The Hamburg Moving Pipe for AFP 220 m

James L Pinfold
University of Alberta

Menu

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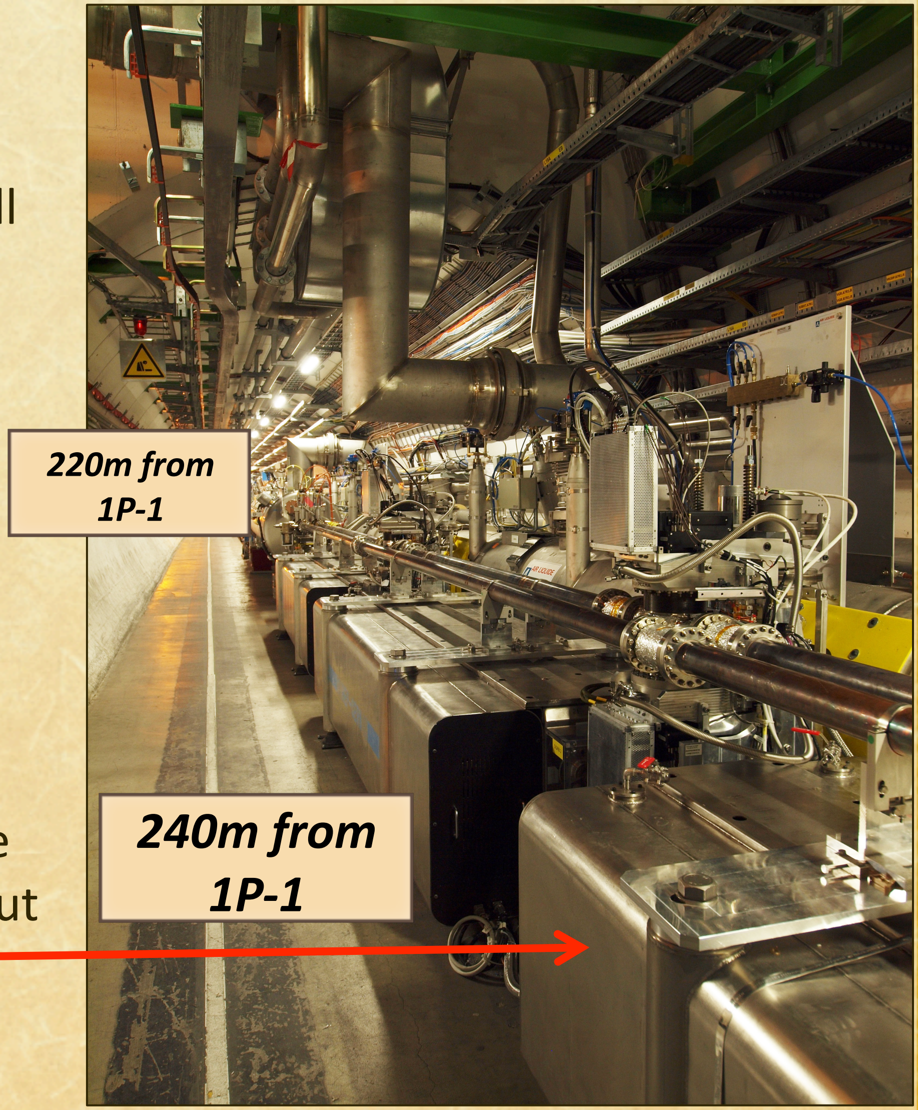
ATLAS –ALFA/AFP Region (220m)

- PHASE-I of AFP Project
  - Two stations of AFP detectors will be deployed at ± 220m from the ATLAS IP – 4 stations in all
  - Each AFP station consists of a moving pipe assembly, equipped with timing detectors (GAsTof & QUARTIC) and silicon trcaking detectors
  - The Moving (Hamburg) pipe assemblies are housed on a table that fits under the beam-pipes but over the quench resistors



The Hamburg Pipe Concept (1)

- Near beam detectors are typically housed in Roman Pots which allow the detector to remain outside of the machine vacuum and be remotely located close to the beam after injection.
- Due to space restrictions, however, AFP plans to use a moving beam-pipe technique developed at DESY - the “Hamburg beam-pipe”
- The Hamburg-pipe is a large diameter section of beam-pipe that has rectangular thin wall “pockets” to house the Silicon pixel detectors Precision ToF detectors used to track and time scattered beam protons at ± 220 m from the ATLAS IP.
- This specialized section of beam-pipe is connected at either end to the standard LHC beam-pipe by bellows that can withstand a transverse displacement of about 25 mm

The Hamburg Pipe Concept (2)

- The Hamburg Pipe mechanics has several advantages over Roman Pot technology.
  - It allows a much simpler access to detectors and provides direct mechanical and optical control of the actual detector positions.
  - Unlike the Roman pot system, which has to compensate for the force arising from pressure differences as the detectors are inserted into the vacuum, the Hamburg pipe maintains a fixed vacuum volume. This results in a greatly reduced mechanical stress allowing a very simple and robust design.
- In effect, the Hamburg pipe is an instrumented collimator, consequently the LHC collimator control system and motor design can be adopted with little modification.

Design Requirements

- The Hamburg pipe has the following requirements:
  - It must allow for a precise and repeatable movement of the detectors by 25 mm, so that the detectors housed in pockets in the Hamburg pipe can be kept a safe distance from the beam during filling and tuning.
  - It must have minimal deformation and a thin vacuum window both perpendicular and parallel to the beam allowing the detector to be placed within a few mm of the beam.
  - The pockets must be optimized to house the different detectors and allow for secondary vacuum and cooling.
  - The RF impact of the pockets should be minimal.
  - Wherever possible standard LHC components should be used to ensure compatibility with 2 the machine and collimator controls.

RF Impact of Hamburg Pipe

- The EM interaction between the beam and its surroundings will be one of the phenomena could limit the LHC performance
  - Because it can lead to single bunch and multi-bunch beam instabilities, beam emittance growth and beam losses.
- In general, the EM effects are enhanced by the use of low electric conductivity materials, by small distances between the beam and the vacuum chamber and by any transverse cross section variation of the vacuum chamber.
- The RF effect of the Hamburg Pipe design is being monitored by measurements with prototypes and simulations (Ansoft HFSS)
- The use of an all copper fabrication of the Pipe is being considered – according to the experts there should be no problems with this per se.

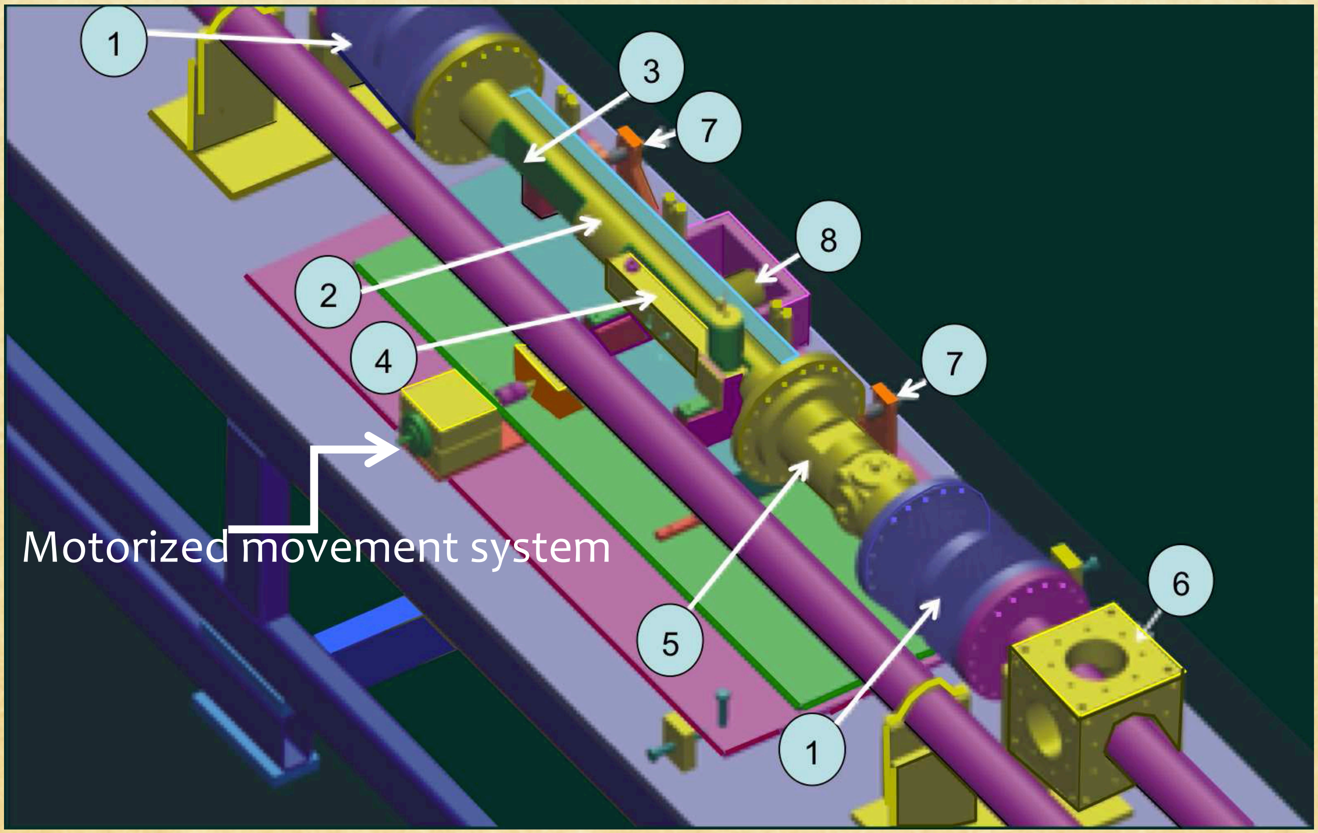
General Rules for Warm Vacuum

- Chambers:
  - Must have low electrical impedance (possibility to make Hamburg Pipe elements out of Copper)
  - All standard LHC elements are Non-Evaporable Getter (NEG) coated (sintered) onto the inner surfaces of the vacuum elements [NEG is a Al-Zr alloy powder that readily forms stable compounds with active gases]
- Bellows:
  - Standard LSS bellows are all RF screened
  - Standard bellows are not NEG coated
- Bake-out:
  - All of the warm vacuum of the LHC is baked
  - All standard sections are baked to activate the NEG
- Design and Materials:
  - All design & materials used in the LHC beamline must be approved by AT-VAC

Safety Review

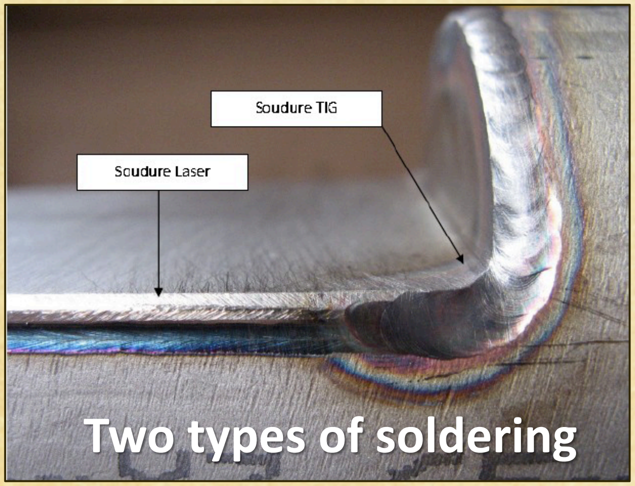
- The design of the Hamburg Pipe system at 220m will need to be reviewed by the:
  - Vacuum Group (TE/VSC) - since it has to be compatible with all UHV requirements (outgassing, electron cloud, leak tightness, vacuum safety, etc.
  - Beam Physics Group (BE/ABP) - to ensure it is compatible with the impedance budget defined for the LHC to avoid beam instabilities and make sure that it will not add aperture restrictions that might generate beam losses
  - Machine Protection Panel (MPP) – to make sure that the moveable pipe operation is safe and all appropriate interlocks are implemented to avoid beam losses or accidents

The Hamburg Pipe Assembly

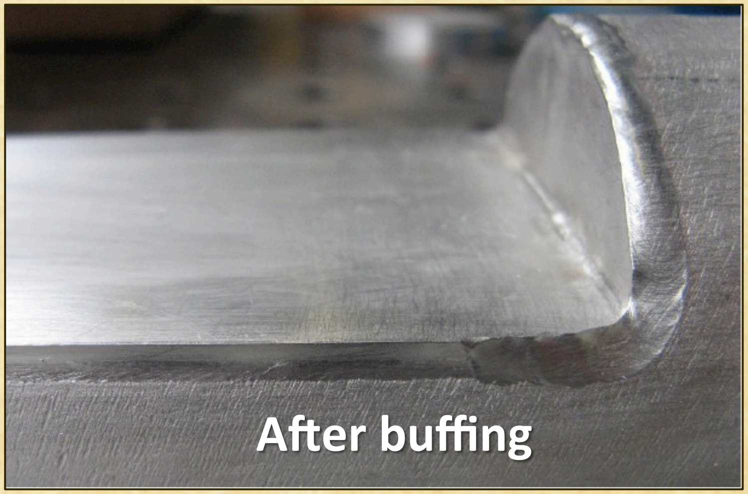


- Top view of one detector section: bellows (1), moving pipe (2), Si-detector pocket (3), timing detector (4), moving BPM (5), fixed BPM (6), LVDT position measurement system (7), emergency spring system (8).

Prototyping



Two types of soldering

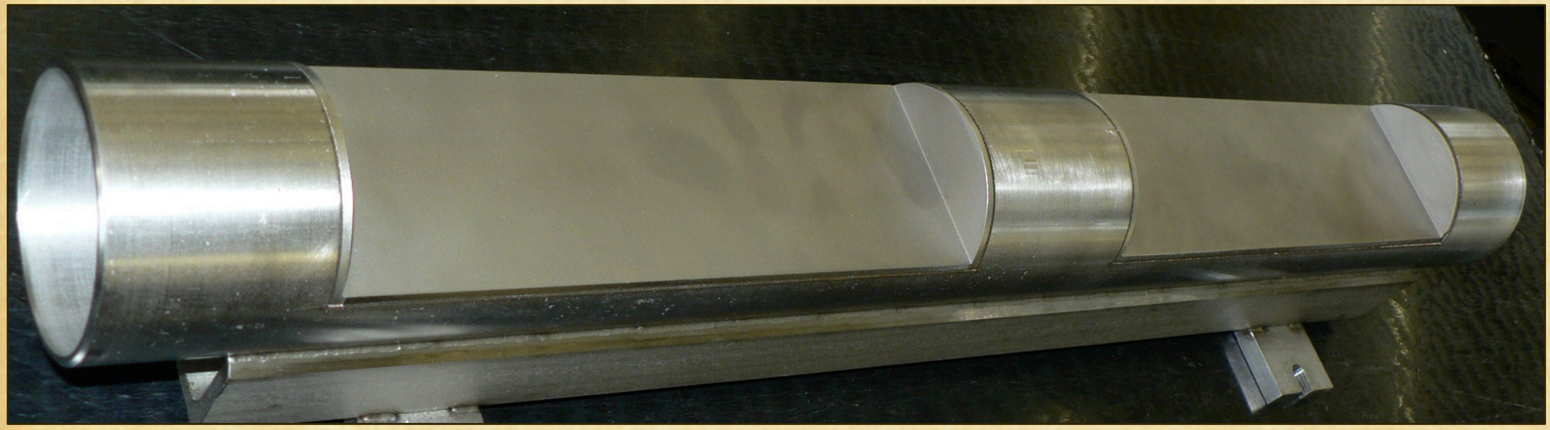

After buffing

Window 400 microns thick

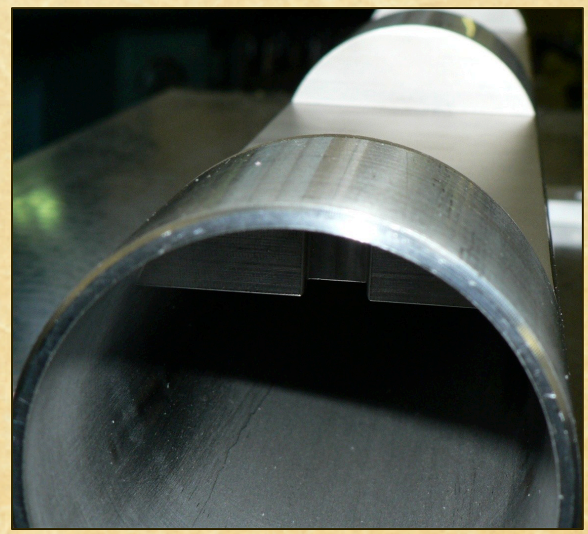

Finished pocket with electro-machined window


Finished pocket with electro-machined window

Two Pocket Prototype



- Two pockets laser welded the second for the Cerenkov timing detector is 30 cm long
- Used for RF tests in Manchester
- Built in UC Louvain, Belgium



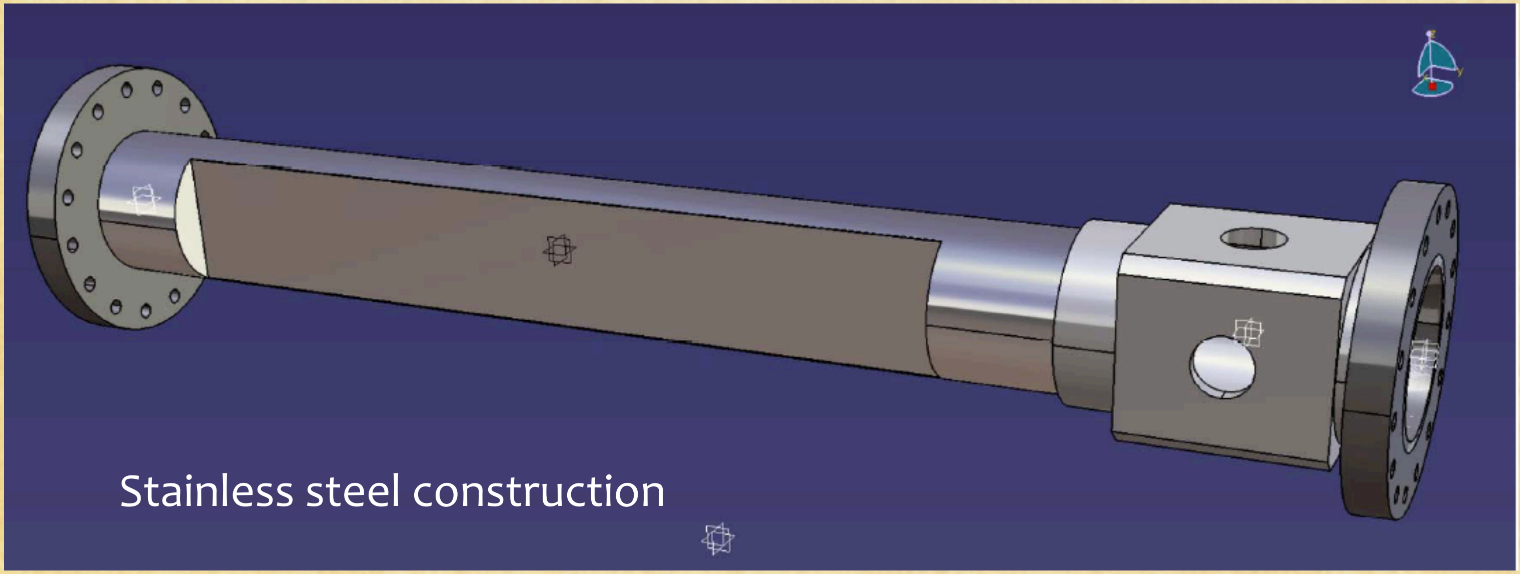
Latest Prototype

- Latest prototype from UC Louvain fabricated in 2009
- Improved laser welding + flatness measurements
- Very good flatness measured to be: ±50 μm over full surface - and between the two pockets !

AFP HP Baseline Design (1)

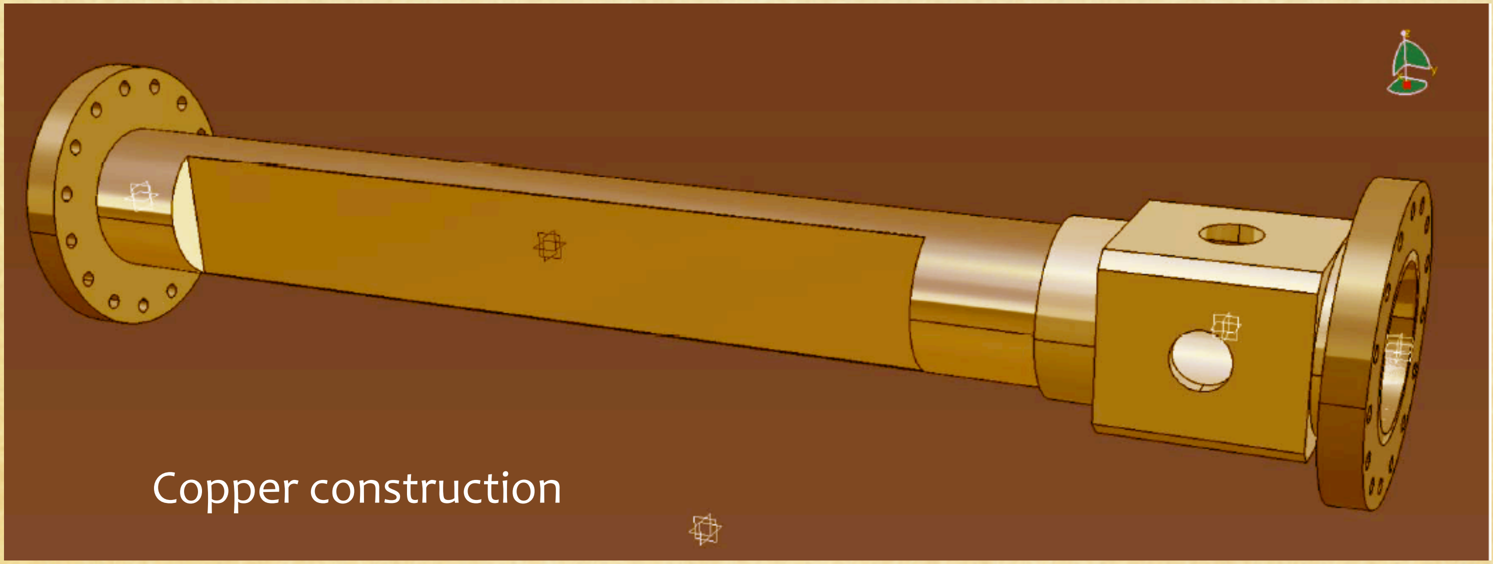
- The KISS Principle utilized along with robust approach.
- The AFP Moveable Beam-pipe Design:
  - One ~45 cm long single pocket (~15cm tracker ~30cm timing) and one, common detector box
  - Use secondary vacuum – already 10^{-3} bar should be OK –controlled (common) environment – temperature/humidity
  - Thin windows of 300-400 mm , inner height ~10 mm, entrance/exit windows slightly bigger than in FP420
  - Support table/LHC interface envelopes – in ‘final’ designs
- Full design developments + Integration aspects (vacuum, RF screens, BPMs, bellows, cooling, motorization, Radiation hardness and activation, interlocks/emergency procedures, etc, etc) – actively being refined for TDR phase

AFP HP Baseline Design (2a)



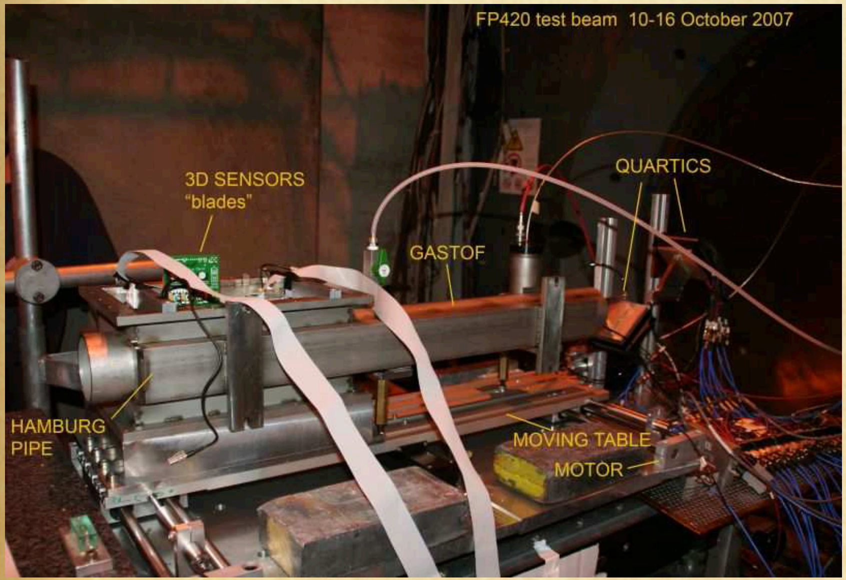
- Single thin window length 450mm - window thickness 400μm
- Machined by Wire Electro erosion from SS 316 LN solid bar.
- Final details to be decided with with CERN Beam groups .
- Beam Position Monitor integrated by laser welding.
- STATUS – being prototyped by Torino group for CMS

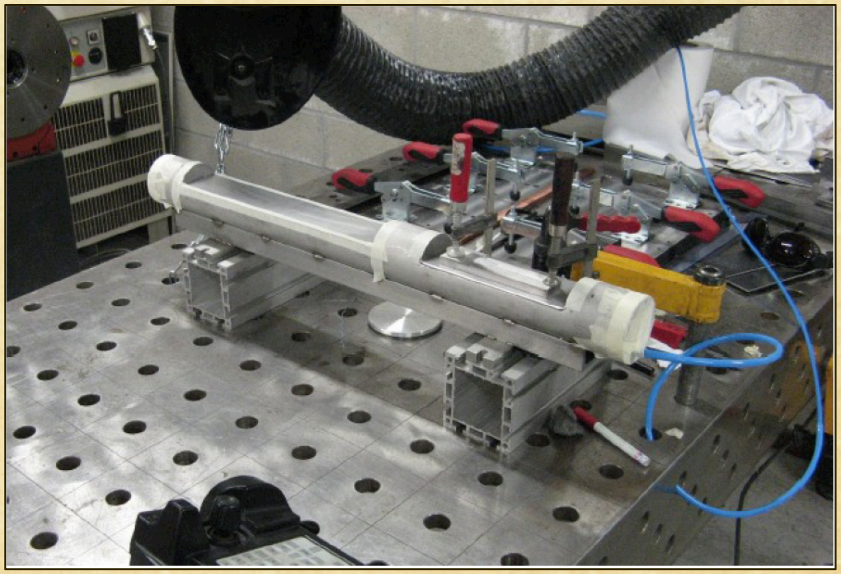
AFP HP Baseline Design (2b)



- Under investigation – fabricating the complete pipe assembly with copper.
- Experts have been consulted and no show stoppers so far
- An all copper construction would give superior RF properties.

Testing So far



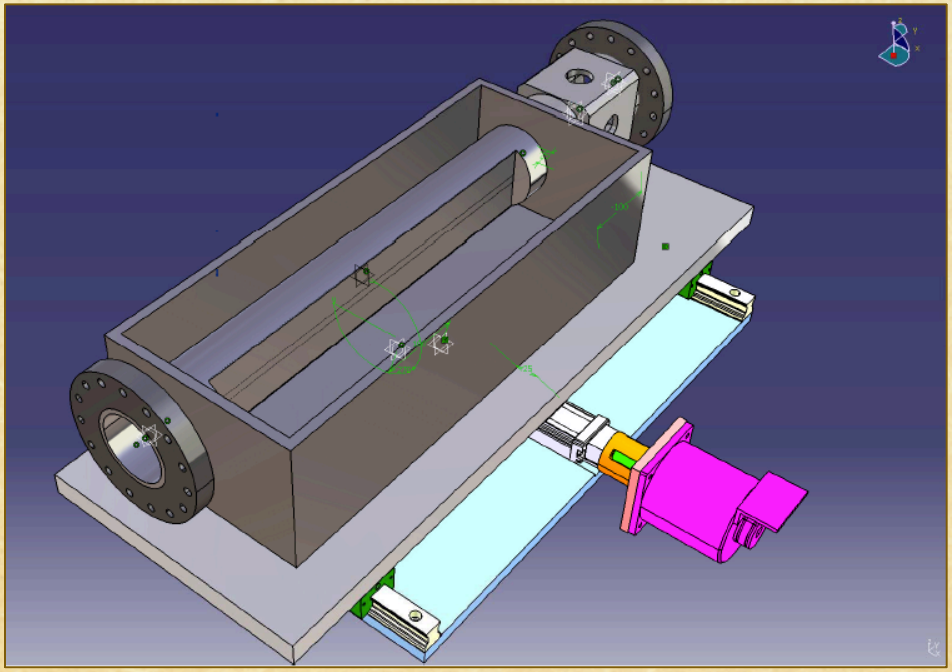


- The FP420 2007 test setup, included: one moveable station, two blades, and timing detectors (one GasTof and 2 QUARTICS)
- The prototypes performed well in terms of vacuum stability and incorporation of detectors

RD Testing

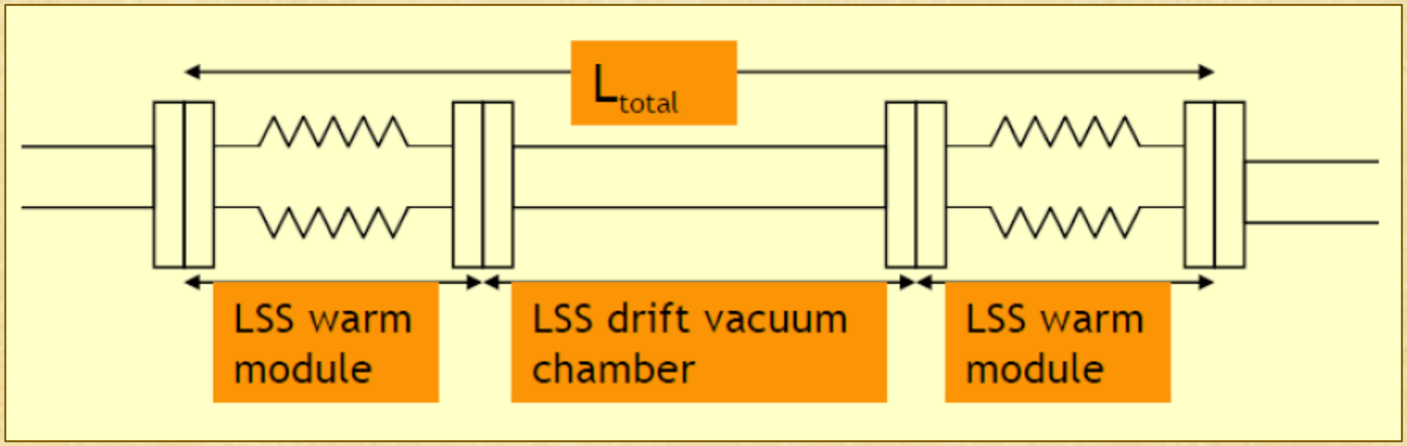
- The FP420 single pocket geometry has been characterised in terms of coupling impedance. Numerical simulations, analytical calculations & lab. measurements showed consistent results,
- All results indicating that this design will have a small impact on the total LHC impedance budget.
- Tapering of the beam pipe indentations is recommended because it does reduce the impedance significantly, as measured both with the single pocket and double pocket designs.
- Since an effective tapering can be done outside the beam orbit region, this design modification can be implemented at no cost in terms of the forward proton signal to background ratio.
- Simulations and laboratory measurements of a new AFP 220m prototype, modified according to the RF studies completed so far, will be continued.

AFP HP Baseline Design (3)



- Detector box and secondary vacuum volume houses Quartic and/or Gastof and Silicon Tracker. IDs are: 230 x 510 x 125 (mm)
- The enclosed volume is vacuum tight (secondary vacuum).
  - Definition of detector dimension, required services and feedthrough is to be defined.

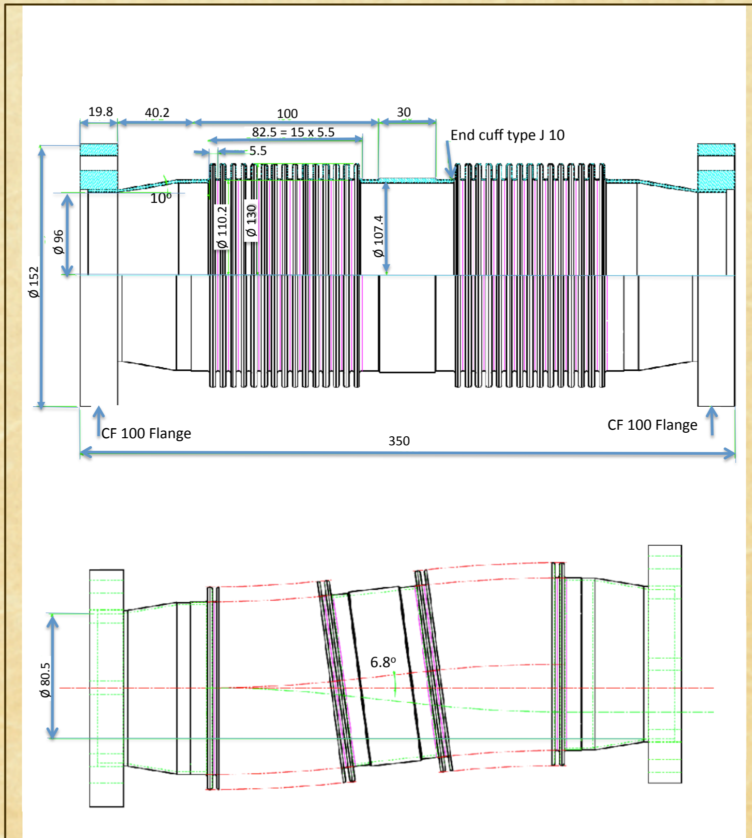
The Bellows Units (1)



- Standard LHC Long Straight Section (LSS); L_{total}= 1215 mm
  - Existing standard component designs, used with offsets as specified by LSS.
- Optimised LSS: L_{total} ~500 mm
  - Existing standard LSS subcomponent component designs considered acceptable by bellows manufacturers
  - Additional testing would be required to verify acceptability for 4000 cycle lifetime

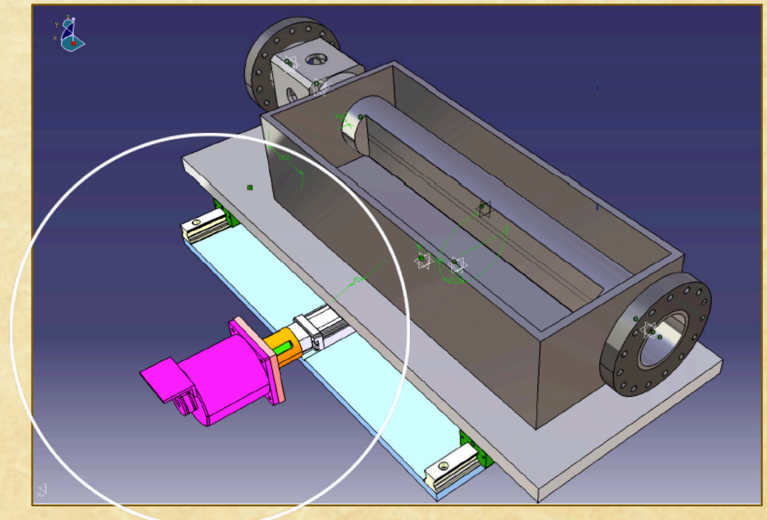
The Bellows Units (2)

- Witzenmann Standard corrugated tube. (CERN Supplier)
  - Bellows with intermediate tube allows extensive
  - lateral movements minimizing stress.
  - In this studio diameter is over dimensioned, D=107,4mm, to allows integration of RF screen.
  - In case RF screen result not necessary, internal diameter can be reduced to 96mm; 93mm; or 85mm.
- RF screen to shield the bellows from the beam?
- Develop design in close collaboration with AT/VAC.
- Validate and finalize design and manufacture to realize a prototype for tests.



Motorization & Controls

- Motor and controls hardware (lvdt, stops) are assumed to be the same of collimators.
- Nevertheless some aspects still require work eg:
  - Auto retraction in garage position in case of hardware or control failure may require feature not compatible with the present layout.
- A preliminary risk analysis is necessary to assess the validity of adopted solution.

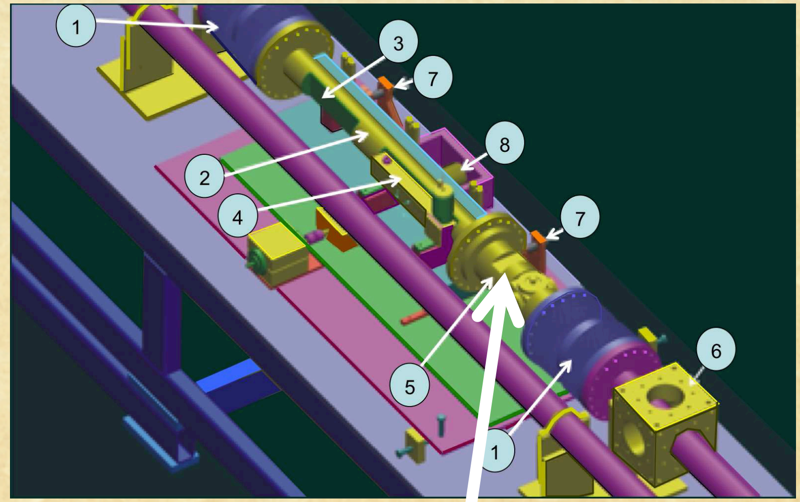


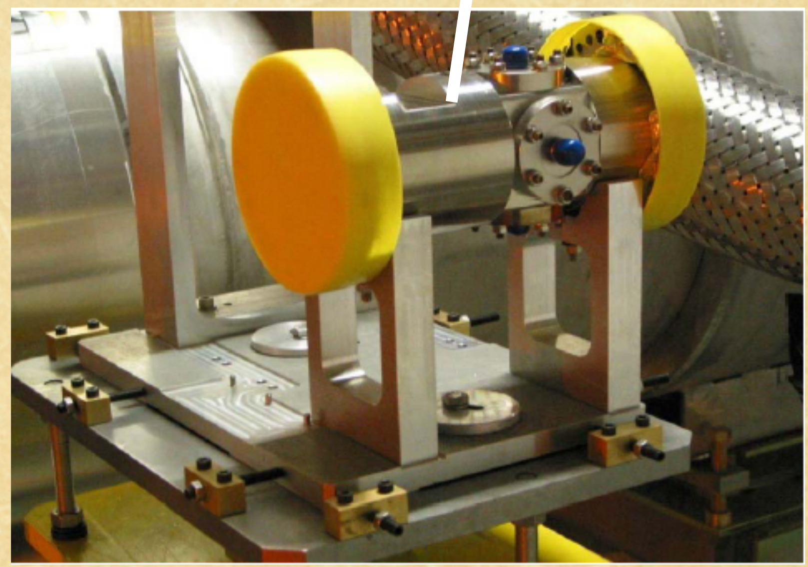
Beam Position Monitoring

- The Beam Position Monitor on the Moveable Beam Pipe Station is now integrated on the Beam Pipe.

- A a body of BPM used in LHC beam instrumentation is adapted. This body has been suggested as the most likely adaptable to our scope

- Finalization of Beam Pipe design require also definition of this component. We need to work with BE/AT group on this .





Cost Estimates

Conclusion

- Integration of various components still needs effort to be effectively defined.
- Close collaboration with CERN group is required to finalize the design.
- Collaboration with CMS's HPS240 Group (Torino, etc.) in this area is vital.
  - *Torino will start production of a prototype beam pipe as defined in this talk in April (2011)*
- Many details need to be agreed and finalized
- But no show stoppers (so far) and the production of moveable pipe system for insertion in 2013 looks realistic