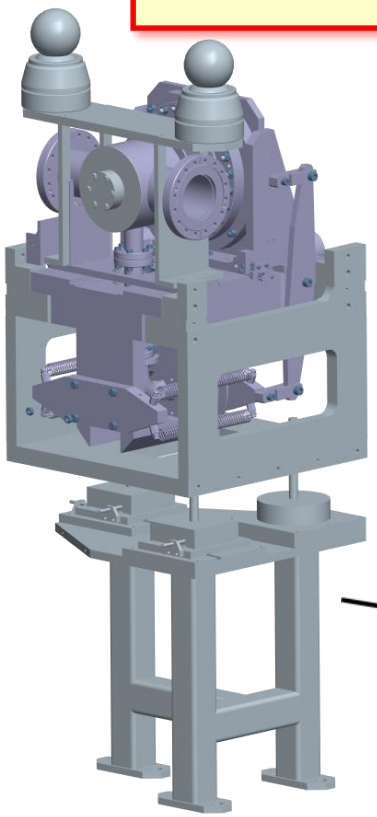
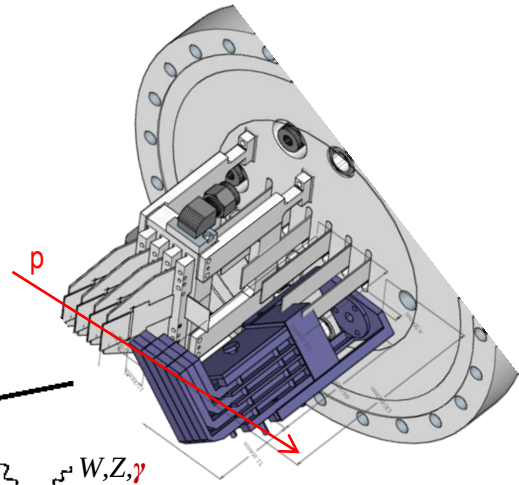
AFP Plans for the HL-LHC

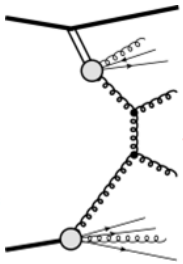


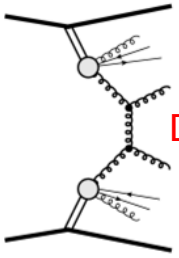
Forward Physics at the HL-LHC?

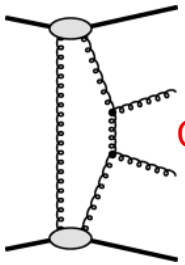
Michael Rijssenbeek
for the AFP Collaboration

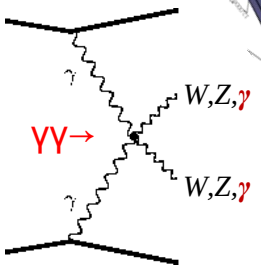


2016 2017 →

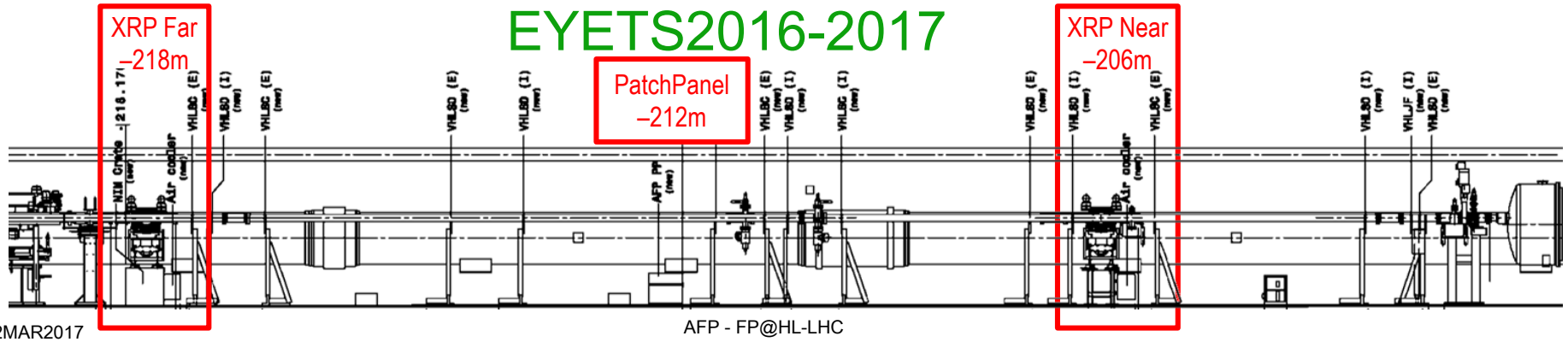

SD


DPEjj

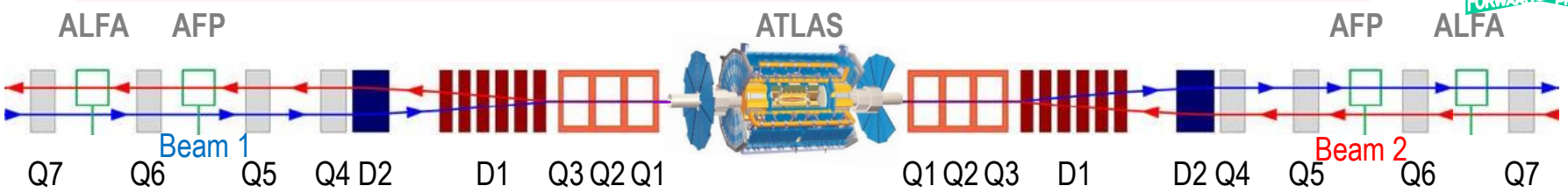

CEPjj



EYETS2016-2017



The ATLAS Forward Proton Project



AFP 2+2 – second phase to be completed in March 2017:

- two arms (2 detectors each arm at ±205m and ±217m), with time-of-flight detectors in the 2nd (far) stations
- Physics:
  - special runs ~10 hrs @ μ≤3: soft central diffraction, central diffractive jets, jet-gap-jet, γ+jet
  - standard runs at 15σ or closer: exclusive jet production, anomalous couplings, QCD and EM processes …

Beyond 2017 …

- 2018 Run: replace current HPTDC by PicoTDC
- AFP aims to continue running for rest of Run 2 and Run 3
  - depends, of course, on AFP performance and AFP physics results !
  - during LS2, we may want to upgrade the ALFA detectors ?

- What about the HL-LHC era (~2025?)
  - again, it depends on AFP performance and FP physics results !
  - case can be easily made IF new discoveries are made ☺
  - else: we must make the case that AFP can run at μ≈200 AND that interesting SM physics can be done (see Rafal's talk):
    - CED Higgs production; invisible Higgs decay modes?
    - aQGC: increase statistics and excluded range of anomalous couplings
    - … ?
    - special low-μ runs (at most 1 week/yr) for diffractive studies

FP @ HL-LHC: Detectors …

- Tracking with small pixels (50x50 μm^2 *or smaller*)
  - profit from ATLAS ITk upgrade work …
  - non-uniform irradiation ! Must be thoroughly tested !
- Time of Flight
  - 1-2 ps resolution and **t0** from ATLAS (σ_{t0}≃10 ps after averaging?)
    - LGAD or similar? Studies in progress …
  - good pixellation (≲1x1 mm^2)
- Trigger:
  - need better selectivity at μ=200: try for a two-proton trigger *with vertex match* at L1

- In principle, the detector package could be pre-evacuated and vacuum-sealed, and inserted/moved inside the beam aperture via UHV feedthroughs …
  - better LHC protection (no thin windows needed)?
  - needs a detailed feasibility study and prototyping …

3D Pixel Detectors for Tracking

- We must rely on HL-LHC pixel tracker developments for tracking; FP collaborations cannot develop these on their own …
  - ideally: 25μm size in ξ-direction (horizontal)

- additional requirements:
  - able to stand highly non-uniform irradiation ! Pre-radiation?
  - Edgeless ! 3D …

Time-of-Flight Detectors

- Requirements:
  - Pixel size 1×1 mm^2 or similar (➔ 200-400 channels)
    - size is not a problem, but acceptance/uniformity may be …
  - Very high and non-uniform irradiation expected: 10^{16} /cm^2 and more …
  - edgeless …
  - resolution: 1-2 ps !

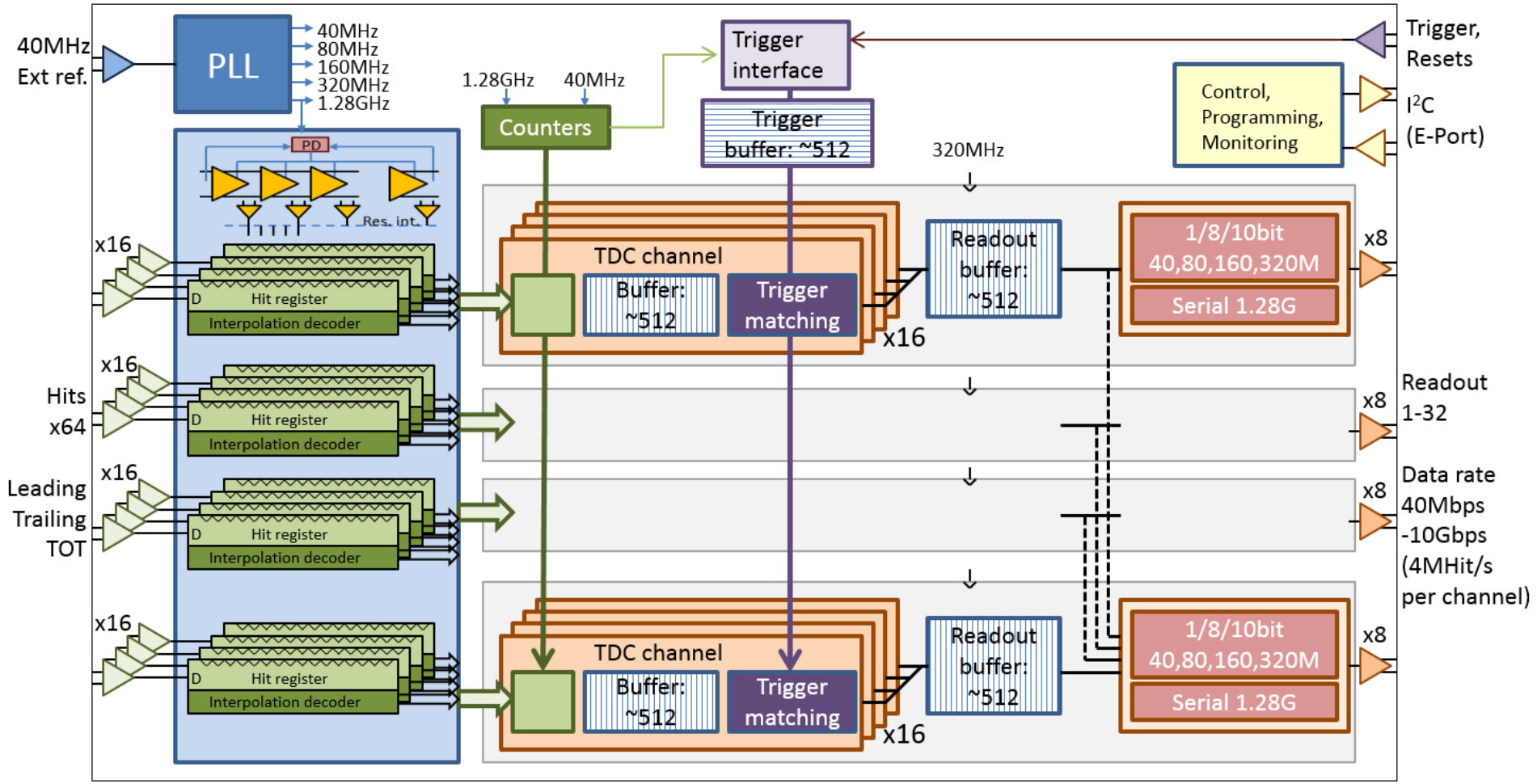
- Candidate technologies:
  - Fast Silicon ? Early days !
  - LGAD ? Promising but not (yet) radiation-hard enough …
  - other ?

- Electronics:
  - analog front-end ? PA1(on-sensor) → PA2+CFD+Trigger → TDC → DAQ ?
  - example: PicoTDC (next slides)

early 2018:

picoTDC Architecture

Moritz Horstmann, Jorgen Christiansen, Bram Faes (KU Leuven), Lukas Perktold (Now AMS), Jeffrey Prinzie (KU Leuven)
CERN/EP-ESE



64 channels, 3ps or 12ps time binning, 100us dynamic range

64 channels, 3ps: ~1W; 64 channels, 12ps: ~0.5W; 32 channels, 12ps: ~0.3W

130 µm Prototype (2015): 6 ps LSB

Measured Performance

Moritz Horstmann, Jorgen Christiansen, Bram Faes (KU Leuven), Lukas Perktold (Now AMS), Jeffrey Prinzie (KU Leuven)
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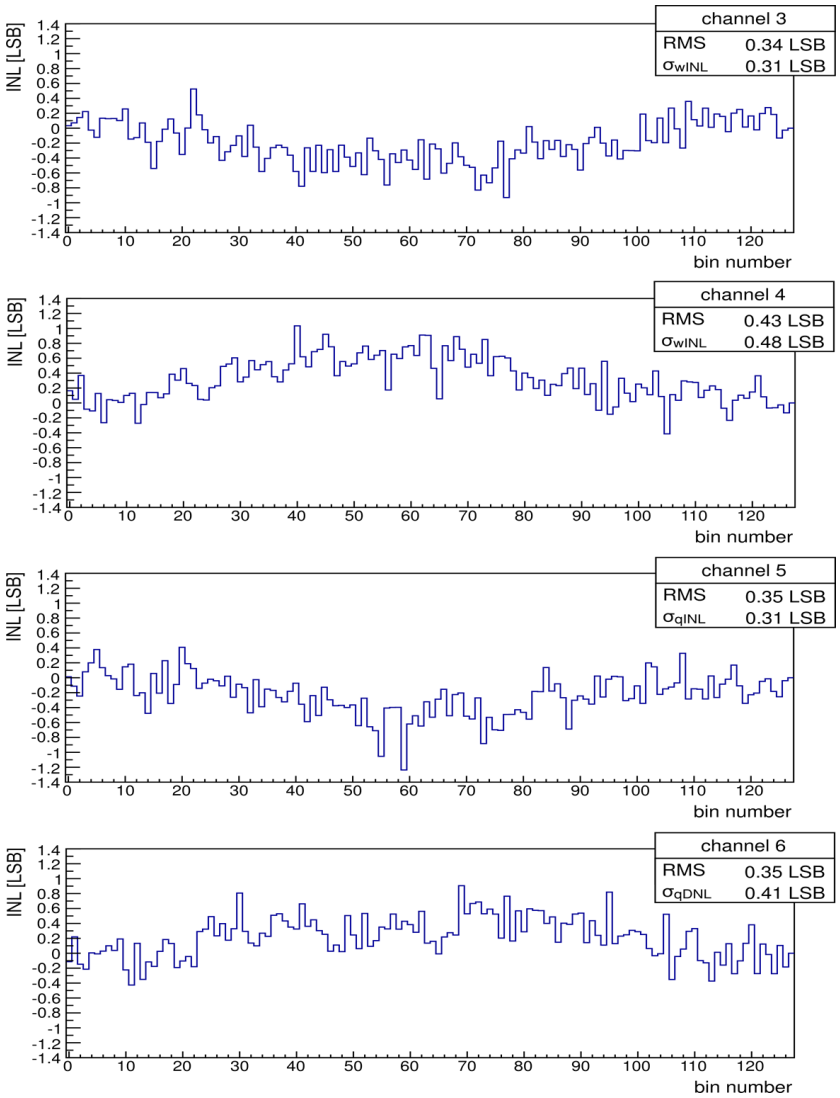

Code Density Test

INL = ± 1.3 LSB

RMS = < 0.43 LSB (2.2 ps)

Expected RMS resolution from circuit simulatio
including quantization noise, INL & DNL

2.3 ps-RMS < $\sigma_{qDNL/wINL}$ < 2.9 ps-RMS

INL can be corrected for in software

DNL, Noise and jitter can not be corrected (single shot measurements)

Moritz Horstmann, Jorgen Christiansen, Bram Faes (KU Leuven), Lukas Perktold (Now AMS), Jeffrey Prinzie (KU Leuven)
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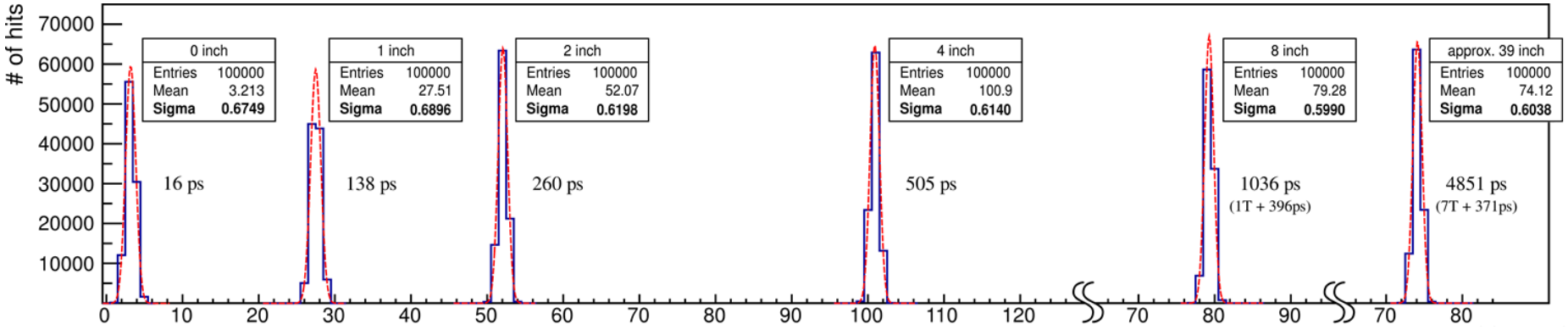
Single Shot Precision

- Three measurement series using cable delays
  - Both hits arrive within one reference clock cycle
  - Second hit arrives one clock cycle later
  - Second hit arrives multiple clock cycles later (~5ns)



σ_{TDC} < 2.44 ps-RMS

TWEPP2013 slides and paper: https://indico.cern.ch/event/228972/session/6/contribution/61
ESE seminar: https://indico.cern.ch/event/225547/material/slides/0.pdf

Moritz Horstmann, Jorgen Christiansen, Bram Faes (KU Leuven), Lukas Perktold (Now AMS), Jeffrey Prinzie (KU Leuven)
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Mapping to 65nm

- Uncertain long term availability of IBM 130nm (now Globalfoundries)
- 2x time performance: -> 3ps binning
- Lower power consumption: < ~½
  - ~1/8 if DLL binning of 12ps enough (RMS ~4ps).
- Larger data buffers
- More channels
- Smaller chip
- But higher development costs

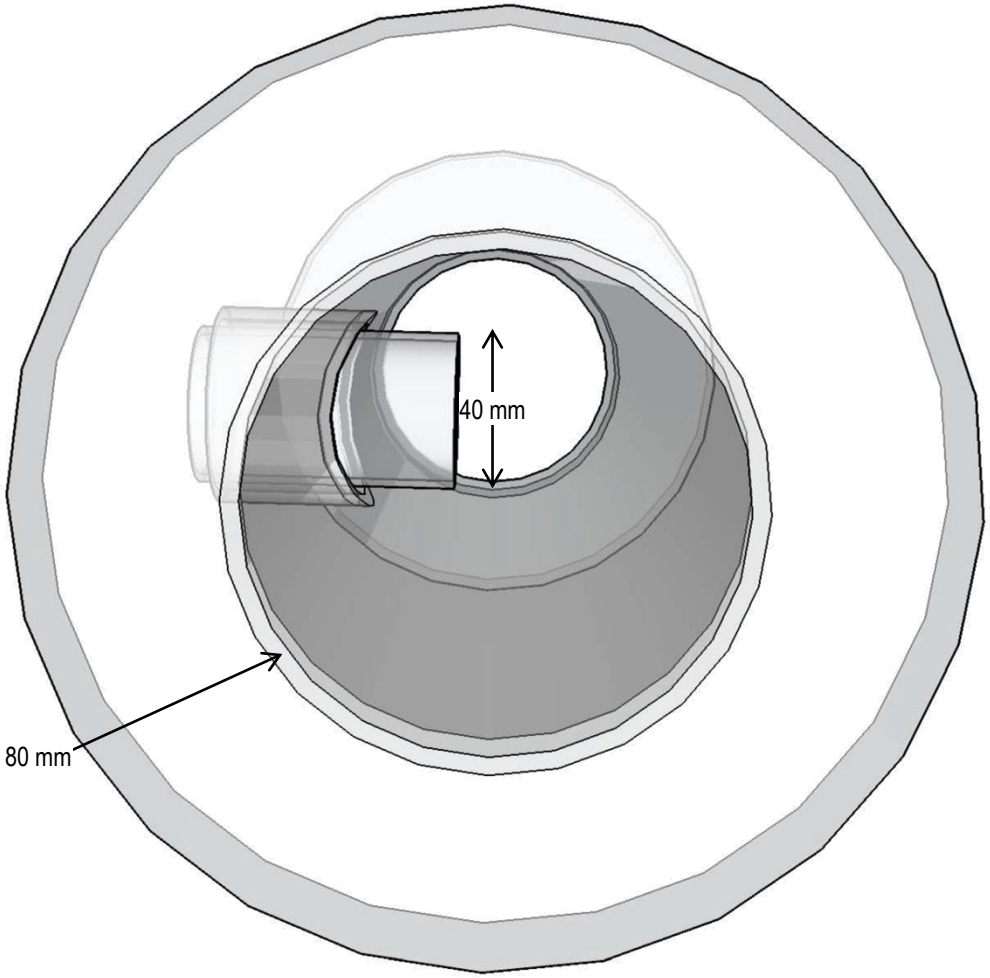
AFP @ HL-LHC: New Pot & Stations!

- at the HL-LHC assume:
  - small detectors: 20 x 20 mm^2
  - Timing with LGADs or the like

➡ we should develop *small* "pots"
  - simplifies design: smaller forces
    - but: would like better accuracy
  - round or rectangular entry?
    - narrow clearance required

- also: More radiation!
  - motors, switches, motion/position sensors …

- Must do RF simulation to determine the effect on the beam, and pot heating …



- aim to collaborate in FP@LHC Working Group; LoI to ATLAS later this year

Conclusion

- Need to study FP at the HL-LHC:
  - must start this year
  - LoI to experiments this Summer
- in order of importance:
  1. Physics arguments
  2. HL-LHC optics optimization, and optimal detector locations
     - ξ- and t-reach, mass reach
     - ξ and t, and mass resolution
  3. mini-Roman Pot (or other) beam interface
     - design
     - prototyping
  4. Detector technology
     - Tracker (3D pixel)
     - Time-of-Flight …