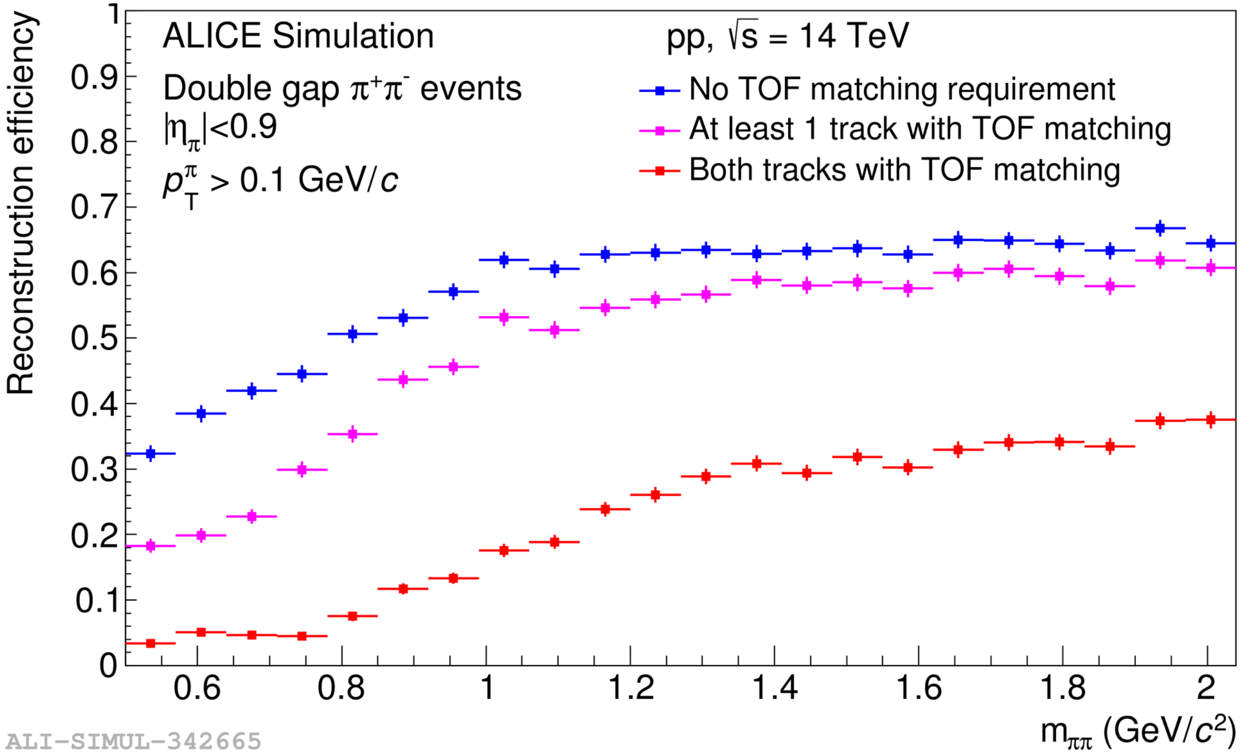
Reconstruction

- Initial studies suggest that it will not be possible to identify a Heartbeat (HB) frame (period of 1 orbit) containing a double gap signature from TOF and FIT information alone.
- Expect O(10) compatible bunch crossings in each HB frame
- Need a full reconstruction of each HB frame to identify tracks and to match to TOF clusters.



ALI-SIMUL-342672

Reconstruction study



- Preliminary reconstruction study performed, generating pion pairs with flat distributions in y, ϕ and $M_{\pi\pi}$,
- First conclusion:
  - Not much reduction in reconstruction efficiency if we demand at least one track should have a matching TOF hit. We can expect efficiency of ~60% for $M_{\pi\pi} > 1$ GeV.
- TOF hits allow the exact time of the interaction to be determined. Allows correlation with activity in forward detectors.

Interaction Rates

- We know that our projected selections for double gap events select O(10^{-4}) of events.
- We are aiming for an interaction rate of 1 MHz, so we will end up with a double gap recording rate of about 100 Hz, which fits comfortably with our allocation.
- More accurate details will become available when we have determined a cross section for the ALICE run 1 and run 2 data.

Conclusions

- Continuous readout will require a completely different event selection and reconstruction strategy from what was used in runs 1 and 2.
- We have started tuning such a chain using simulation events.
- First indications are that studies of double gap events are feasible using an approach similar to that already being tested.
- Work to produce more realistic simulations and improved efficiencies is underway.