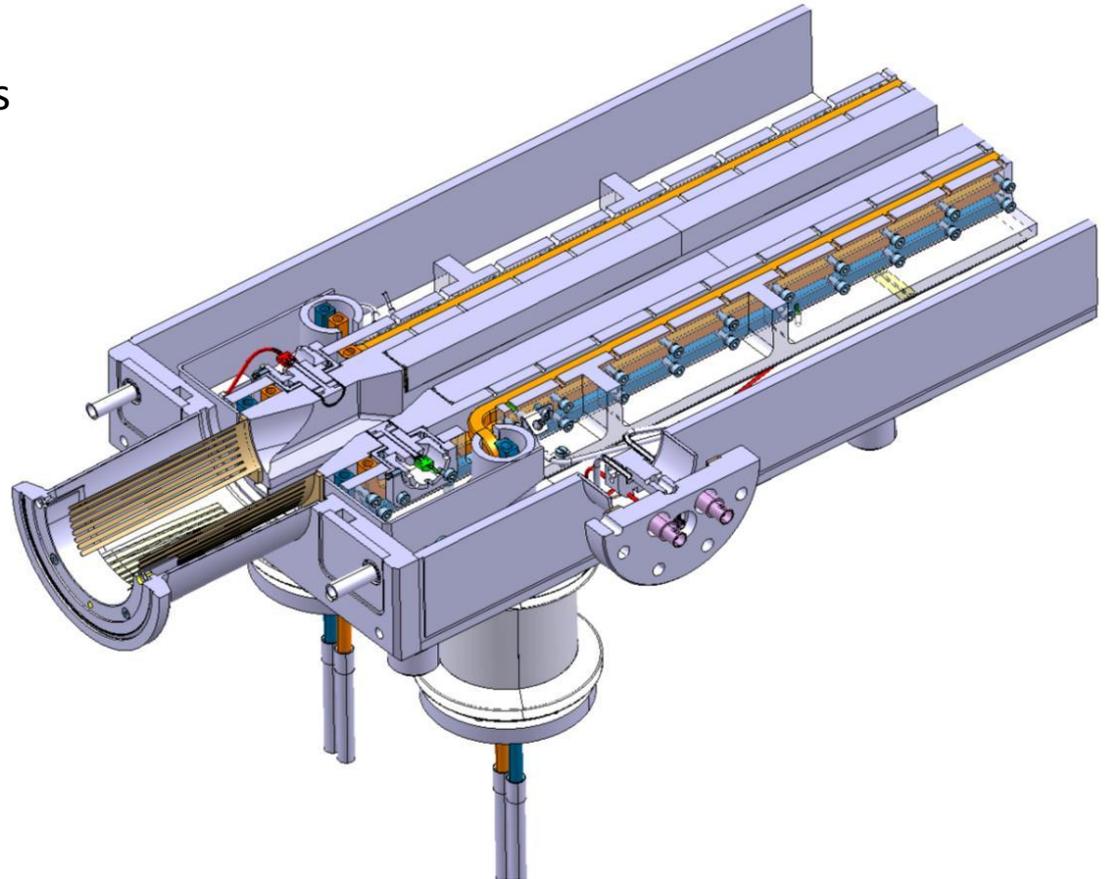# THE LHC COLLIMATOR BPM SYSTEM

## OUTLINE

- Introduction to collimators
- Integration of BPM
- Mechanical design
- Electrical design
- Processing
- Simulations
- Results
- Conclusions & Outlook

CHRISTIAN BOCCARD ON BEHALF OF THE COLLIMATOR BPM TEAM OF BE-BI-QP
BI DAY      24 NOVEMBER 2011    VILLA DU LAC

# WHAT IS A COLLIMATOR ?

✓ LHC Collimators must clean the beam halo at given positions so that the rest of the machine is protected.

✓ To this purpose collimators insert absorbing materials into the vacuum pipe.

✓ Absorbing jaws are movable and can be placed as close as 0.25 mm to the circulating beam !

✓ Nominal distance at 7 TeV: ≥ 1 mm.

High stored energy : 360 MJ at 7TeV !

80 kg TNT
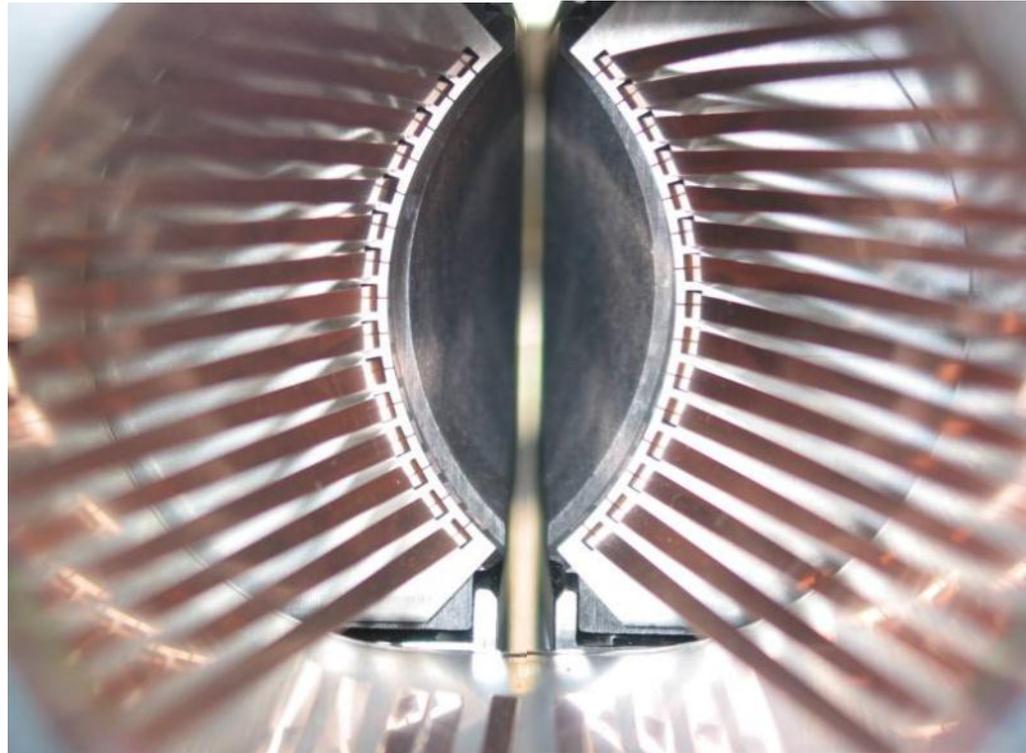
**The LHC collimation was conceived as a staged system:**

**Phase I** collimators:
- Designed to ensure maximum robustness against abnormal beam losses in operating conditions.

**Phase II** collimators:
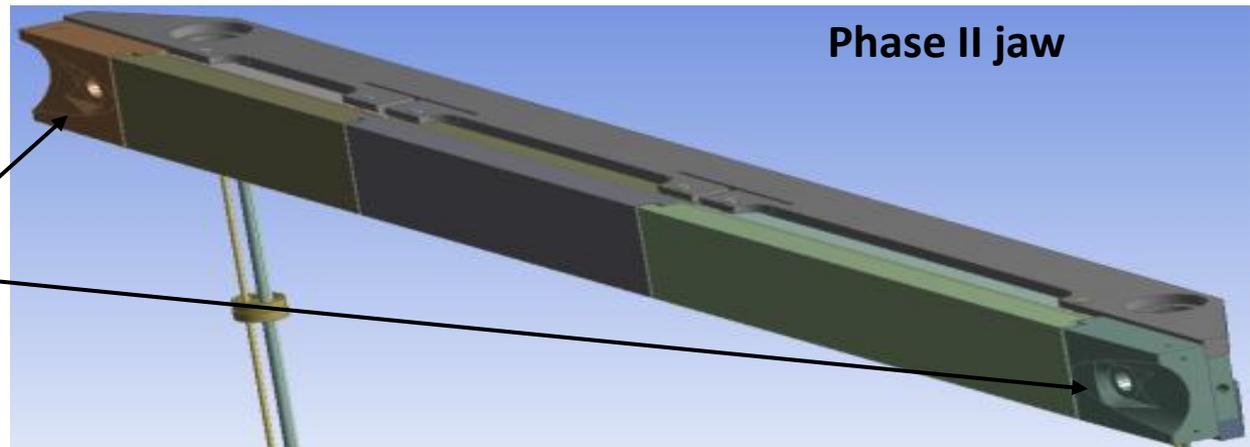- Complement phase I and able to reach nominal intensity and energy.

Constraints:
- Improve collimation efficiency.
- Keep low longitudinal impedance
- **gain factor ≥10 in set-up time**

$\Rightarrow$ **IDEA:**

**EMBEDDED BPM IN COLLIMATORS JAWS**

**Phase I jaw**

**Phase II jaw**

# EMBEDDED BPM IN COLLIMATORS

## ADVANTAGES
## AND CONSTRAINTS

Standard setup method relies on centering collimator jaws by detecting beam loss.

- Procedure is lengthy and can only be performed with pilot fill.

- Big worries about risks, reproducibility, systematic effects and time lost for physics.

**The integration of pick-ups into jaws will allow:**

- deterministic centering of jaws around circulating beam.

- Improvement in set-up time.

- Continuously follow orbit drifts,

- Allow tighter collimator settings, …

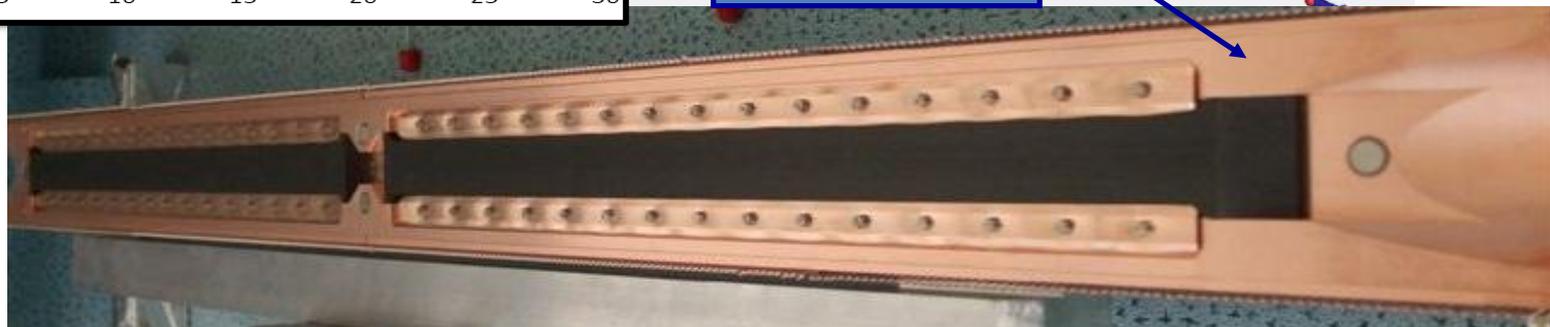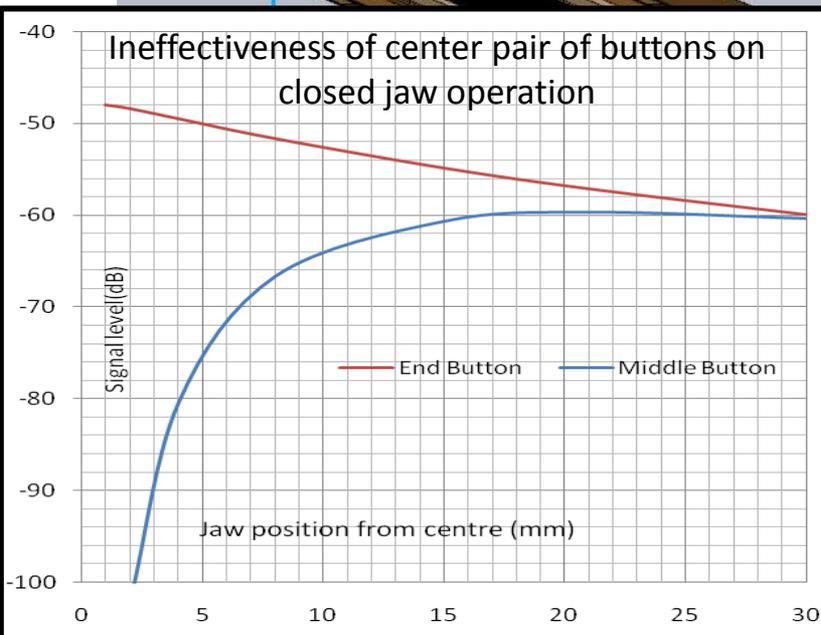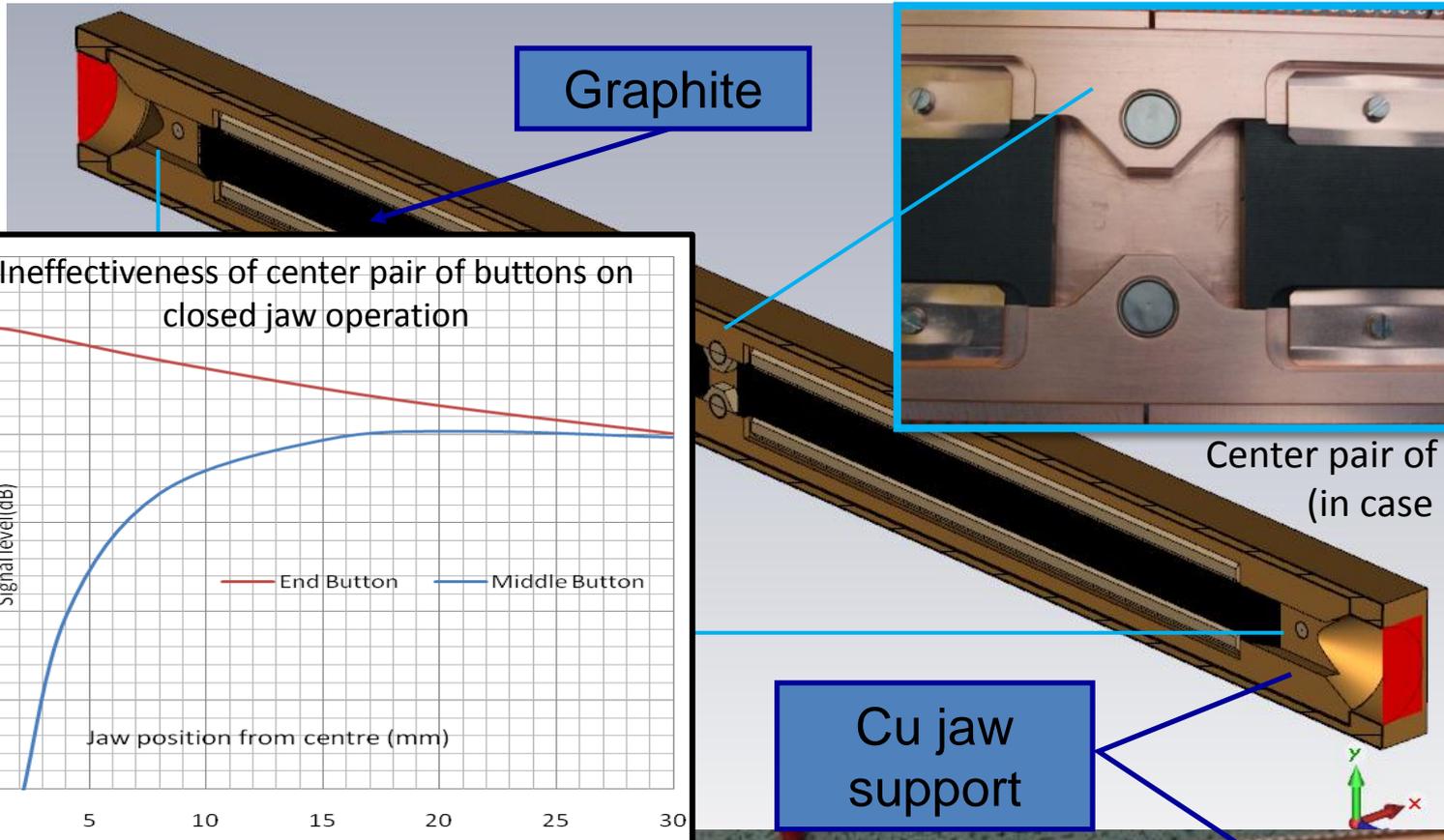**High precision** (<10 um) **and stability** (averaged, not bunch by bunch)

And:

- Protect components from accident cases.

- Withstand a bakeout temperature of 250 º C during 48H.

- Operate under strong radiation (200 Mgy/y).

- Maintain Ultra High Vacuum.

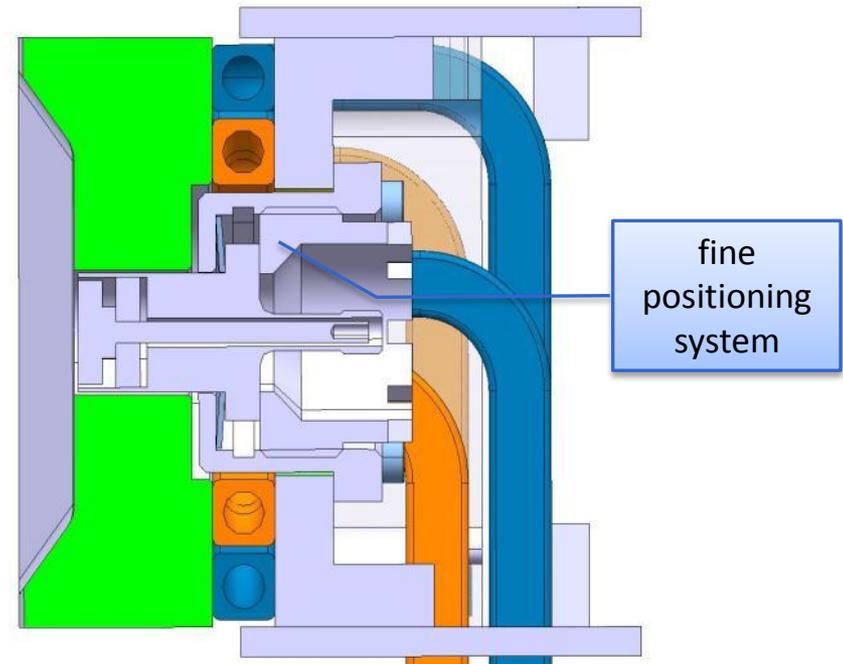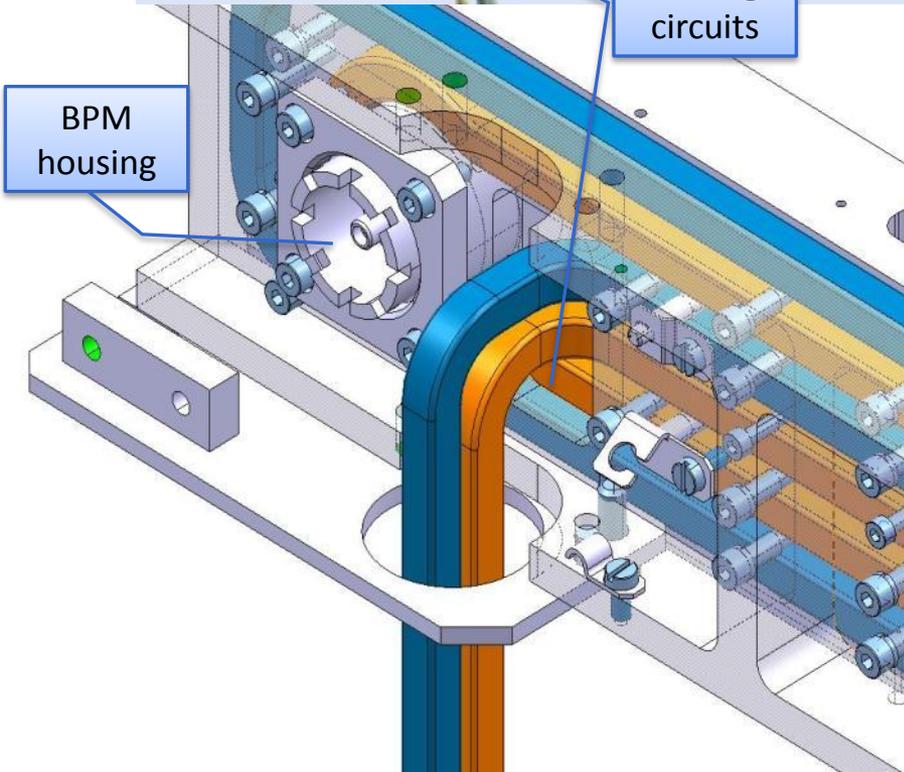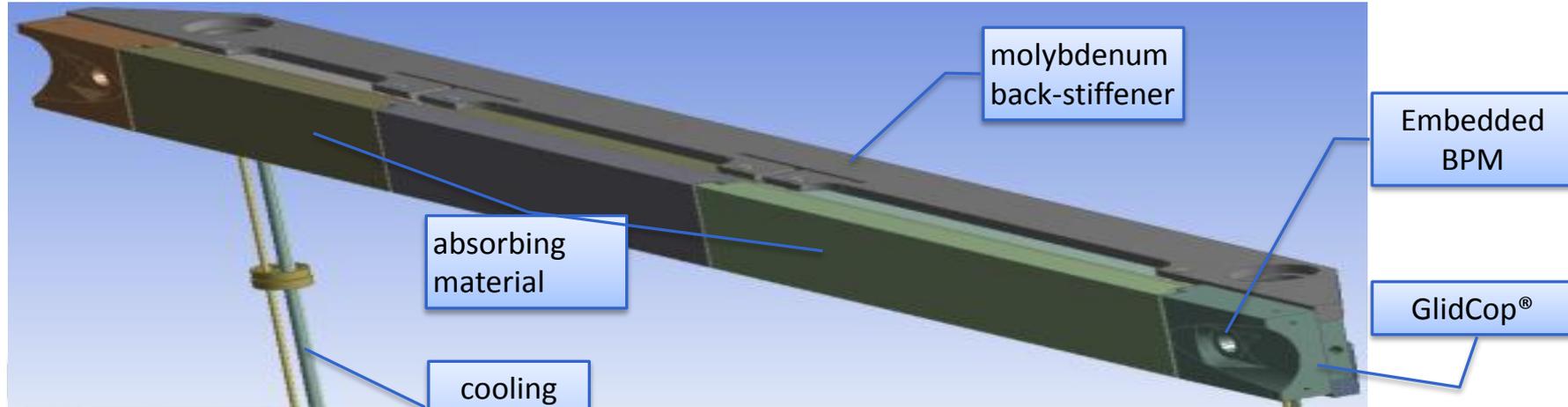- Very accurate geometric stability .

- Low-Z material.

Prototype                    -> Implementation of 4 buttons in Jaws



Graphite

Center pair of buttons
(in case ..)

### Ineffectiveness of center pair of buttons on closed jaw operation

Signal level(dB)

Jaw position from centre (mm)

End Button — Middle Button

Cu jaw support

Based on experience gained with demonstrator    -> Implementation of 2 BPMs

molybdenum
back-stiffener

Embedded
BPM

absorbing
material

GlidCop®

cooling
circuits

BPM
housing

fine
positioning
system

Cross-section of jaw tapering.

# NEW TAPERING



Phase I jaw tapering



Tapering with button



Phase II



| | |
|---|---|
| Type | E-Field |
| Monitor | e-field (t=0..end(0.03);x=0) [pb] |
| Component | Abs |
| Plane at x | 0 |
| Maximum-2D | 214462 V/m at 0 / 1108 / -1.96792e-011 |
| Sample | 15 / 404 |
| Time | 0.42 |
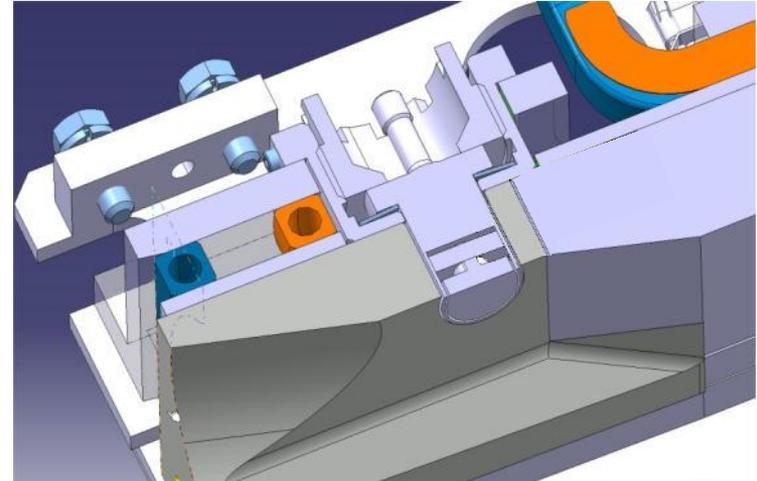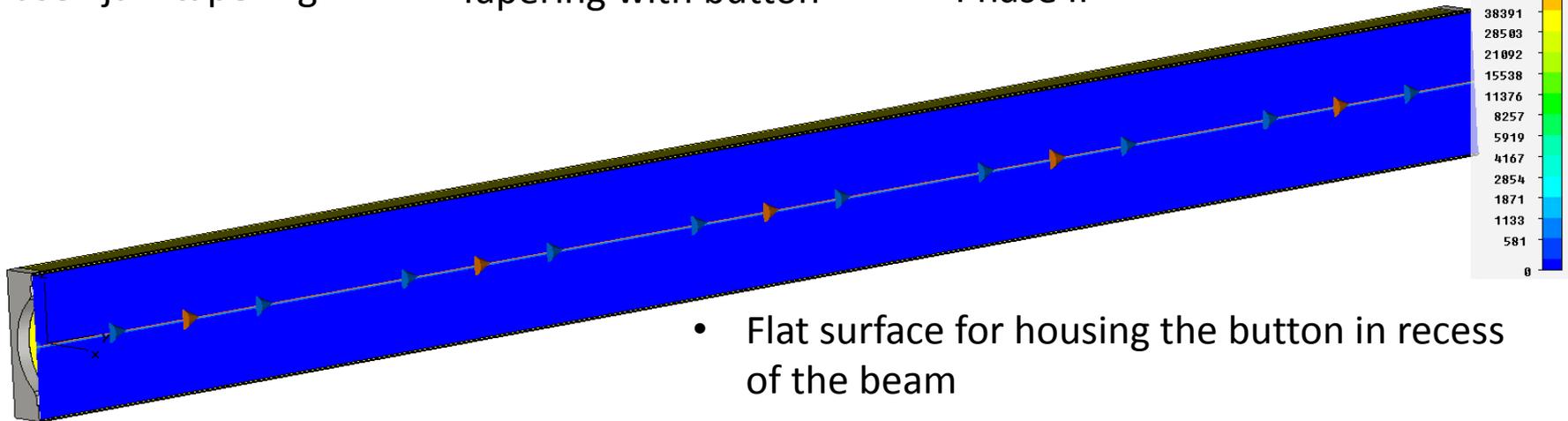
- Flat surface for housing the button in recess of the beam

- Less smooth transition.

- longitudinal trapped modes are mainly generated by the transition region.

## Key component: the RF cables

The coaxial cables needed should:

- Be small, robust and flexible enough to follow the jaw motion during the thousand of cycles expected.
- Be vacuum compatible (choice of materials, reliability, cleanliness and outgasing rate)

## Only SiO2 Cables meet the specification !

- They also provide exceptionally low hysteresis vs temperature and motion, with phase and loss values returning to the same values.

But:

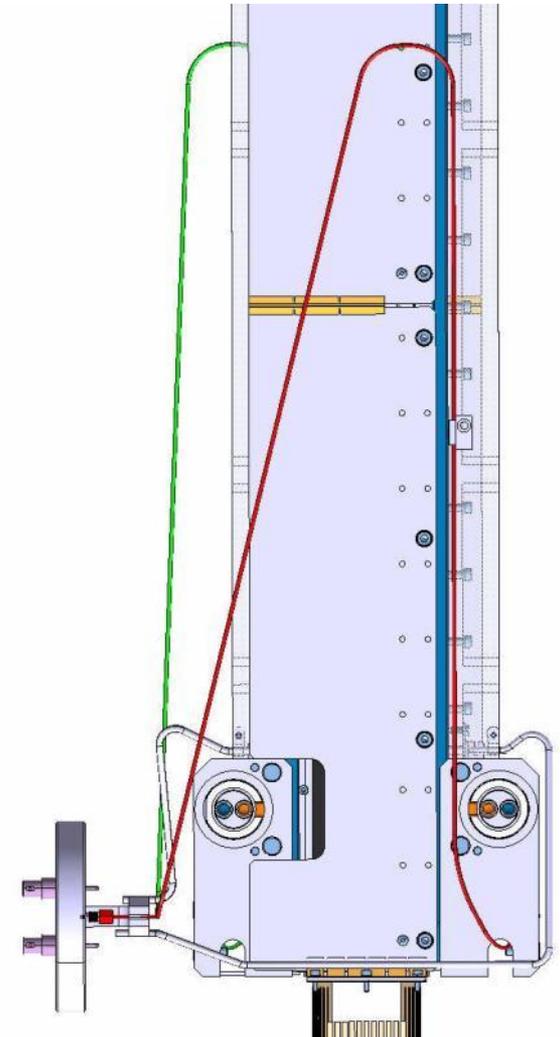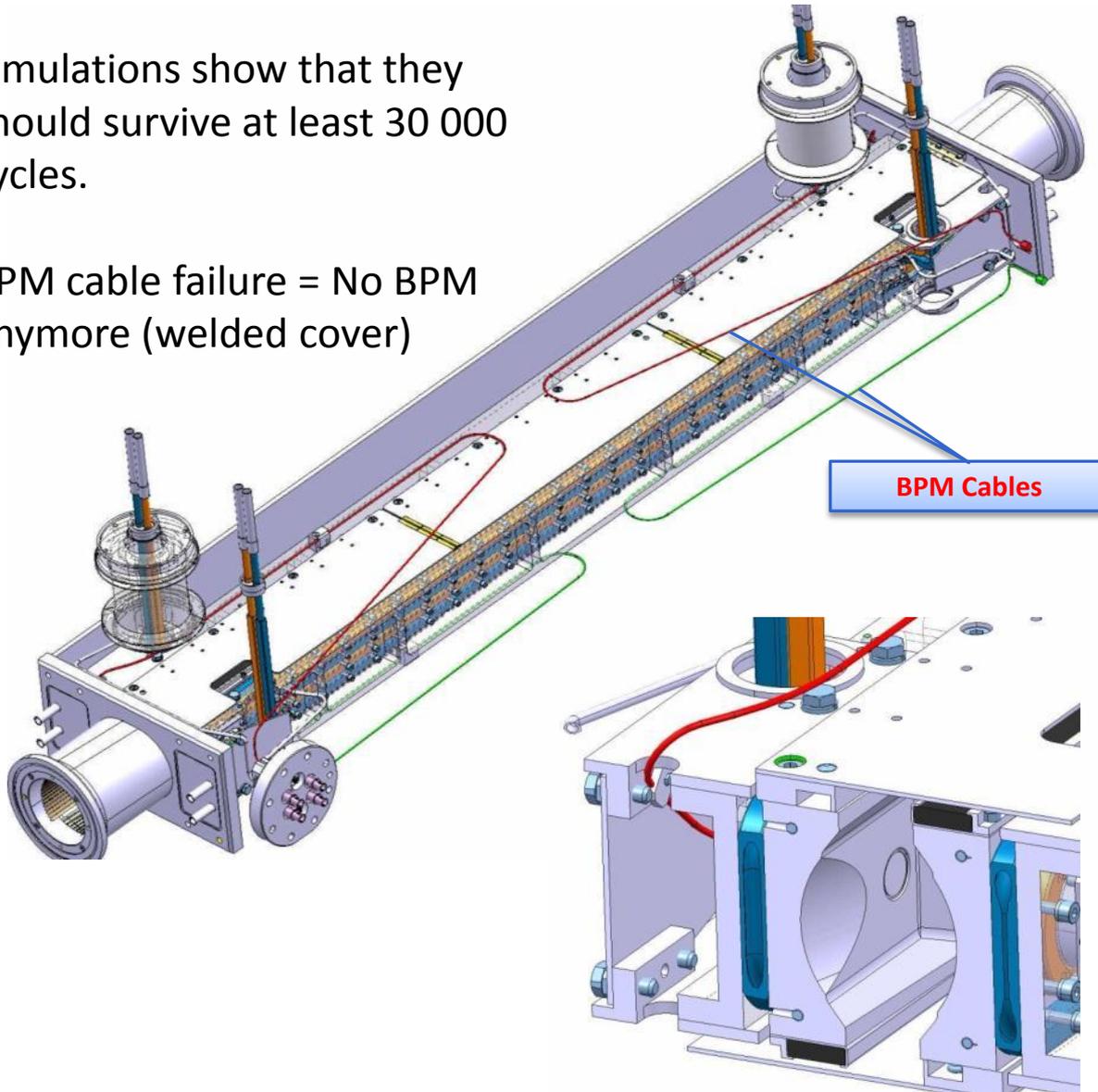- SiO2 dielectric is Hydrophilic and cables are backfilled with Neon gas (chosen for low molecular mass).
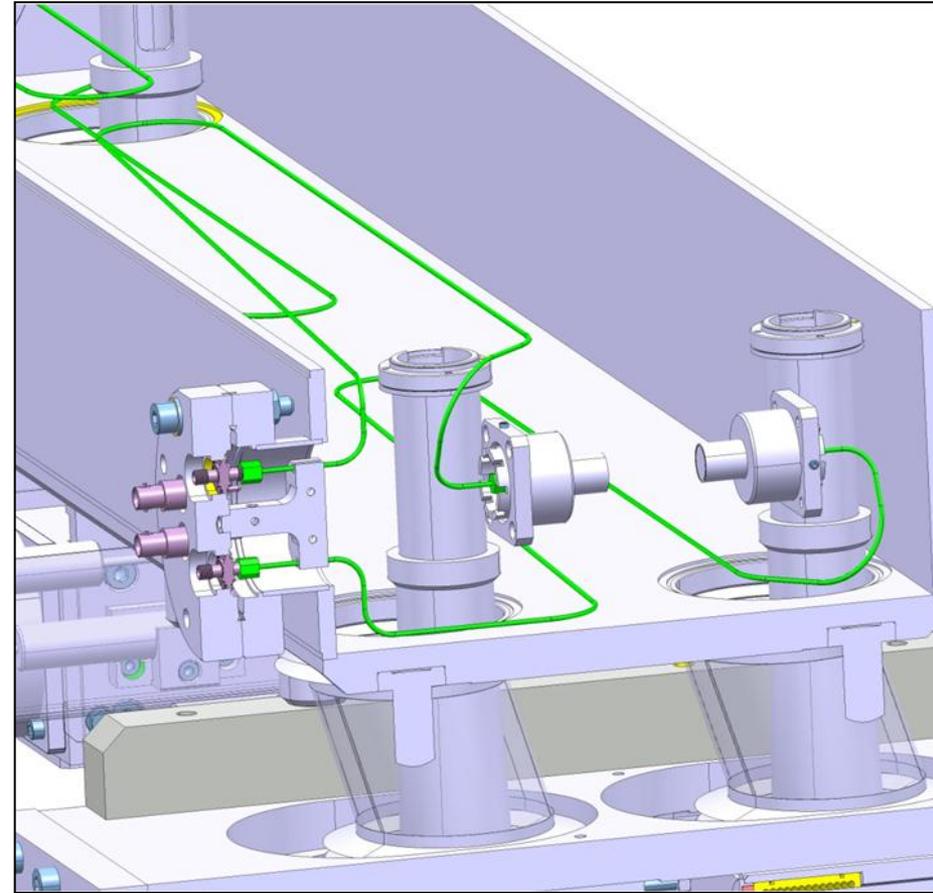


cable routing up to the button fixture.
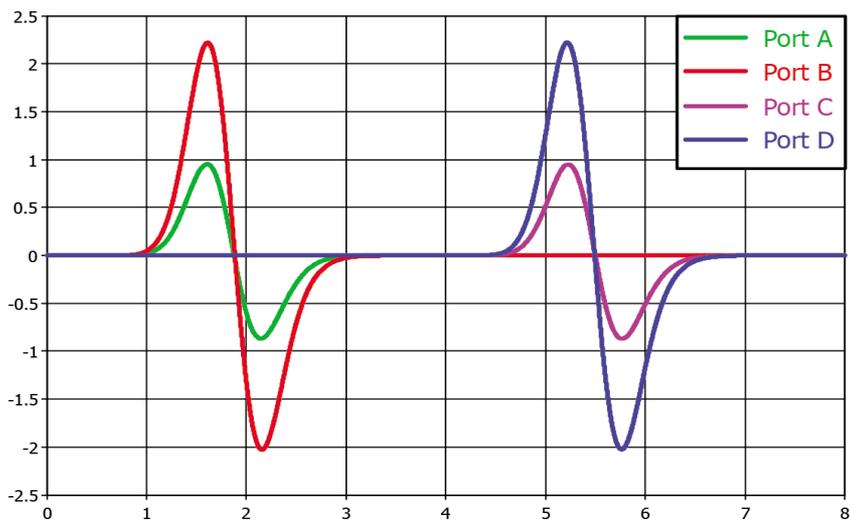
**-> Issue in case of leak in the beam vacuum !**

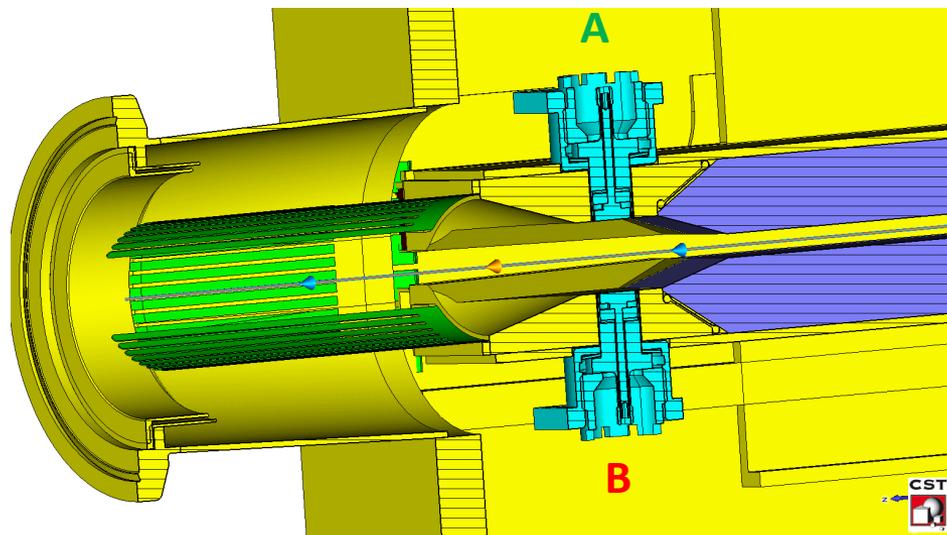- Simulations show that they should survive at least 30 000 cycles.

- BPM cable failure = No BPM anymore (welded cover)

**BPM Cables**

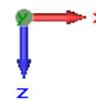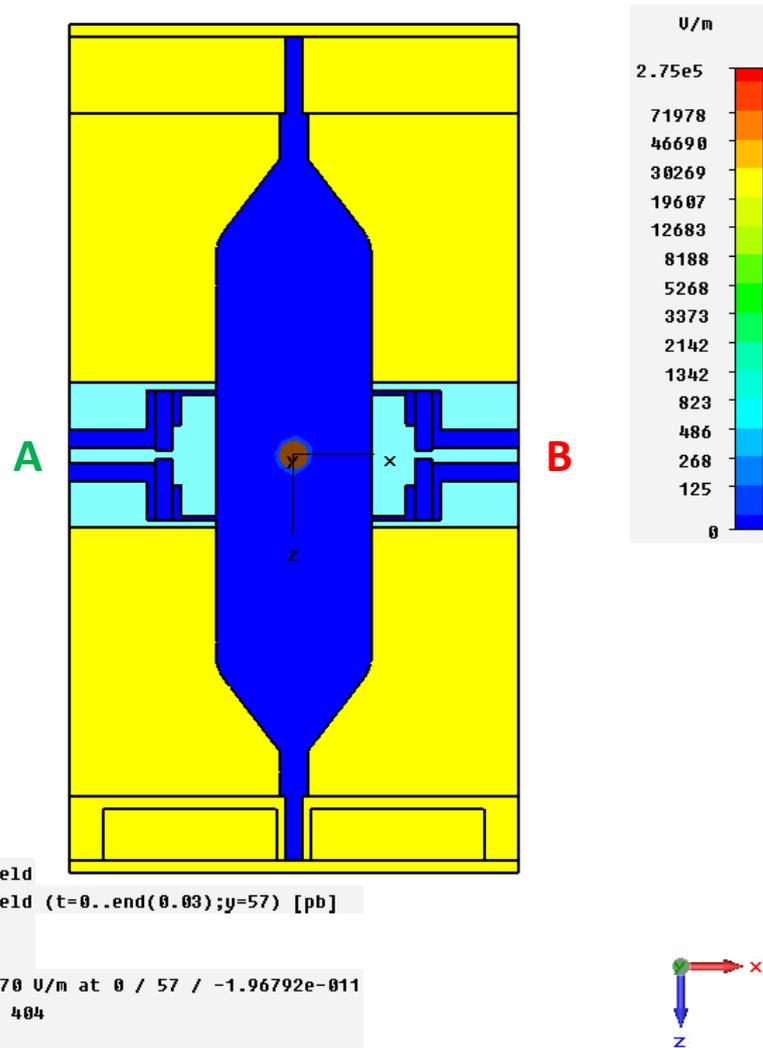**But if vacuum degrades we stop LHC !**

# SIMULATIONS

## Finding non-linearities of the first variable & moving aperture BPM !



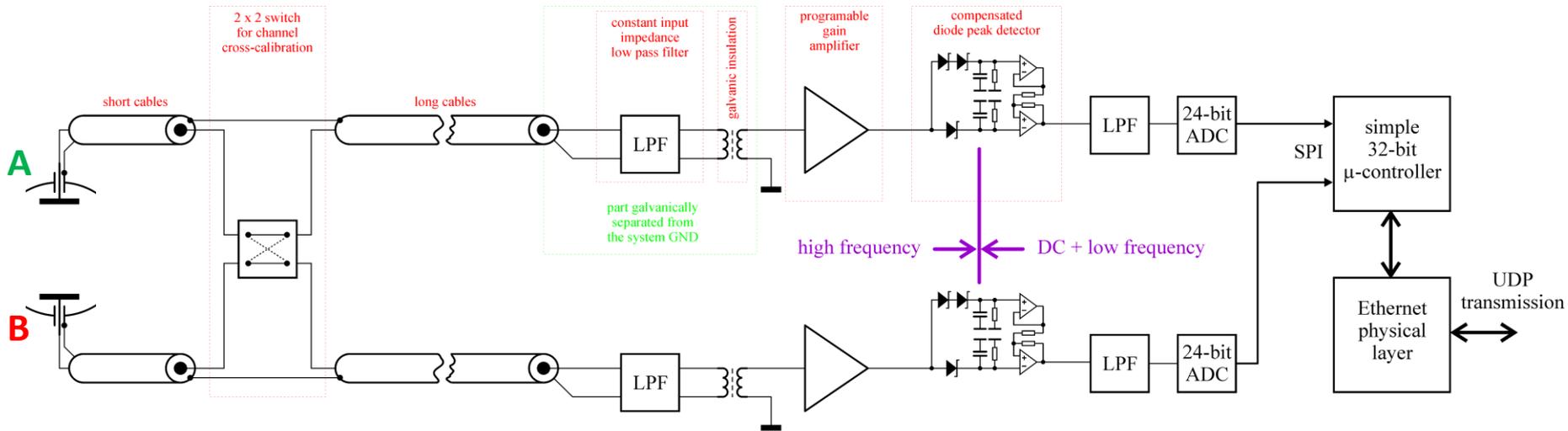Typical up and downstream time signals with beam offset

| Type | E-Field |
|---|---|
| Monitor | e-field (t=0..end(0.03);y=57) [pb] |
| Component | Abs |
| Plane at y | 57 |
| Maximum-2D | 275370 U/m at 0 / 57 / -1.96792e-011 |
| Sample | 20 / 404 |
| Time | 0.57 |

# DIODE ORBIT PROCESSING HARDWARE



Diode Orbit Measurement

2 channels shown for one pick-up plane, one 19" 1U unit accommodates 8 channels

- Signal of each pick-up electrode is processed separately
- The conversion of the fast beam pulses into slowly varying signals is done by compensated diode detectors
- These slow signals can be digitized with high resolution, averaged (~11 turns) and transmitted at slow rate
- All further processing and calculations are done in the digital domain
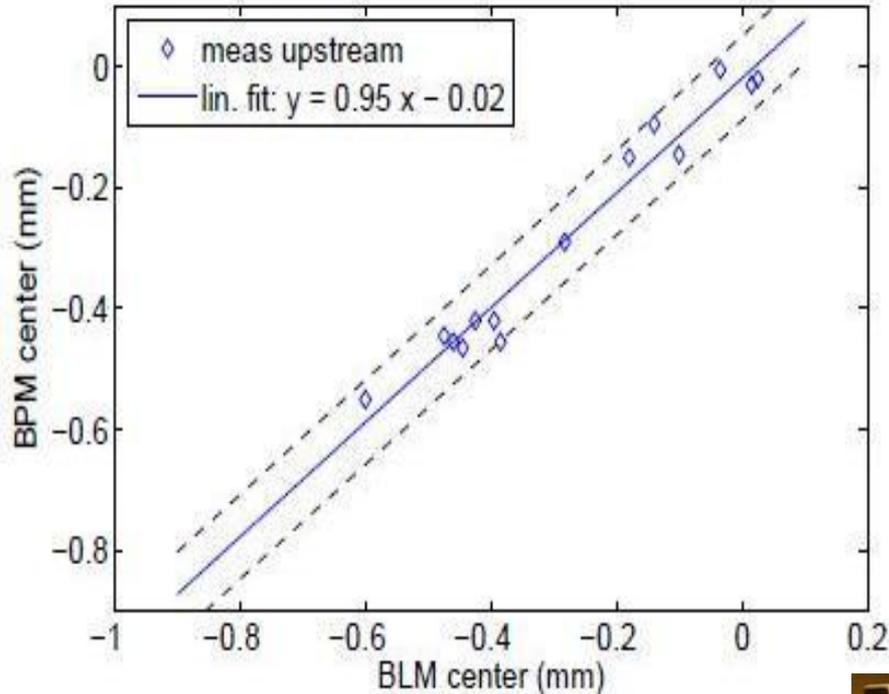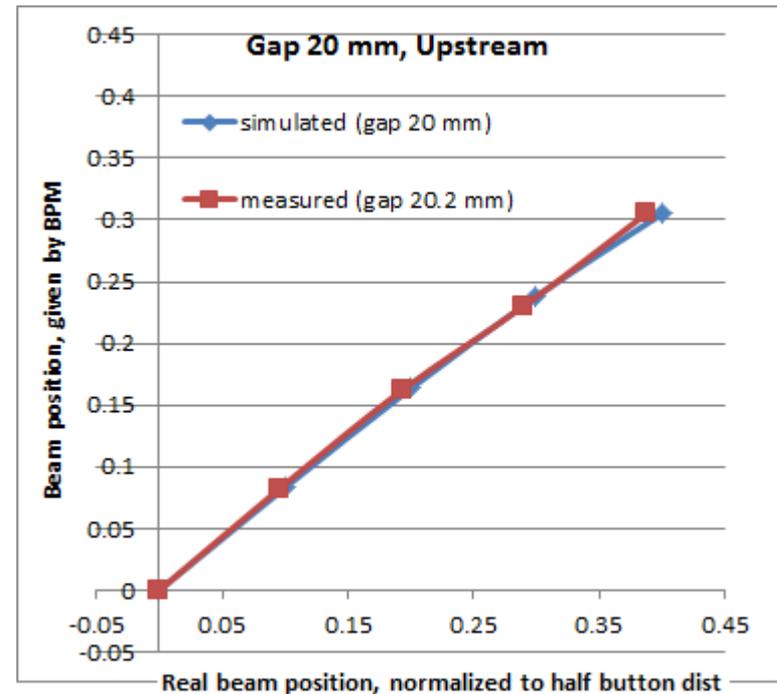- Simple and robust hardware, high resolution, no BST required, low data rates
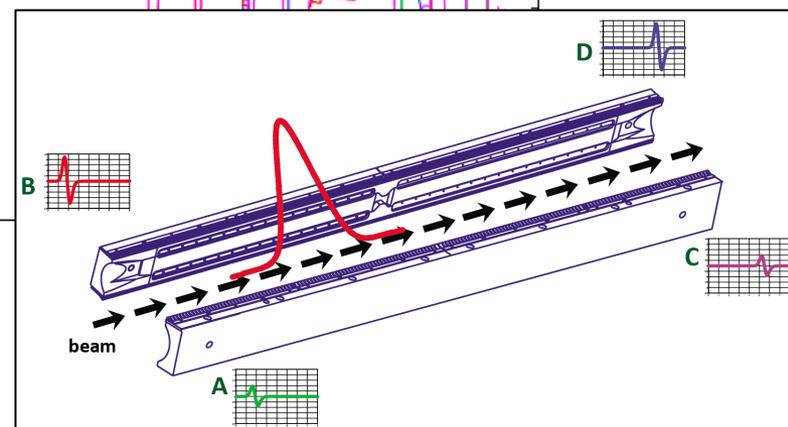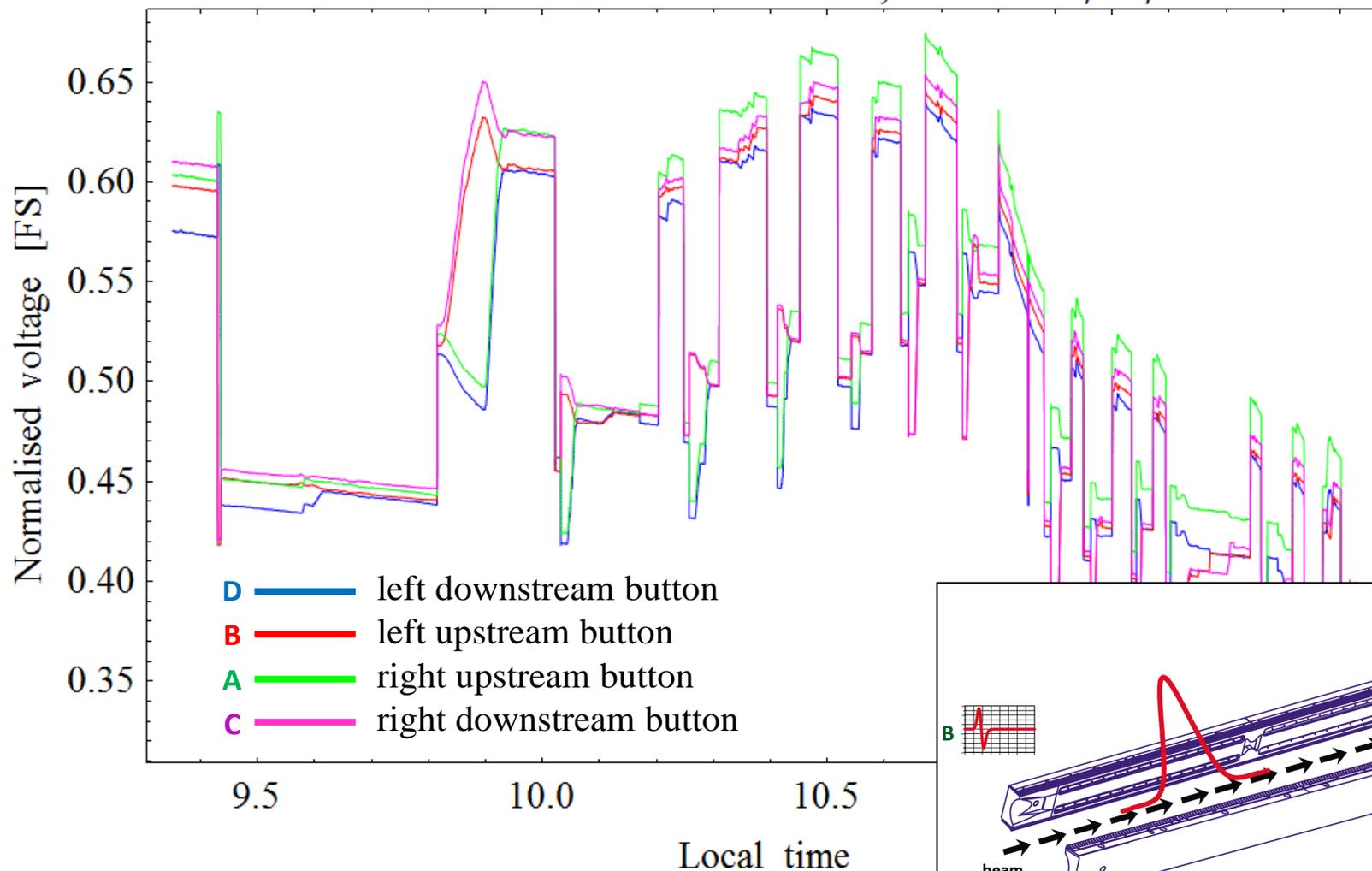
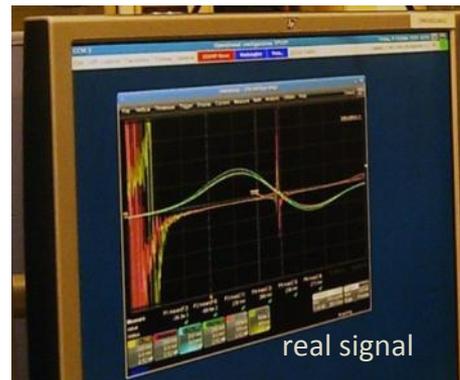An example of raw diode orbit signals from the SPS collimator prototype

# SPS MD RESULTS

✓ correlation between the centres measured with the in-jaw BPMs and the BLM dependent method.

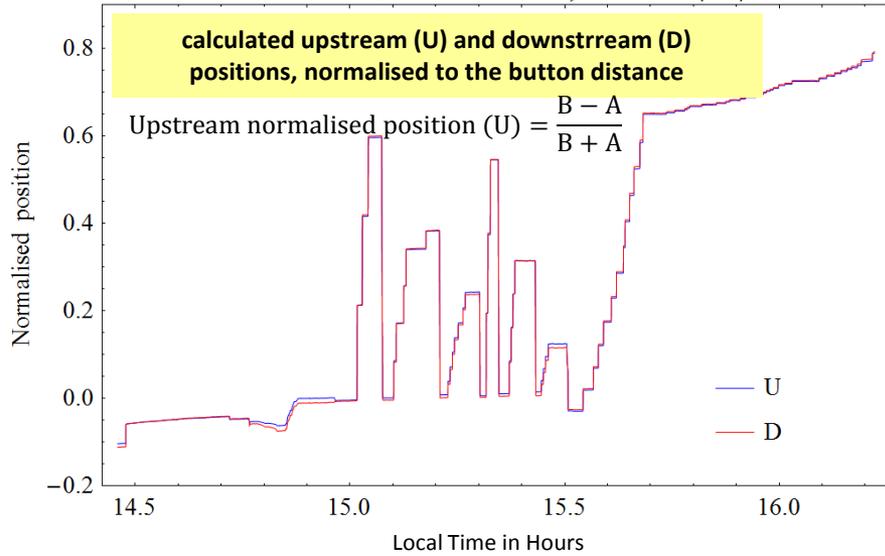✓ Agreement of measured non linearities with simulations results.





Gap 20 mm, Upstream
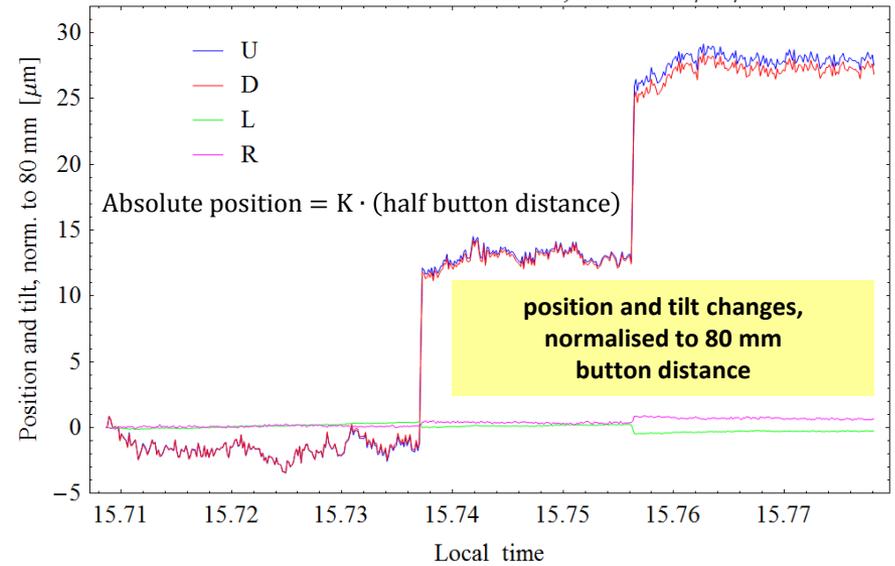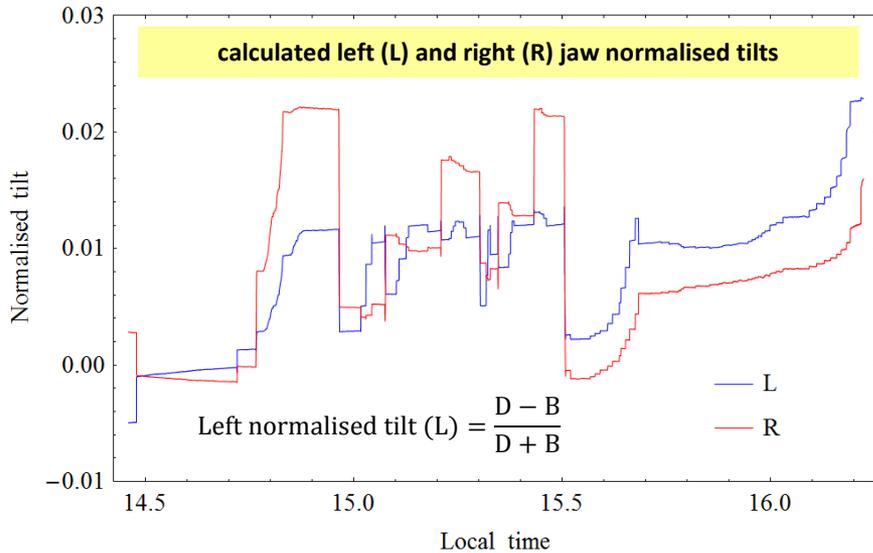
✓ No noise seen due to upstream scraping.



real signal

# RESOLUTION IN SPS

### Diode ORbit @ SPS collimator, MD of 22/09/11

**calculated upstream (U) and downstrream (D) positions, normalised to the button distance**

Upstream normalised position (U) = $\dfrac{B - A}{B + A}$

Normalised position

- U
- D

Local Time in Hours

### Diode ORbit @ SPS collimator, MD of 22/09/11

- U
- D
- L
- R

Absolute position = $K \cdot$ (half button distance)

**position and tilt changes, normalised to 80 mm button distance**

Position and tilt, norm. to 80 mm [$\mu m$]

Local time

### Diode ORbit @ SPS collimator, MD of 22/09/11

**calculated left (L) and right (R) jaw normalised tilts**

Normalised tilt

Left normalised tilt (L) = $\dfrac{D - B}{D + B}$

- L
- R

Local time

### Diode ORbit @ SPS collimator, MD of 22/09/11

— U−D

Position difference, norm. to 80 mm [$\mu m$]

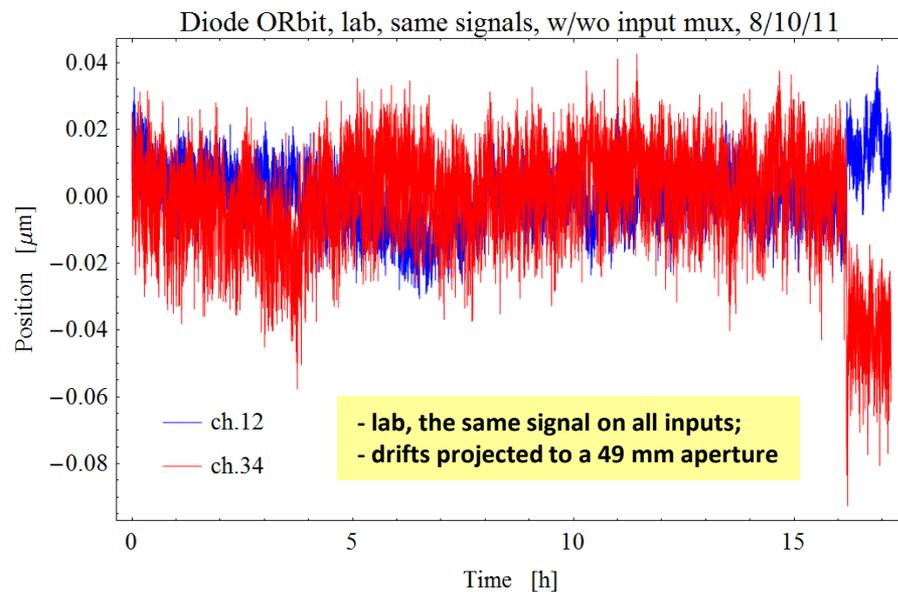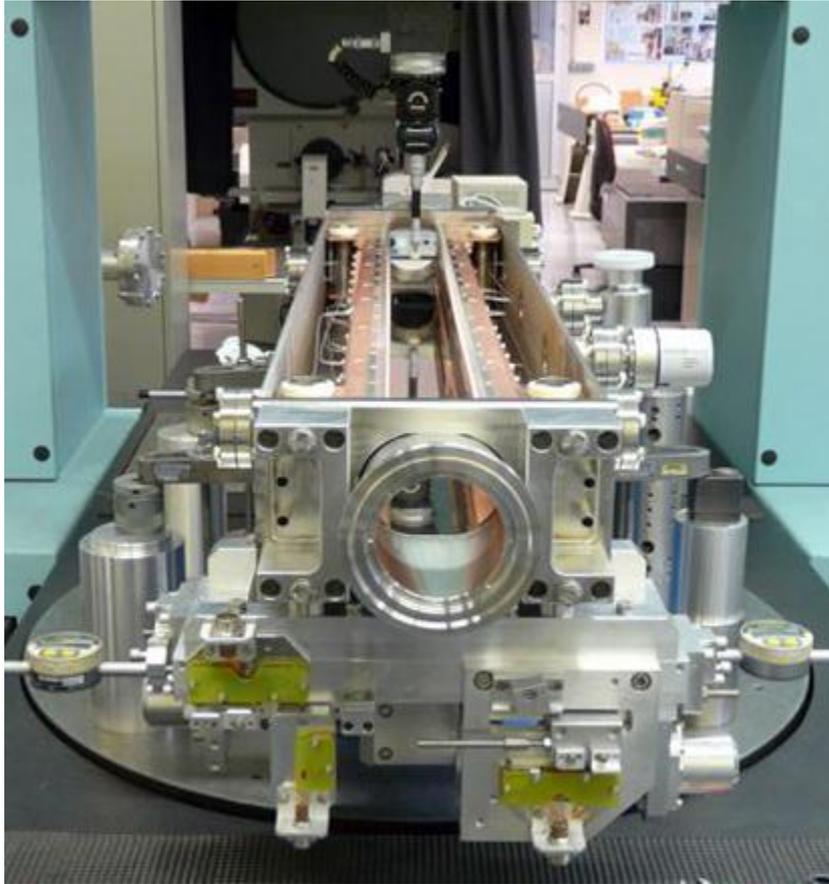**difference of the downstream and upstream readings from the above plot**

Local time

✓ **precision and stability**

- Test installation on BPMC.8L4.B1 (4 channels) as the only user.

- Test installation on BPMSW.A1L5.B1+B2 (8 channels), sharing the signals with the regular BPMs
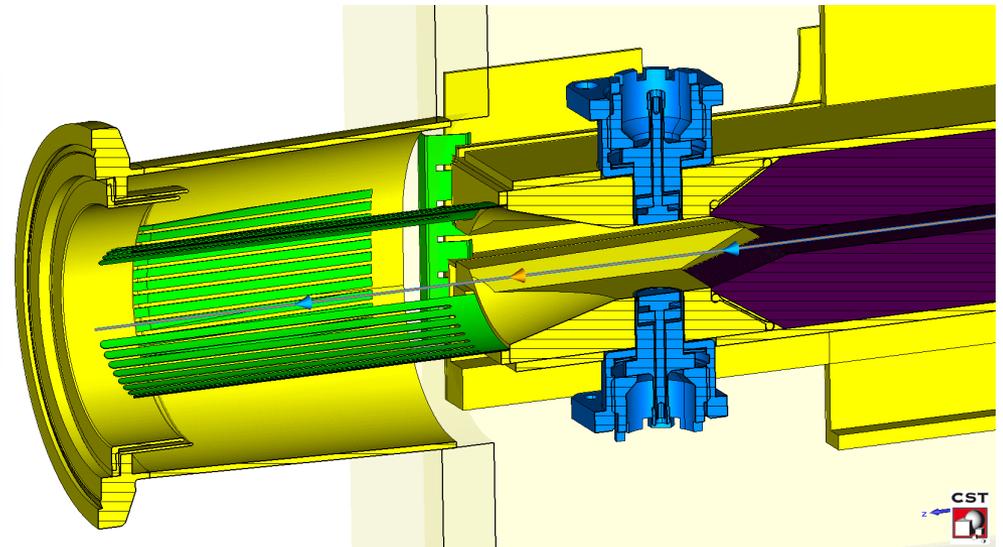
# CONCLUSIONS

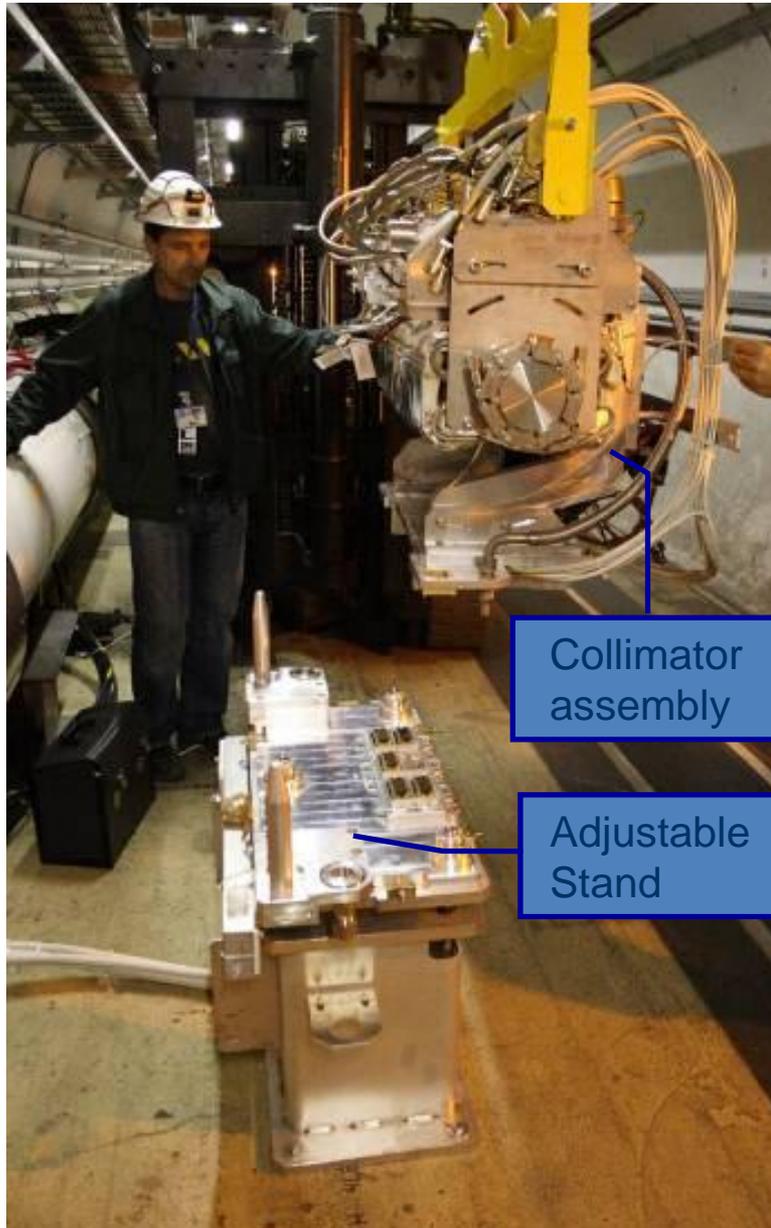From demonstrator installed in the SPS to...



Tertiary Collimators with Embedded BPMs:

- BPM design based on experience and good results gained with demonstrator installed in the SPS.

- Based on Phase II concept.

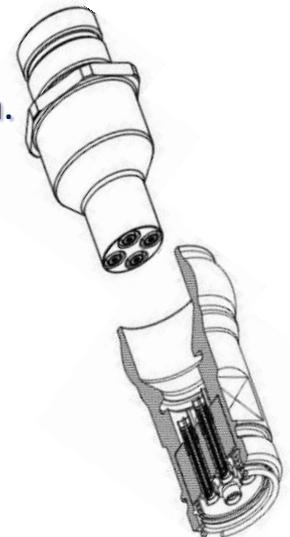- Should achieve precision and stability performance.

Collimator assembly

Adjustable Stand

## Embedded BPMs Collimators:

- Mission to replace all moveable collimators in the Ring with new collimators equipped with BPM

- Start production in 2012 of 20 tertiary collimators (TCTP) with installation of 8 of them during LS1.

- Production of 2 Secondary collimators (TCSP) for point 6.

- Baseline for other collimators, and ideas for Beam Beam Long Range Compensator.

- Development of calibration system.

- Development of a blind Plug-in system for collimators located in IR3 and IR7 allowing to quickly connect the BPM collimator to the base support.



**THE END**