Diagnostics for ThomX

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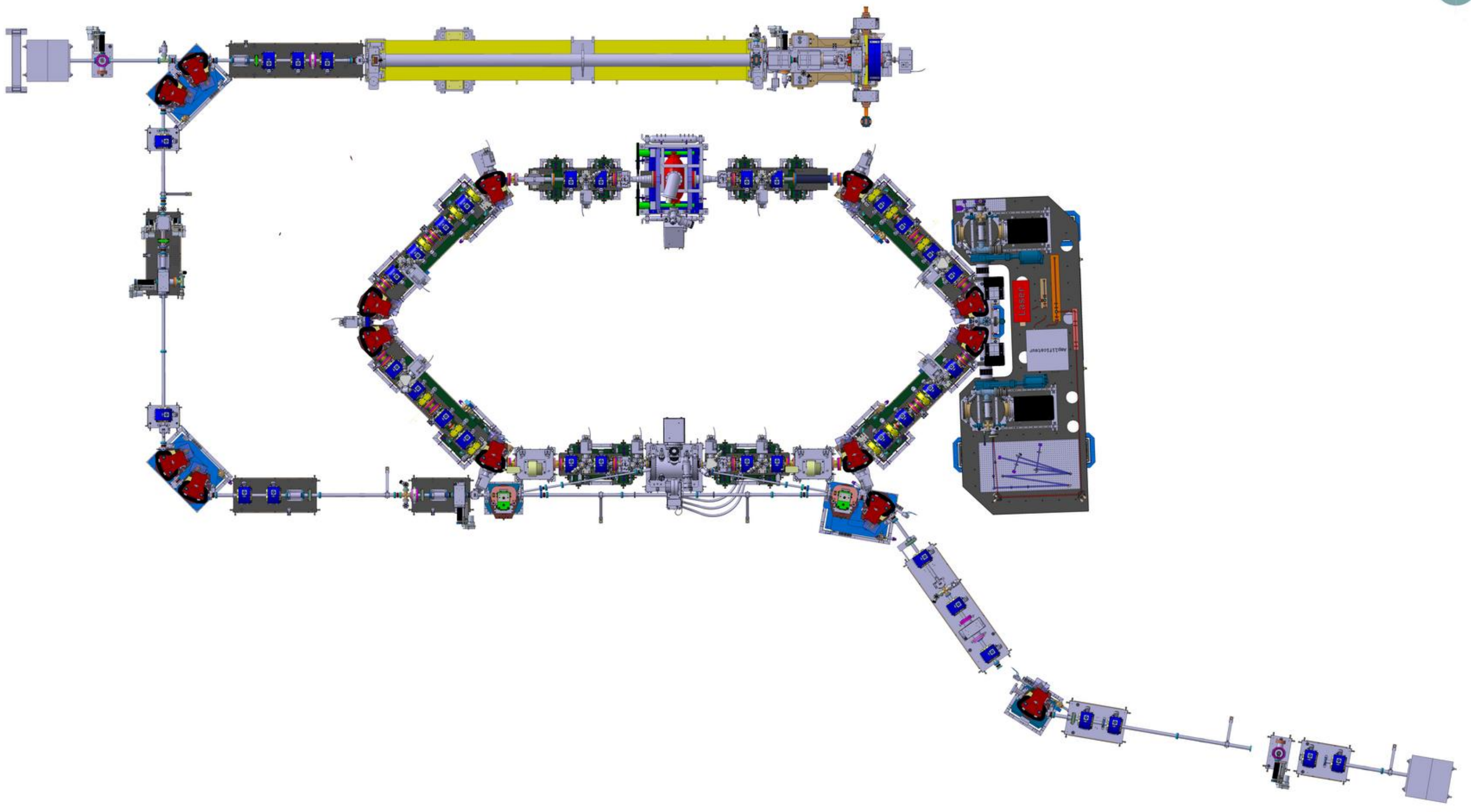
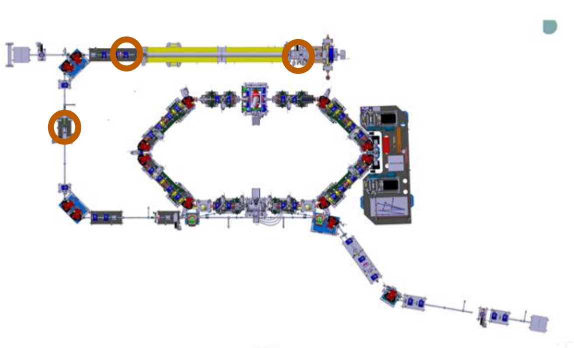
Diagnostics for ThomX (outline)

- Charge
- Position
- Diagnostic stations
- Length
- Stripline for transverse feedback
- Losses



Charge measurement (Typ. 1 nC @ 50 Hz)

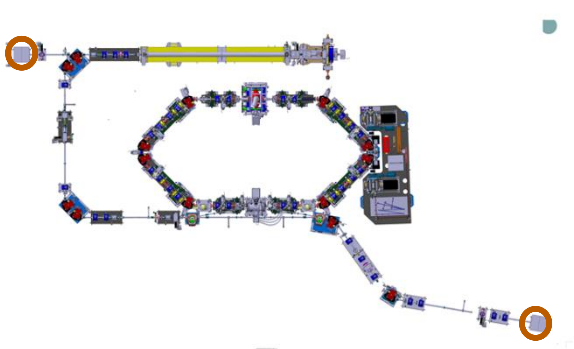


- 3 integrated current transformer (ICT)
  - Location:
    - @ LINAC entrance
    - @ Linac exit (before first TL bending magnet)
    - @ Transfer Line (between the 2 bending magnets)
  - Type:
    - In-flange integrating current transformer from Bergoz
    - Dedicated electronics BCM-IHR provides analog voltage proportional to the beam charge
    - Acquisition to be integrated in the control system (Red Pitaya, 14 bits).
  - Expected resolution <1 pC

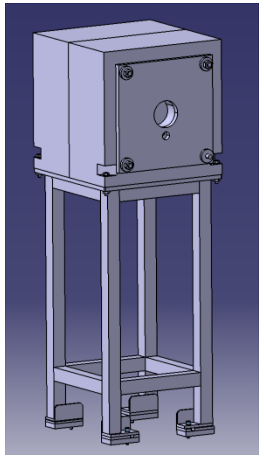
Bergoz in-flange ICT & Electronics

14 bits Red Pitaya acquisition board

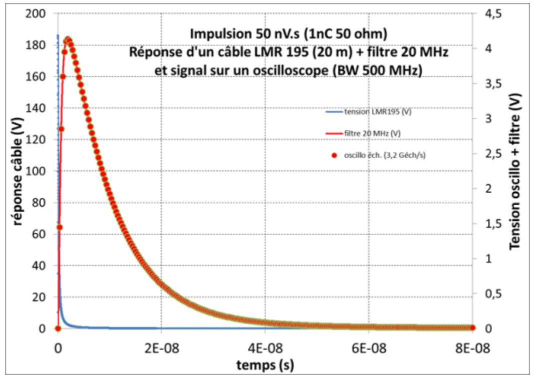
Charge measurement (Typ. 1 nC @ 50 Hz)



- 2 Faraday cups (FC)
  - Location: in the beam dumps
    - @ the end of Linac (behind first TL bending magnet)
    - @ the end of extraction line
  - Acquisition:
    - Few tens of ns pulse to be acquired synchronously to injection or extraction trigger
    - Use of Low Pass filtering and acquisition with the Wavecatcher board (BW 500 MHz; 3.2 GS/s, 12 bits)
    - Tango device ready



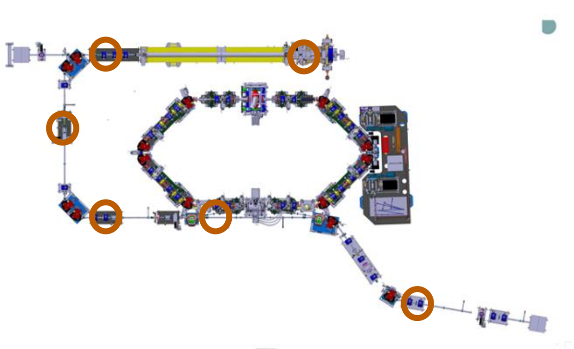
Beam dump



Low-pass filtered signal

Wavecatcher

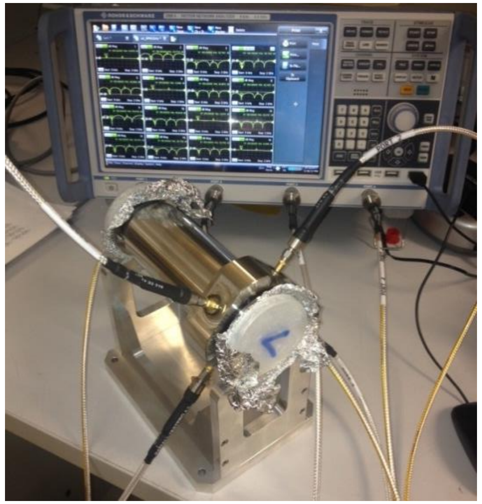
Position measurement (BPM)
Mechanics

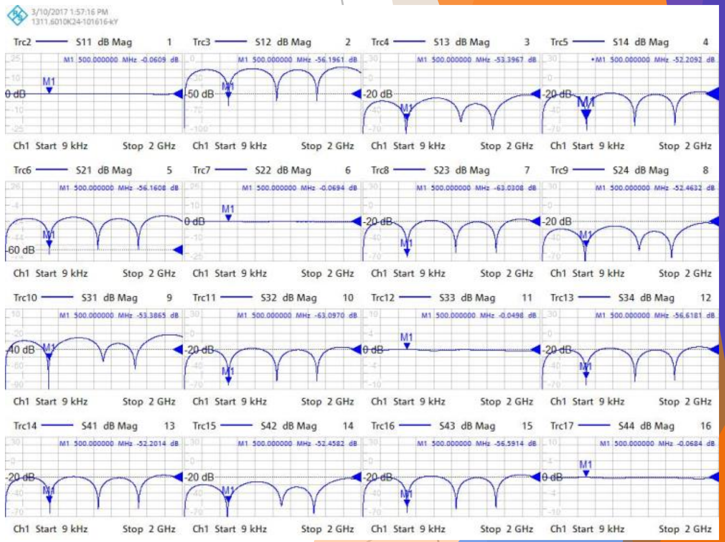


- 6 Striplines
  - 1 stripline on the LINAC
  - 4 striplines on the transfer line
  - 1 stripline on the extraction line

  - λ/4 @ 500 MHz -> Electrode length = 150 mm
  - Resolution requirements: < 100 µm for 1 nC
  - 4 electrodes @ 90° covering ~2/3 of circumference

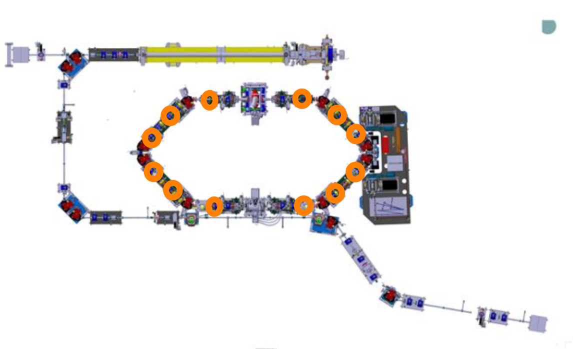
  - Linac stripline has different design due to larger vacuum chamber diameter
  - Mechanics and soldering (feedthroughs) are done at LAL
  - Electrical tests and calibration done at SOLEIL



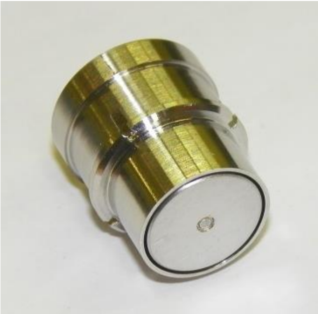


Calibration based on "Lambertson" method using a logic network analyzer

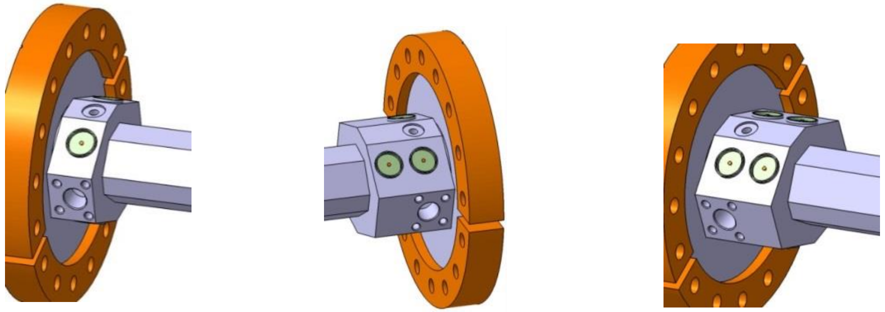
Position measurement (BPM)
Mechanics



- 12 button BPMs for the storage ring
  - Resolution ~1 µm @ 10 Hz
  - Prototype done at LAL
  - Mechanics and soldering are done by RIAL Vacuum, to be delivered in spring
  - Additional electrodes on double BPM for:
    - Transverse and longitudinal bunch by bunch feedbacks
    - Polarization for ion cleaning



ESRF (old) type
10 mm button



4, 6 and 8 buttons BPMS

BPM prototype

- ✓ Design
- ✓ Prototyping
- ➢ Manufacturing
- ➢ Feedthrough welding
- ➢ Electrical test

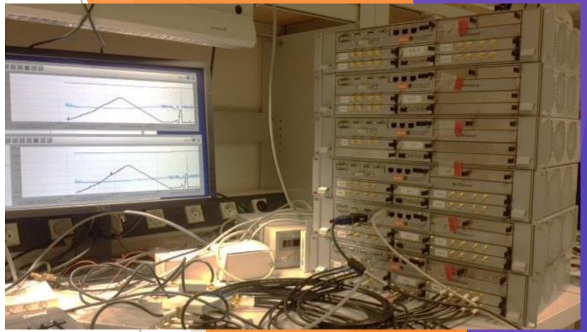
Position measurement (BPM)
Electronics

- Libera Brilliance+ (Instrumentation Technologies)
  - 4 BPM boards per crate
  - Data Flow:
    - Single Pass for Linac and Transfer Line
    - @ 8,33 MHz (half rev. freq.) ~turn by turn data for storage ring
    - @10 Hz slow acquisition data for storage ring
  - Automatic gain control
  - Post-mortem and interlock possibilities
  - Tango device available and fully configurable embedded on the ARM processor

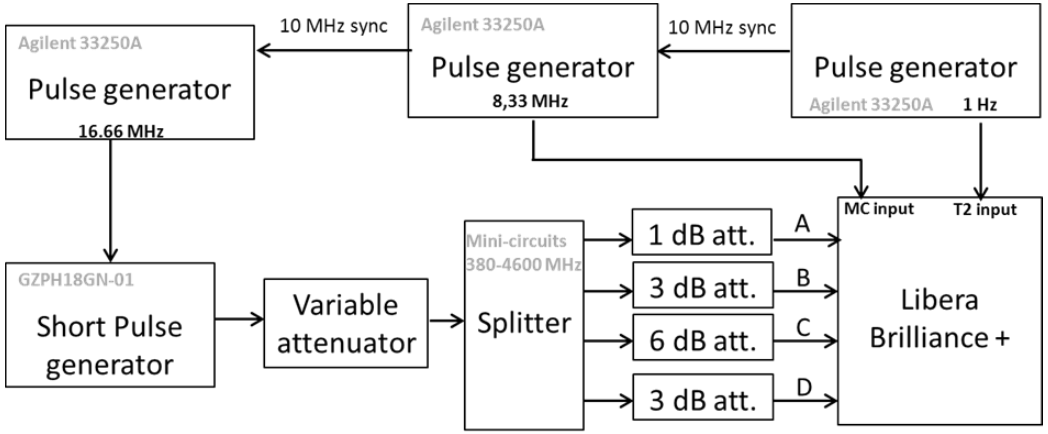
Libera Brilliance +

- ✓ Design (adaptation)
- ✓ Manufacturing
- ✓ Reception tests (more than one year…)

Position measurement (BPM)
Electronics

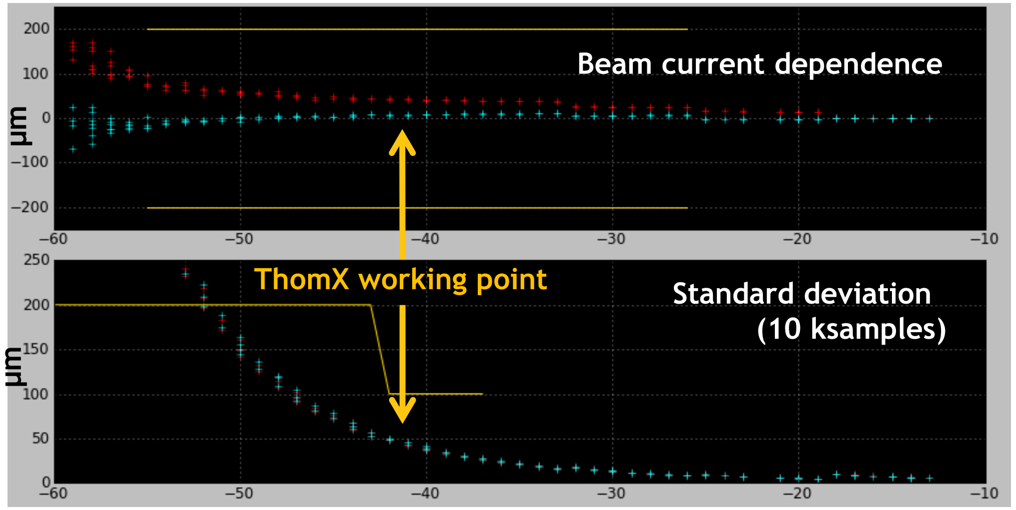


- Acceptance tests: Turn by Turn (8.33 MHz) and Slow Acquisition data (10 Hz)

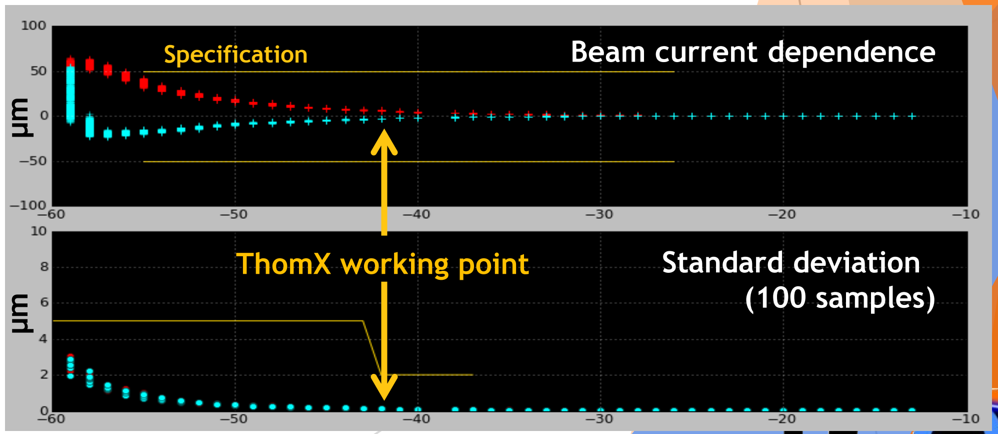


Test bench for acceptance test

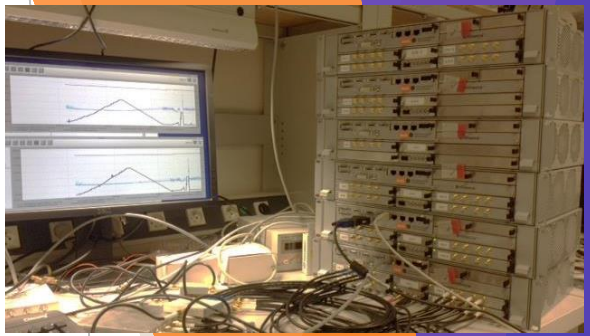
Turn by Turn Data



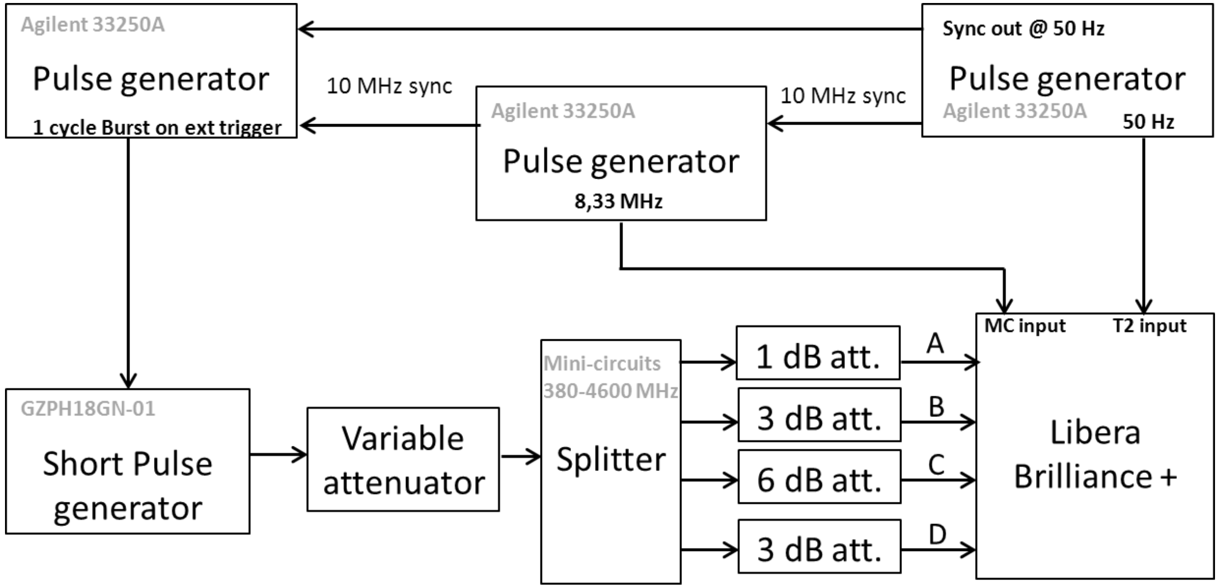
Slow Acquisition Data



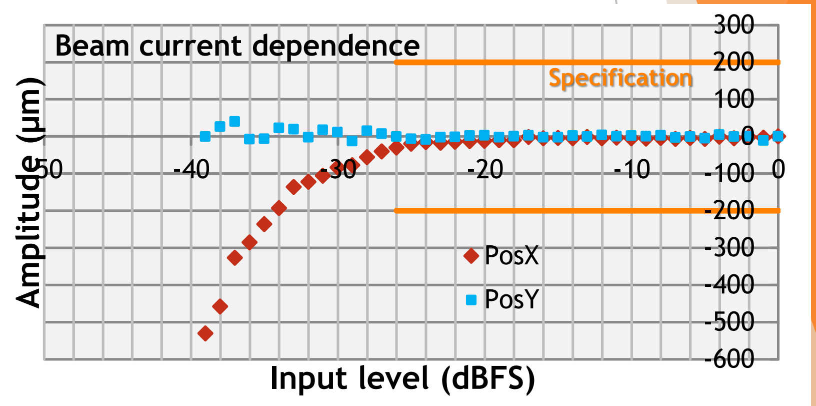
Position measurement (BPM)
Electronics

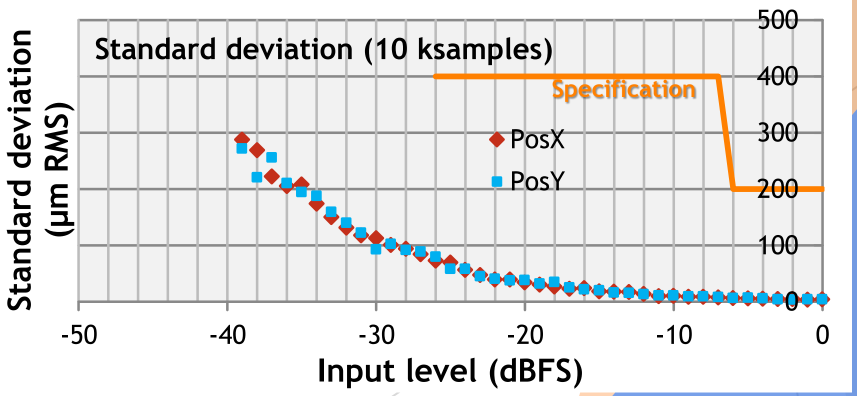


- Acceptance tests: Single Pass Data



Test bench for acceptance test

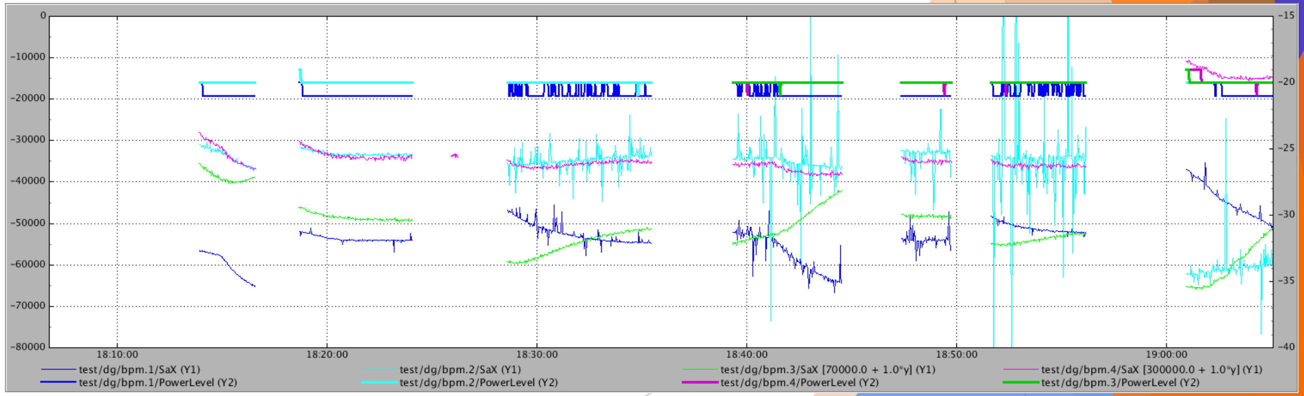




Position measurement (BPM)
Electronics

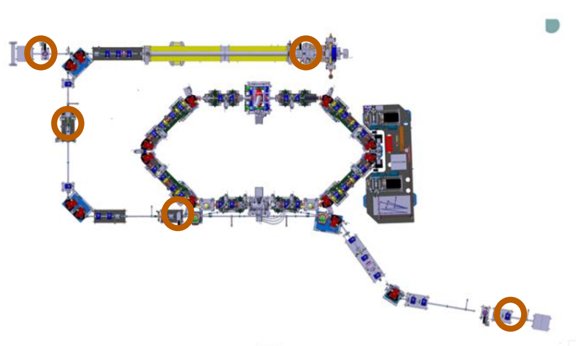
- Reliability issues during Libera Brilliance+ acceptance tests
  - First unit delivered in January 2015
    - Acceptance test validated in march 2015
      - Performances (beam current dependence, resolution…) are ok
      - Reliability issues pointed out (boot, data availability, Tango device server)
  - 5 other modules delivered in september 2015
    - Acceptance test not yet validated
      - Performances (beam current dependence, resolution…) are ok.
      - Still reliability issues
        - Software upgrade: november 2015
        - 1 module back to I-Tech during 6 month
        - Software upgrade: november 2016
        - Hardware patch: november 2016
        - FPGA upgrade: January 2017
        - OS upgrade: March 2017

Libera Brilliance +



Spikes issues with boot dependance

Diagnostic stations

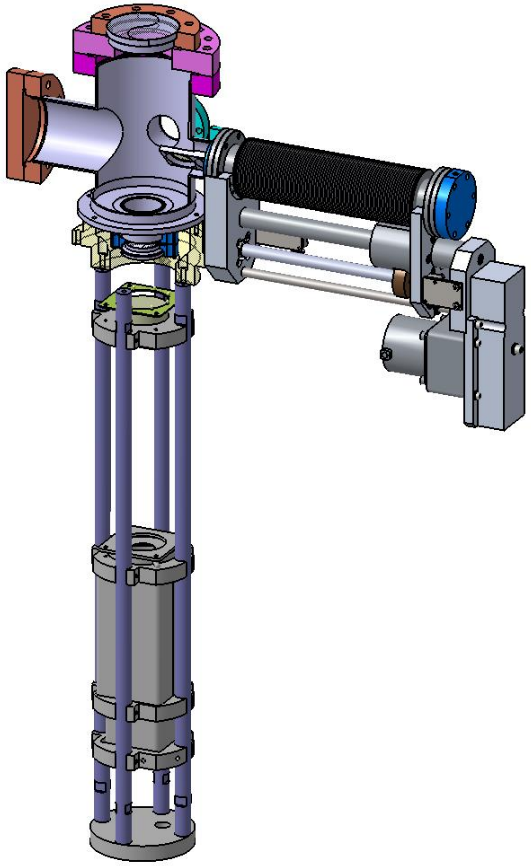


- Location
  - 5 Stations on Linac and transfer lines
- Purpose:
  - Beam size, emittance and energy measurement
- Principle:
  - Screen translation stage
    - Calibration plate
    - YAG (Ce): 25 mm diameter, 100 µm thick
    - OTR : 25 mm diameter, 100 µm aluminised silicon wafer
    - Sapphire screen (station 2 @ end of Linac)
  - View port: Fused Silica DN 60 CF
  - Imaging system
  - Gigabit Ethernet trigged CCD

✓ Design

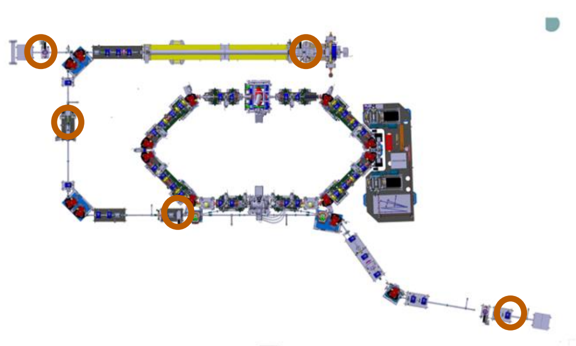
✓ Screens are delivered

✓ 1 translation stage is ready, the others to be ordered



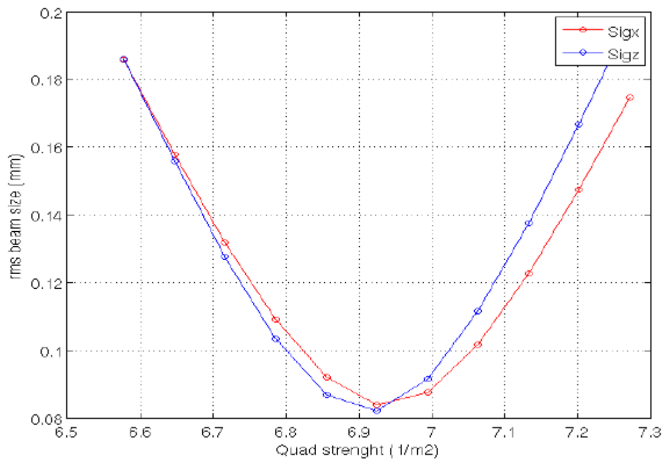
Screen translation stage

Diagnostic stations

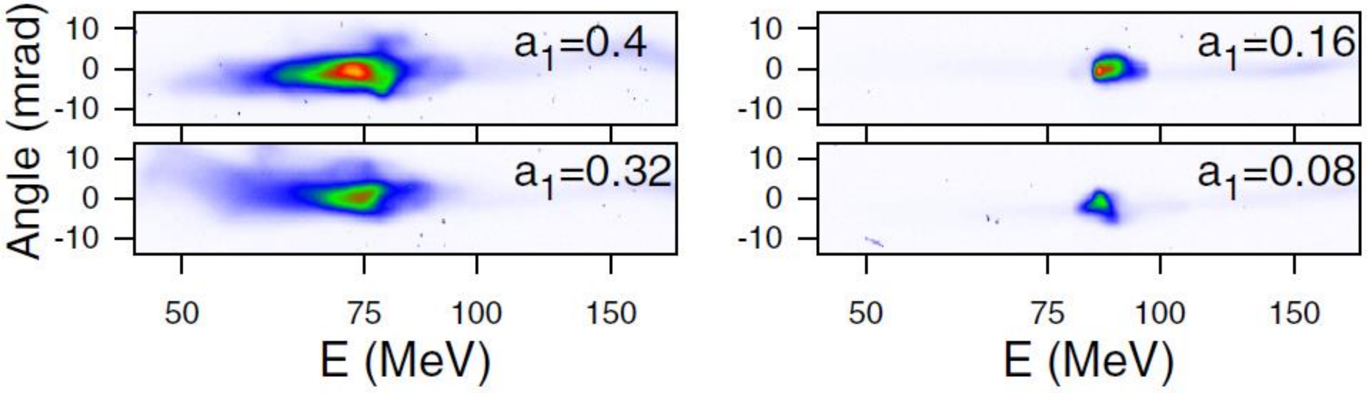


- **Transverse size measurement (1 to 2.5 mm)**

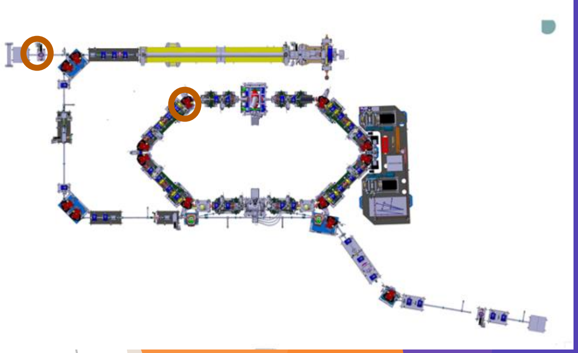
- **Emittance measurement**
  - Using Quadrupole scan method
    - Measure beam size vs Qpole strength
    - Required resolution: 10 pixels/sigma
    - Devices: 1 quadrupole + screen + CCD
    - Location:
      - @ Diag stations 2 and 3



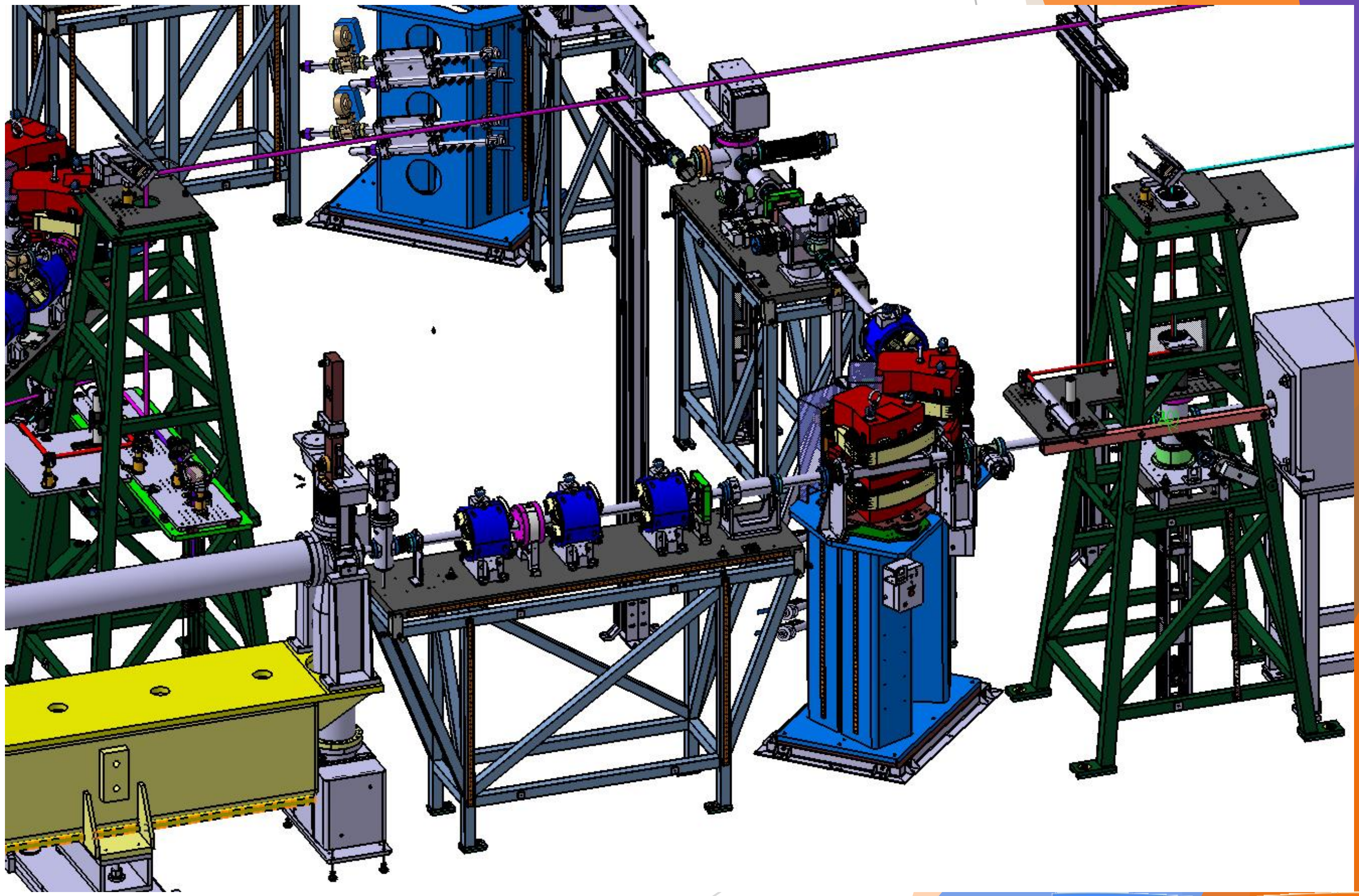
- **Energy measurement:**
  - Passing through dipole magnet → dispersion
    - <x> → E = energy
    - dx → dE = energy spread
  - Device:
    - Dipole + screen + CCD
  - Location:
    - @ middle of transfer line (Diag Station 3)
    - @ dump 2 (Diag station 5)

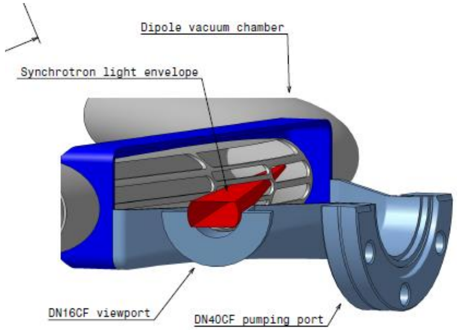


Bunch length measurement



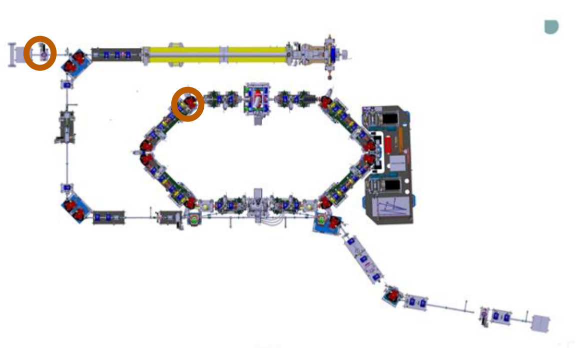
- End of Linac (4.3 ps expected):
  - Cherenkov radiation produced when the electron beam passes through the sapphire screen
  - Sapphire window to extract light
  - Transport the radiation to a streak camera to measure the photon pulse length.
- Storage Ring (5 to 20 ps expected):
  - Synchrotron radiation produced when the electron beam changes its trajectory in the bending magnet
  - Sapphire window to extract light
  - Transport the radiation to a streak camera to measure the photon pulse length.





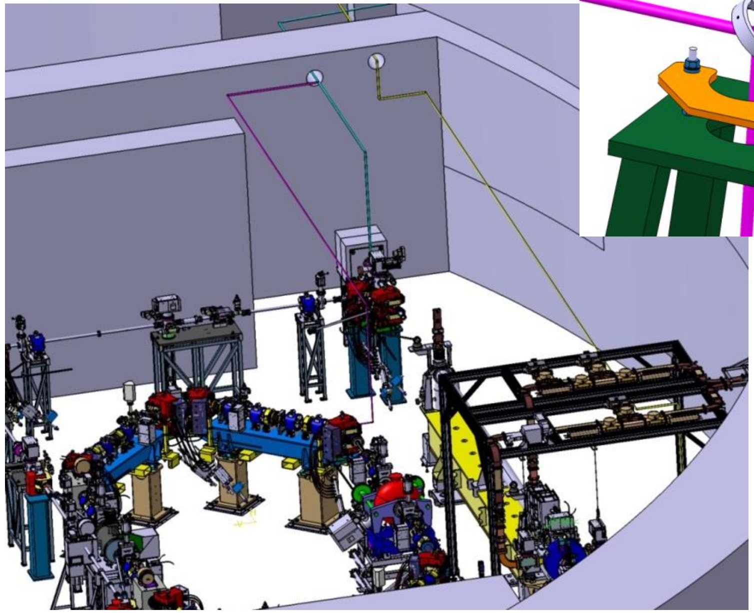
SR extraction port

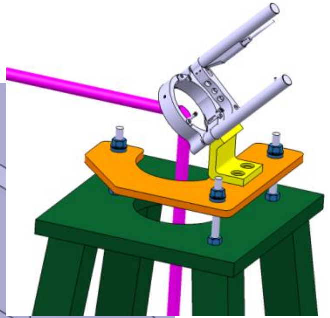
Bunch length measurement



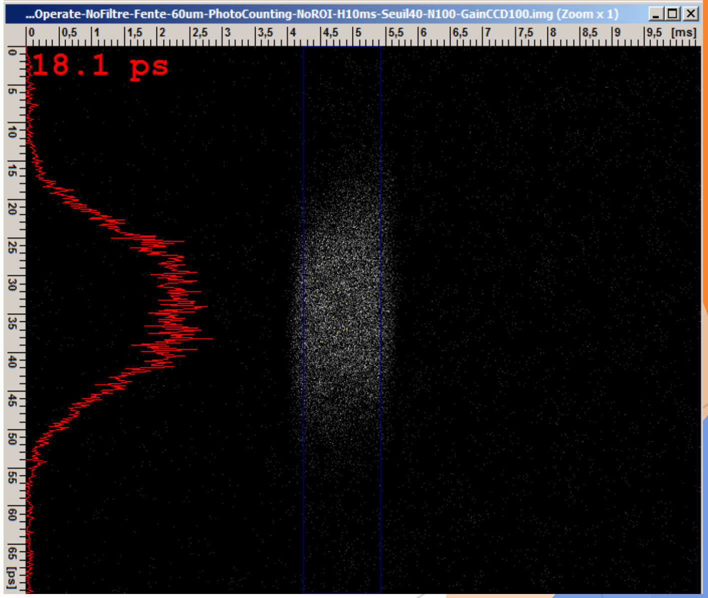
- Complex transport path to the streak camera
  - Streak camera installed inside laser hutch
  - Mirror support at 2.3 meter high

- Hammamatsu streak camera
  - Double sweep and UV tube



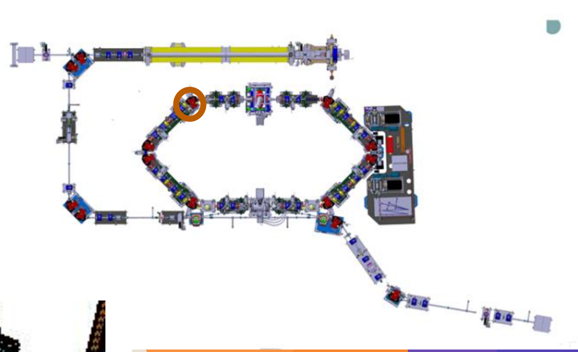


Mirror support

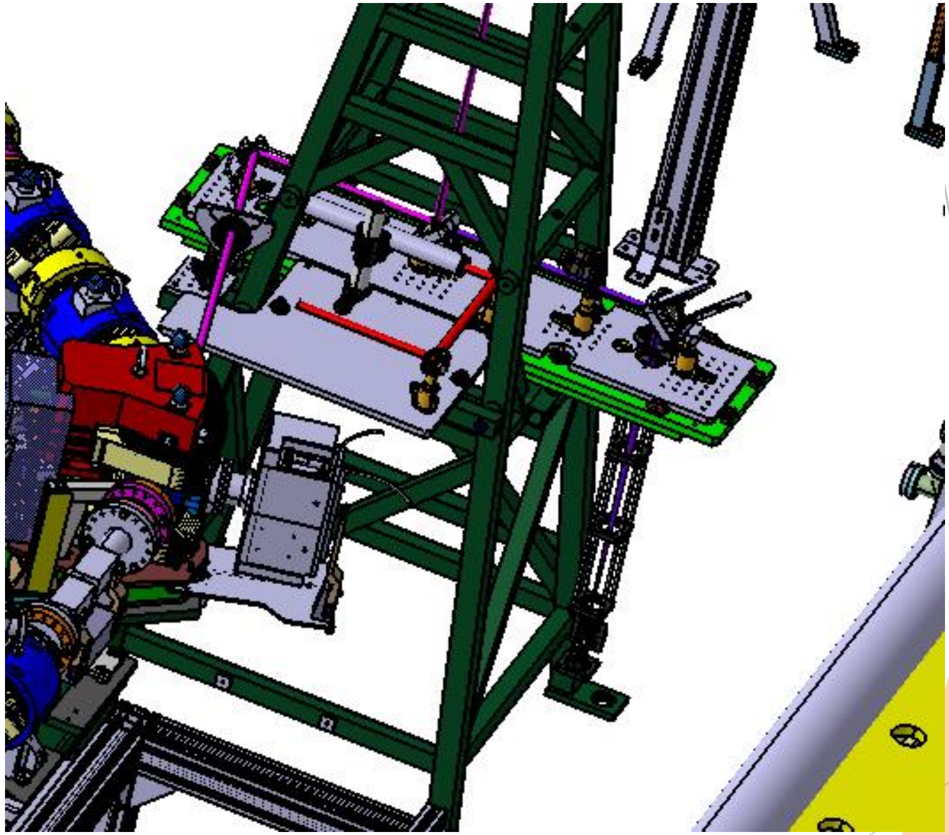


Cerenkov radiation longitudinal measurement on PHIL with ThomX streak camera (photon counting mode)

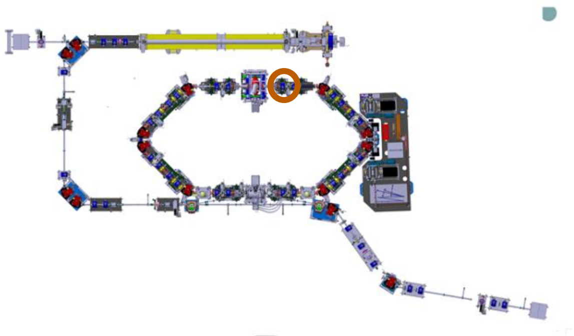
Synchrotron Light Monitor



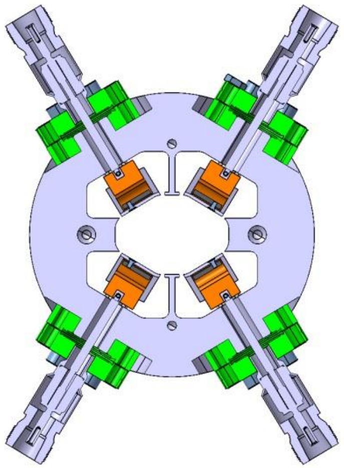
- Visualization of the beam on the storage ring in transverse plane



Transverse feedback



- Detector:
  - One set of additional button from BPM
- Actuator
  - Stripline (kicker)
    - Electrode length: 300 mm (λ/2 @500 MHz)
    - 4 electrodes for acting in H and V planes
    - Rise time < 1 ns



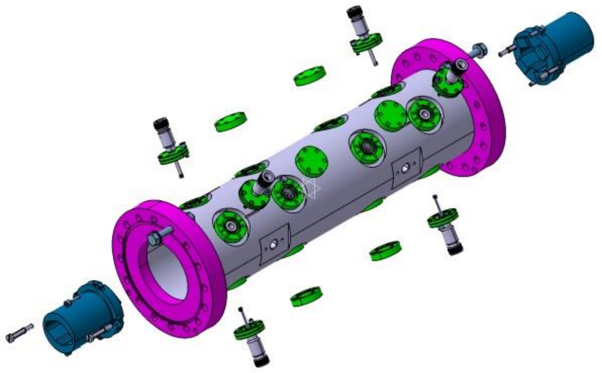
FBT stripline

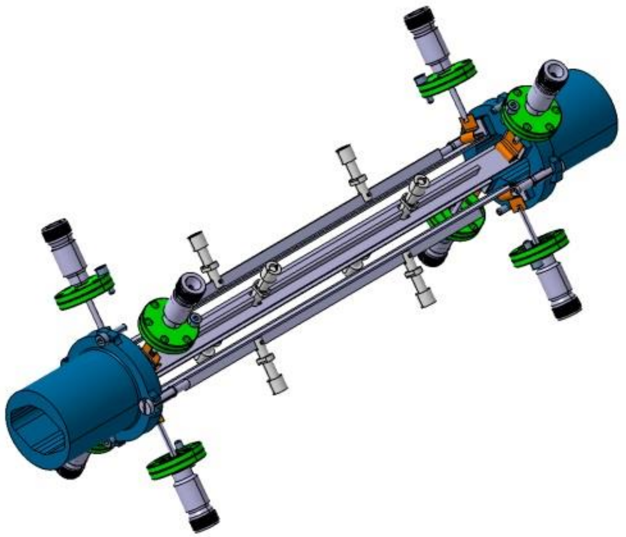
- Design main steps:
  - Characteristic impedance
    - Geometric factor
    - S parameters
  - Shunt impedance
    - Efficiency
  - Wakefield/Beam longitudinal impedance
  - Thermic studies

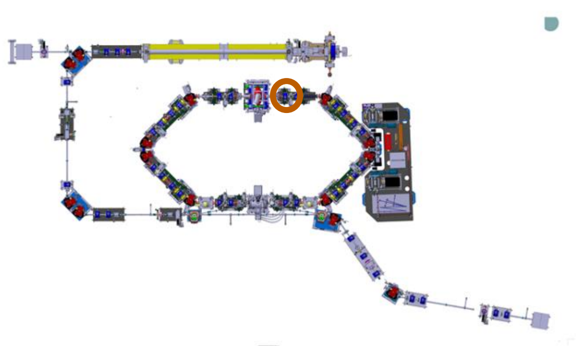
- ✓ Simulations and design
- ✓ Drawings
- Consultation
- Manufacturing
- Reception tests

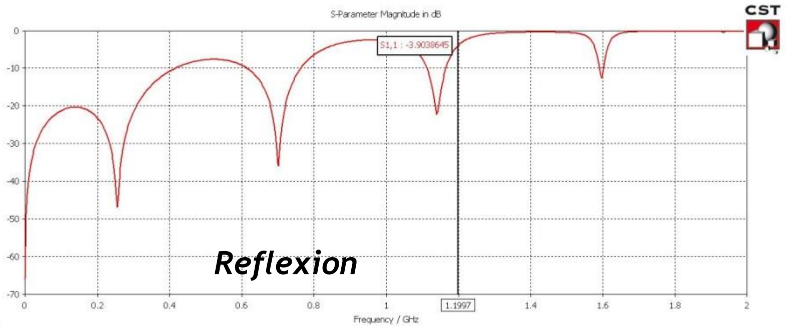
Transverse feedback

Stripline

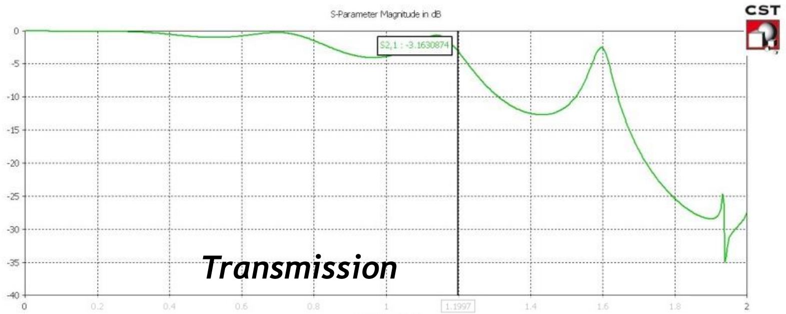






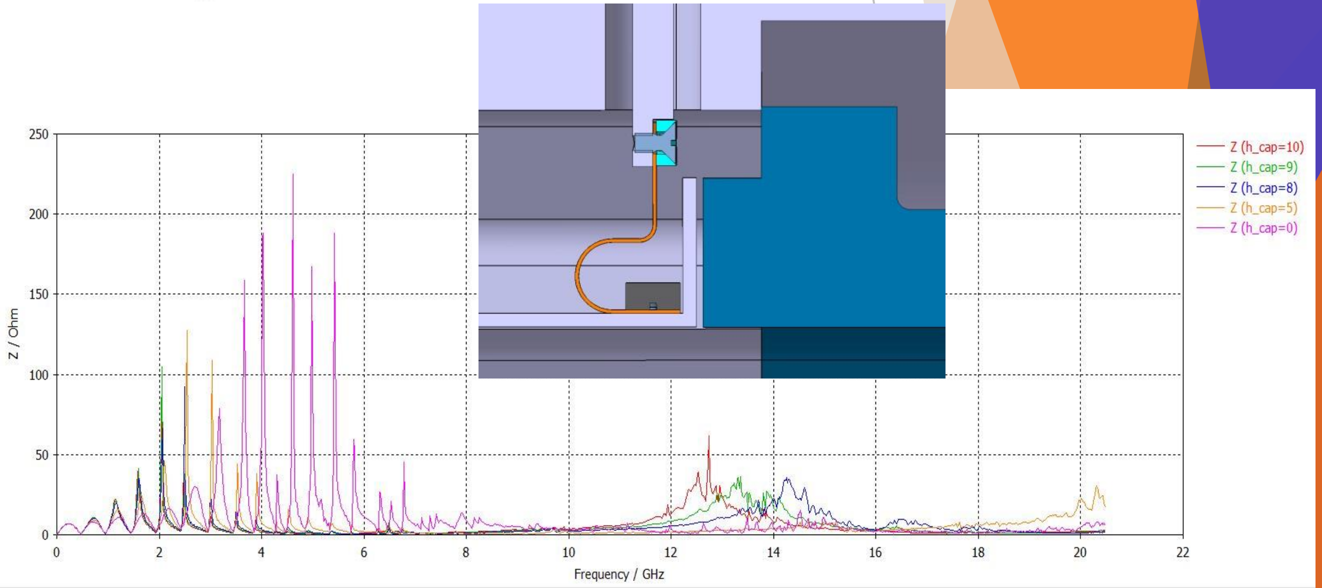


Reflexion



Transmission

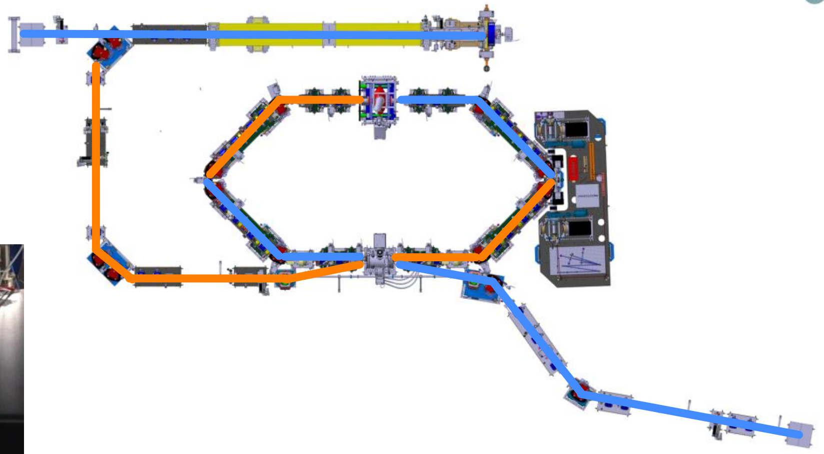
Stripline Adaptation (Characteristic impedance)

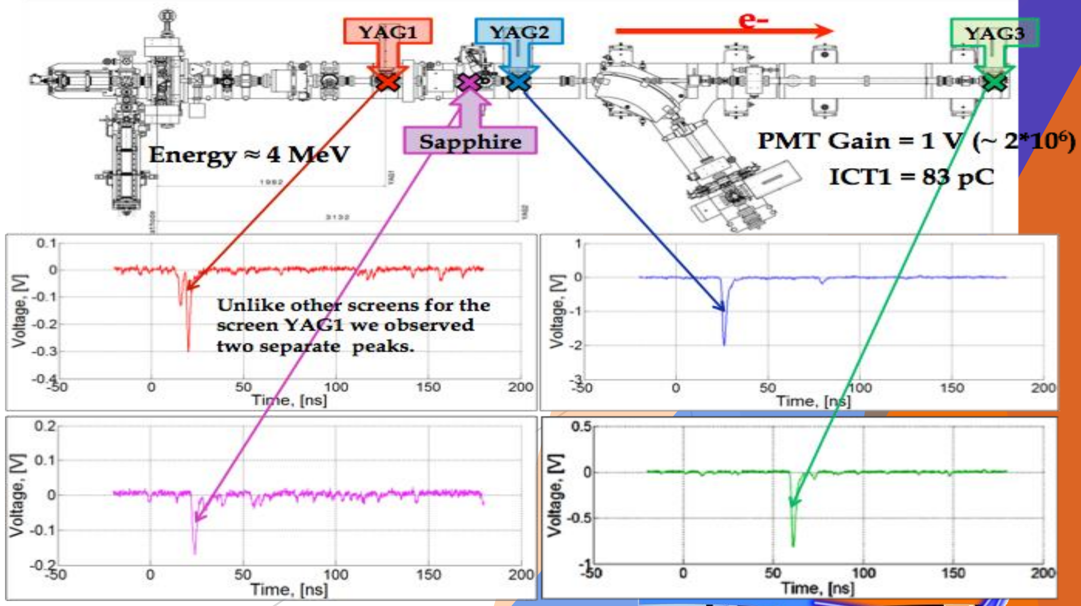


Longitudinal impedance minimization

Beam Loss Monitors

- Fiber Beam Loss Monitor (FBLM)
  - Principle:
    - Particle loss → passes through the fiber → generates Cherenkov light pulse in the fiber.
    - Pulse propagates to photomultiplier
    - Time at witch the loss pulse arrives with respect to the trigger (reference) gives the location of the loss
  - 1 fiber for the LINAC, 1 for the TL, 4 for the SR and 1 for the EL.
  - The choice of the fibers and PMTs are made, the order to be passed at beginning of 2017. The controller for the DAC to control remotely the PMT gain: the order to be passed at the beginning of 2017.
  - DAQ: Wavecatcher + Scope for the SR (to be ordered at the beginning of 2017)
  - Beam test @ PHIL: Wavecatcher and its Tango DS have been successfully tested with the FBLM.

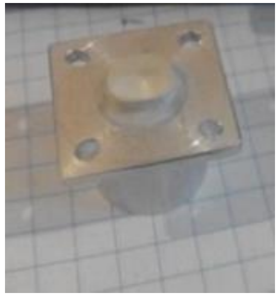


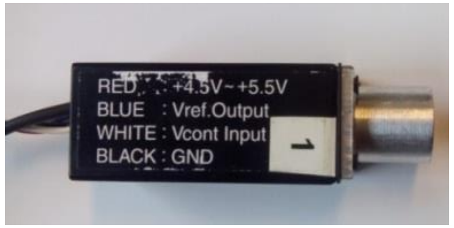


Fiber BLM tests on PHIL

Beam Loss Monitors

- Scintillators coupled to the PMT to monitor the local losses (e.g. @injection)
  - Scintillator: Thalium activated Cesium Iodide CsI(Tl)
  - More sensitive than fibers
  - Positioned at specific locations and to be used during the commissioning and operation.
  - Scintillator is available, PMT and controller for the DAC will be ordered at the same time as for the FBLM.
  - DAQ: RedPitaya card (Tango DS is ready) is under the test => inside crate Diag 5 and 6.
  - The assembly has been tested using the scope with the radioactive sources and with the beam @ PHIL.





CsI(Tl) + PMT

Red Pitaya