# New TOTEM Roman Pot timing detectors

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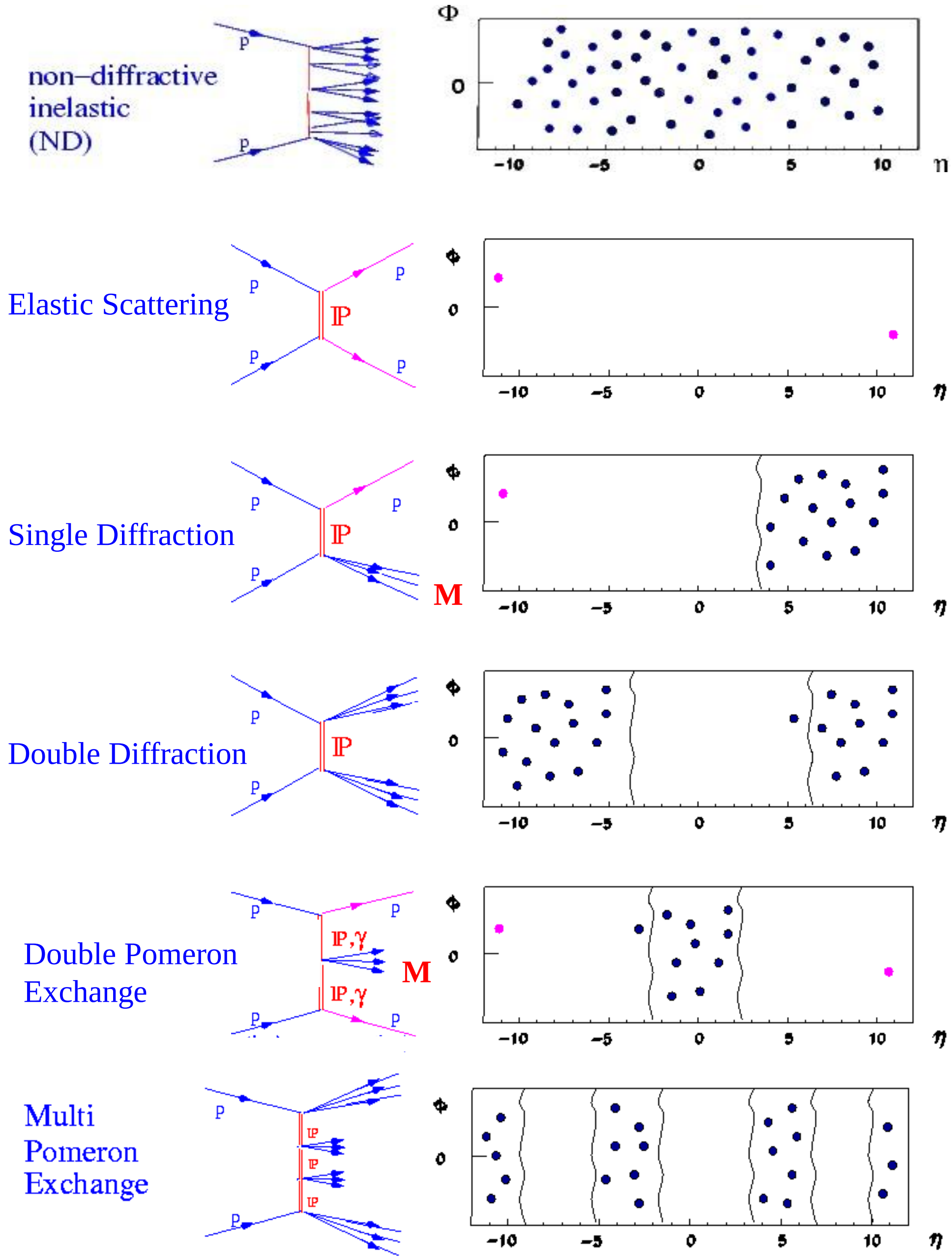
On behalf of the TOTEM collaboration

# Inelastic and Diffractive Processes




~60 mb

~25 mb

~10 mb

~5 mb

~1 mb

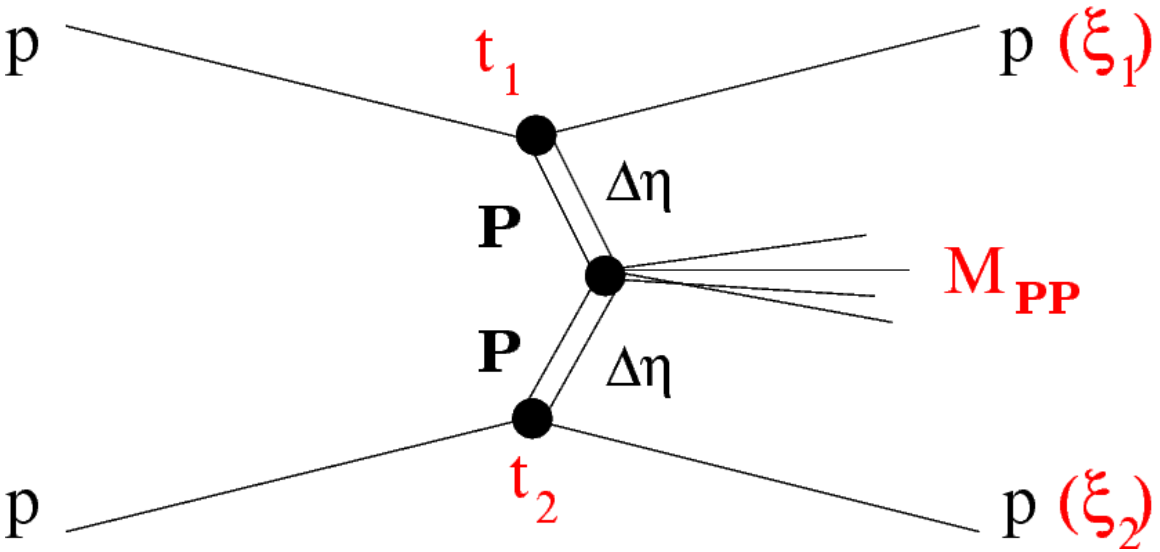
<< 1 mb

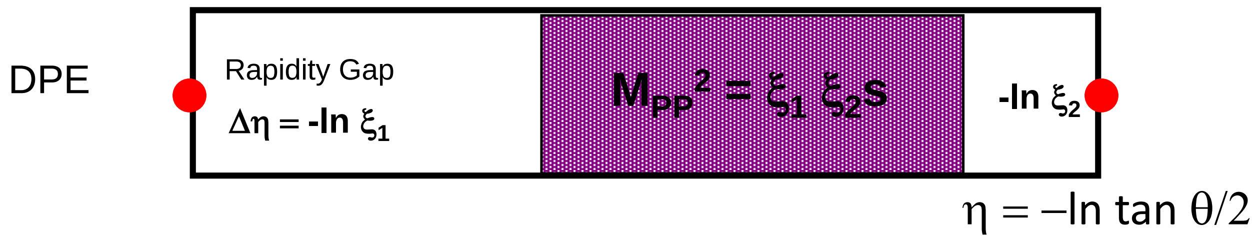
All the drawings show soft interactions.
In case of hard interactions there should be jets,
which fall in the same rapidity intervals.

**Diffractive scattering is a unique laboratory of confinement & QCD:**
**A hard scale + hadrons which remain intact in the scattering process.**

**Measure σ (M,ξ,t)**

# Double Pomeron Exchange

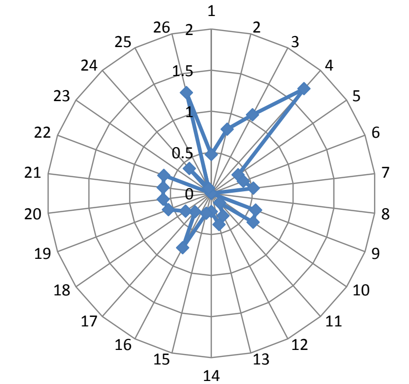



**Use the LHC as a Pomeron-Pomeron (gluon - gluon) collider**

*Central Diffraction  **Central Exclusive Production

# LHC Optics: RP sensitivity

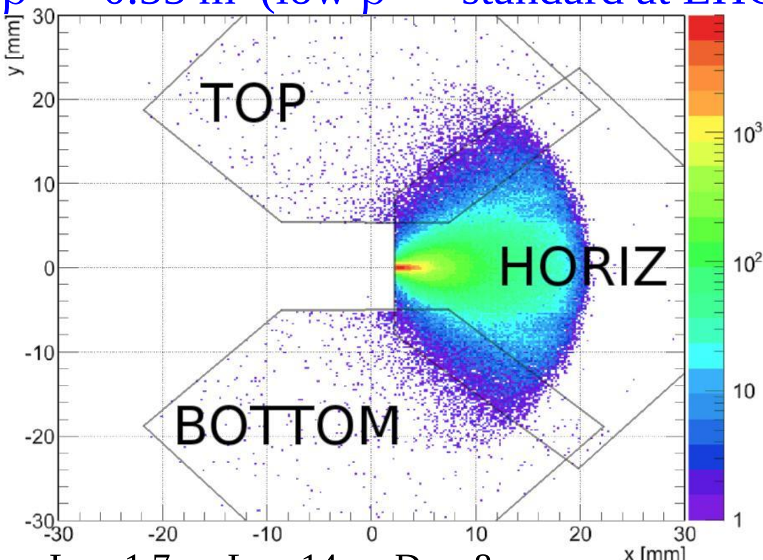


Optics parameters: data full non-linear fit, harmonics, displacements,…

Hit maps of simulated diffractive events for 2 optics configurations

($\beta^*$ = betatron function at the interaction point)

$\beta^* = 0.55$ m (low $\beta^*$ = standard at LHC)

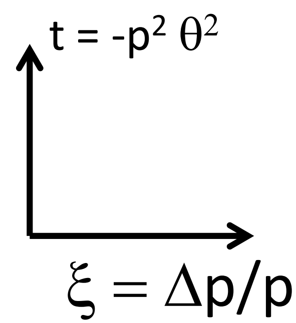



$L_x = 1.7$ m, $L_y = 14$ m, $D_x = 8$ cm

diffractive protons: mainly in **horizontal** RP

elastic protons: in vertical RP near $x \sim 0$

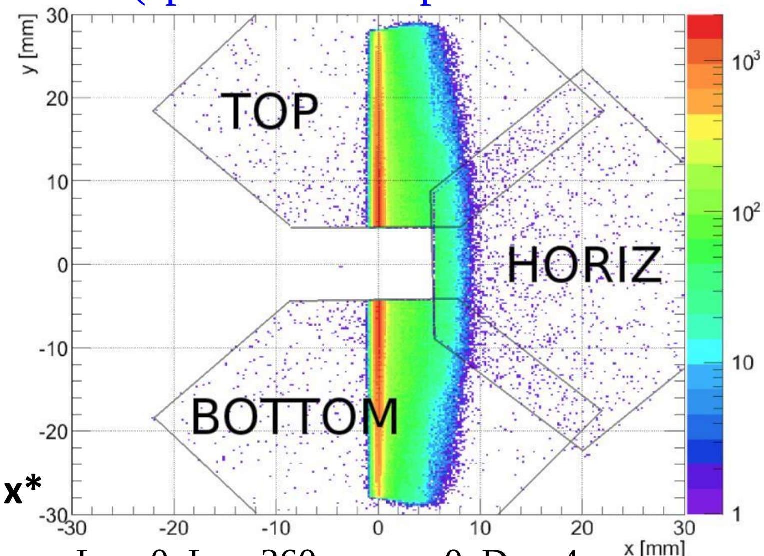
sensitivity only for large scattering angles




$y = L_y \Theta_y + v_y y^*$

$x = L_x \Theta_x + \xi D + v_x x^*$

$\beta^* = 90$ m (special development for RP runs)




$L_x = 0$, $L_y = 260$ m, $v_y = 0$, $D_x = 4$ cm

diffractive protons: mainly in **vertical** RP

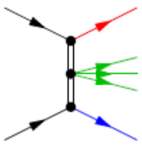
elastic protons: in narrow band at $x \cong 0$,

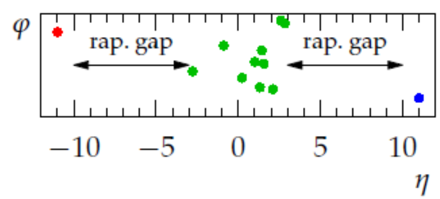
sensitivity for small vertical scattering angles

| | Beam width @ vertex | Angular beam divergence | Min. reachable $\lvert t \rvert$ |
|---|---|---|---|
| | $\sigma^*_{x,y} = \sqrt{\frac{\varepsilon_n \beta^*}{\gamma}}$ | $\sigma(\Theta^*_{x,y}) = \sqrt{\frac{\varepsilon_n}{\beta^* \gamma}}$ | $\lvert t_{min} \rvert = \frac{n_\sigma^2 p \varepsilon_n m_p}{\beta^*}$ |
| $\beta^* \sim 0.5$–$3.5$ m | small | large | $\sim 0.3$–$1$ GeV$^2$ |
| $\beta^* = 90$ m | large | small | $\sim 10^{-2}$ GeV$^2$ |

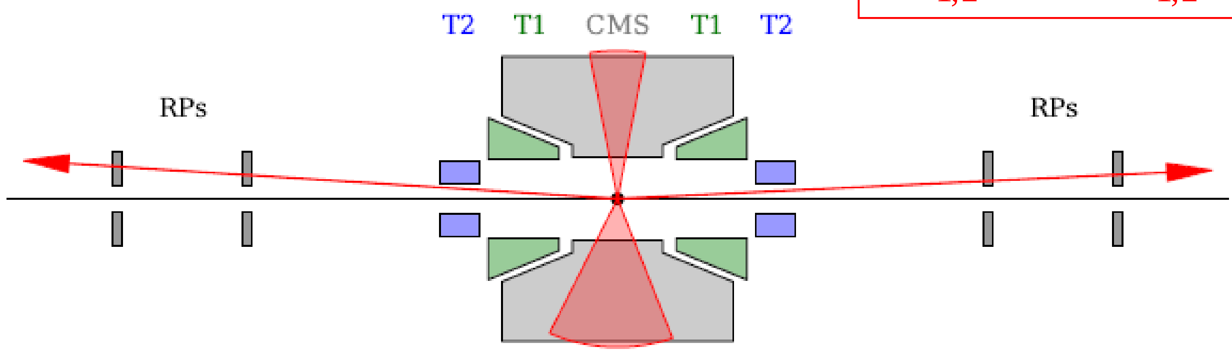
# Diffractive Physics Program LHC Run II

- TOTEM: standard measurement of elastic scattering
  (from the largest to the smallest *t*)
  and of the total and inelastic cross section at the new LHC energy
- TOTEM+CMS: physics search on low mass spectroscopy (1-3GeV)
  - gluonic states and glueball searches
  - diffractive $\chi_c$ production
- TOTEM+CMS: central-diffractive jet production
- TOTEM+CMS: missing/escaping mass



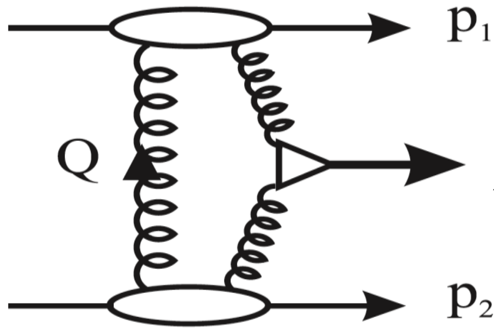



$$\Delta\eta_{1,2} = -\ln \xi_{1,2}, \quad M^2 = \xi_1 \xi_2 s$$




**Preliminary investigation of some physics channels in progress with the analysis of data from joint CMS-TOTEM high $\beta^*$ run (90m) , 8 TeV , July 2012**

# Central Exclusive Production (CEP)




$p_1$ ($\xi_1$)   $M^2 = \xi_1\ \xi_2\ s$

X at rapidity $y_X$   gg collider

$p_2$ ($\xi_2$)   $y_X = \frac{1}{2}\ln\frac{\xi_1}{\xi_2}$

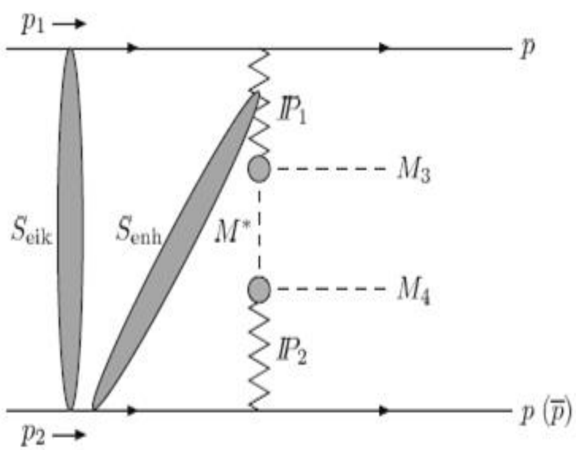
also $\gamma\gamma$ fusion & photoproduction

- exchange of colour singlets with vacuum quantum numbers
  $\Rightarrow$ selection rules for system X: $J^{PC} = 0^{++}, 2^{++}$, … resonances, jets,?….
- <u>With double-arm proton detection:</u>
  $\beta^*$ = 90m runs: all M(pp), $\mu \sim 0.05 - 0.5 \Rightarrow$ O(0.1-10 $pb^{-1}$/day)
  low $\beta^*$ runs: M(pp) > ~ 350 GeV, $\mu$ ~ 30 - 50 $\Rightarrow$ O(1 $fb^{-1}$/day) (CTPPS)
- Comparison/prediction from forward to central system:
- M(pp) =? M(central), $p_{T,z}$(pp) => $p_{T,z}$(central), vertex(pp) => vertex(central)
- Prediction of central particle flow topology from proton $\xi$'s (rapidity gaps): $\Delta\eta_{1,2} = -\ln\xi_{1,2}$
- CMS & TOTEM common runs: access to O(pb) production cross-sections

# CEP low-Mass States & Glueballs

*LHC: a unique lab to study CEP low M states*

1 resonance / meson pair
(ππ, KK, ρρ, ηη)




- small $p_T$'s of final state mesons
  ⇒ **CMS tracking** ΔM ~ 10 MeV (‹‹ ISR, RHIC, Tevatron)
- π/K/p separation using CMS tracker dE/dx
- proton tagging in $\beta^*$ = 90m runs ⇒ $p_T$ ~ 40 MeV
- **RP proton tagging** ⇒ no need to invoke rapidity gaps
- large η coverage & protons ⇒ exclusivity ensured with excellent S/B
- spin determination from decay angles & proton azimuthal correlations

Small ξ **~$10^{-3}$ $10^{-4}$ at LHC** from RP vertices ⇒ pure gluon pair ⇒ masses ~ 1-3 GeV

Pomeron ≈ colourless gluon pair/ladder
⇒ Pomeron fusion likely to produce glueballs

- Past luminosity: ~ 0.003 $pb^{-1}$ ⇒ need × 300 (~ 1 $pb^{-1}$) to produce resonances
- Study of glueballs & $\chi_c$ in hadronic modes require × 3000 (~ 10 $pb^{-1}$)
- Increase in integrated luminosity in high β runs may be obtained :
  - > Increasing bunch number (requires crossing angle for high β runs)
  - > Increasing running time

Pileup μ~1

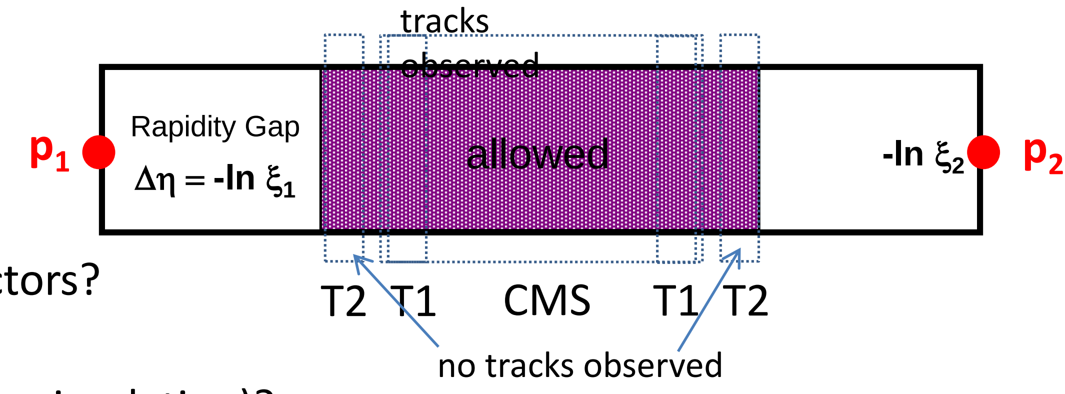
# Central Diffraction Missing Mass Searches

- Check <u>escaping-mass candidates</u>
- Pile-up protection
- $p_{CMS}$(Particle Flow) $\neq$ $p_{TOTEM}$(pp)
  $M_{CMS}$(Particle Flow + missing momentum) $\leq$ $M_{TOTEM}$(pp)
  $\rightarrow$ <u>existence of tracks undetected by CMS</u>

- No tracks observed in forward detectors 'allowed' by rapidity gaps
- More forward regions excluded by rapidity gaps $\rightarrow$ 'allowed' = 'required' ?

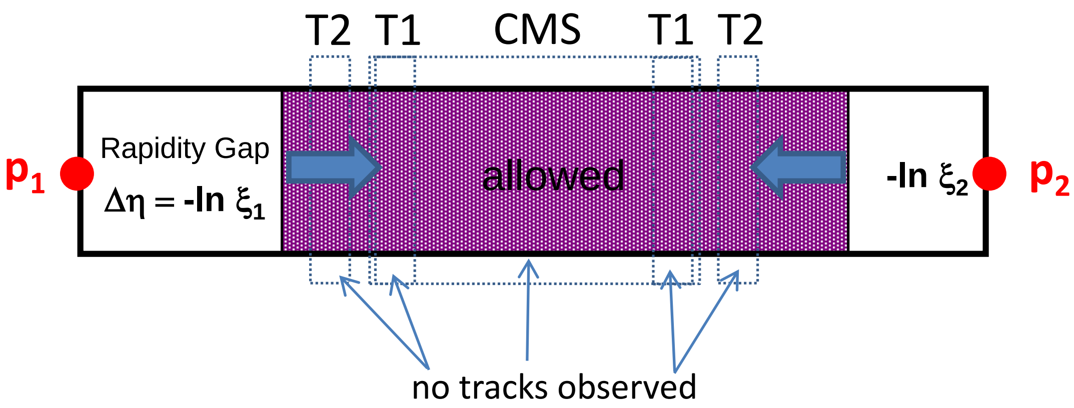
- energetic gammas in T2, $N^* \rightarrow p$
- detectors' 'inefficiency'?
- acceptance gaps between detectors?
- high energy neutrinos?
- neutral particle flow in T2 (under simulation)?
- real escaping energy?

These depend on amount of missing energy



# Exclusive Missing Mass Searches

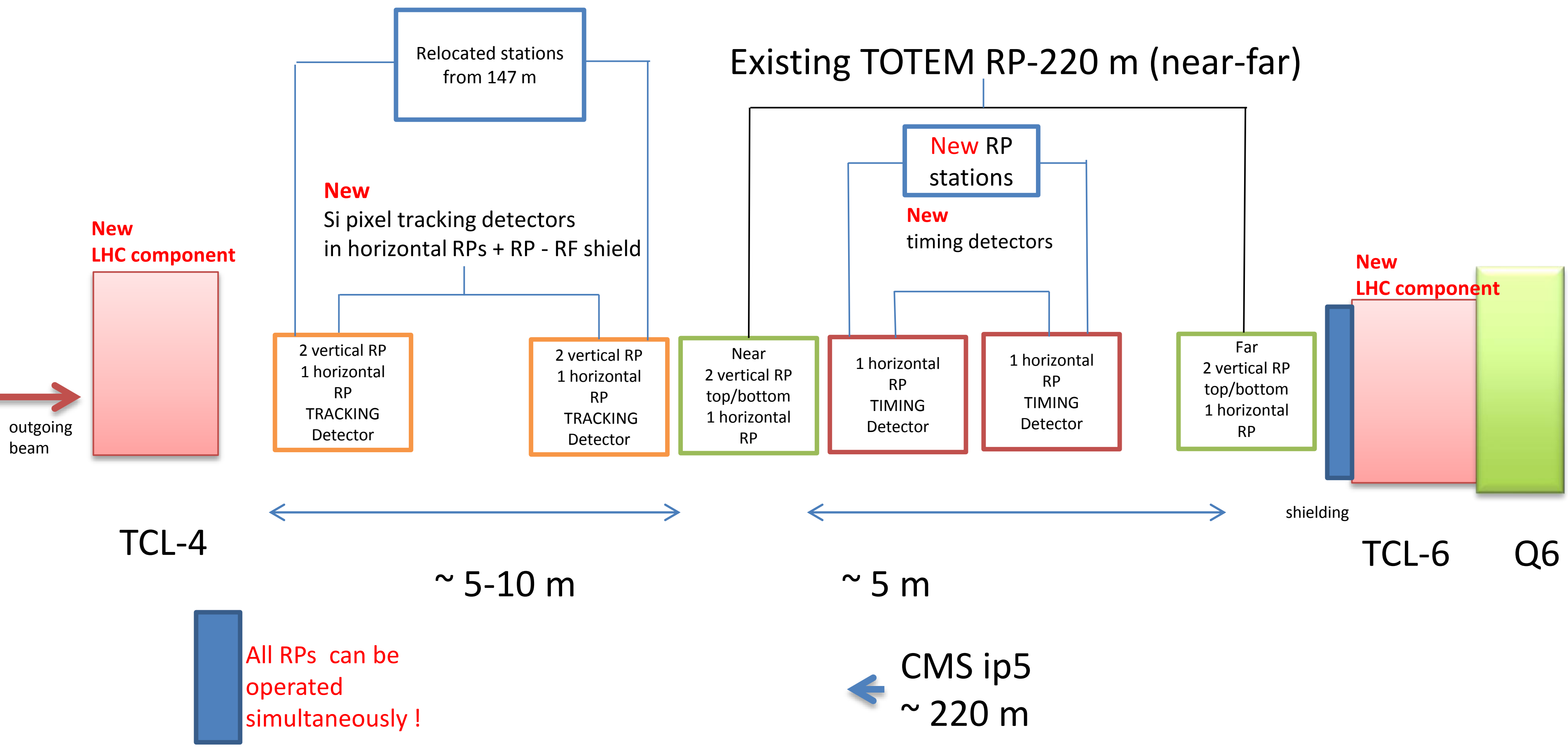
DPE pp candidates in Roman Pots.   CMS, T1, T2 empty.



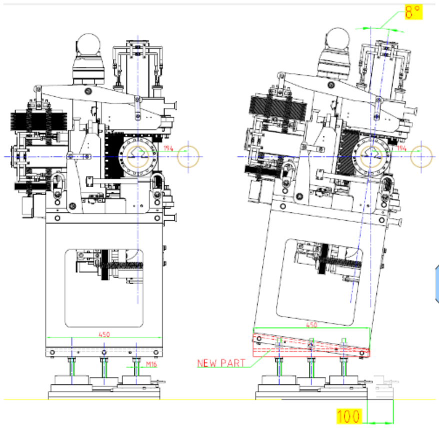

If ξ ~1% logic applies to CMS tracker allowed & everything else forbidden (then it could work also if pile-up).

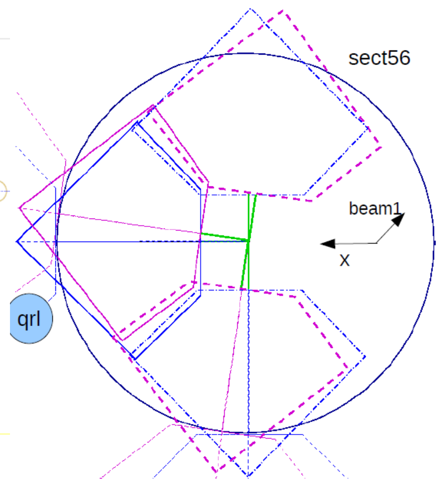
# RPs Consolidation & Upgrade – LS1

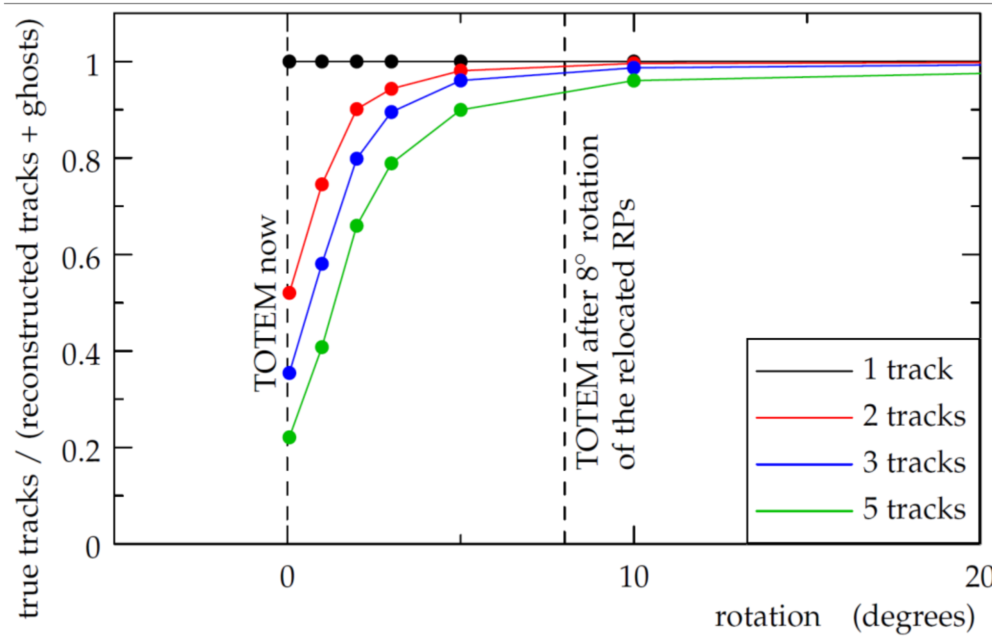
overview (schematic)



# RPs Performance

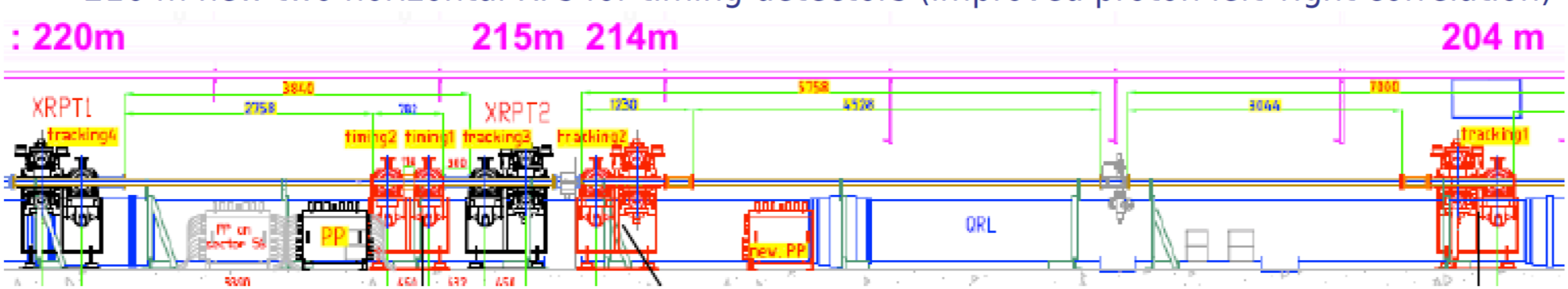


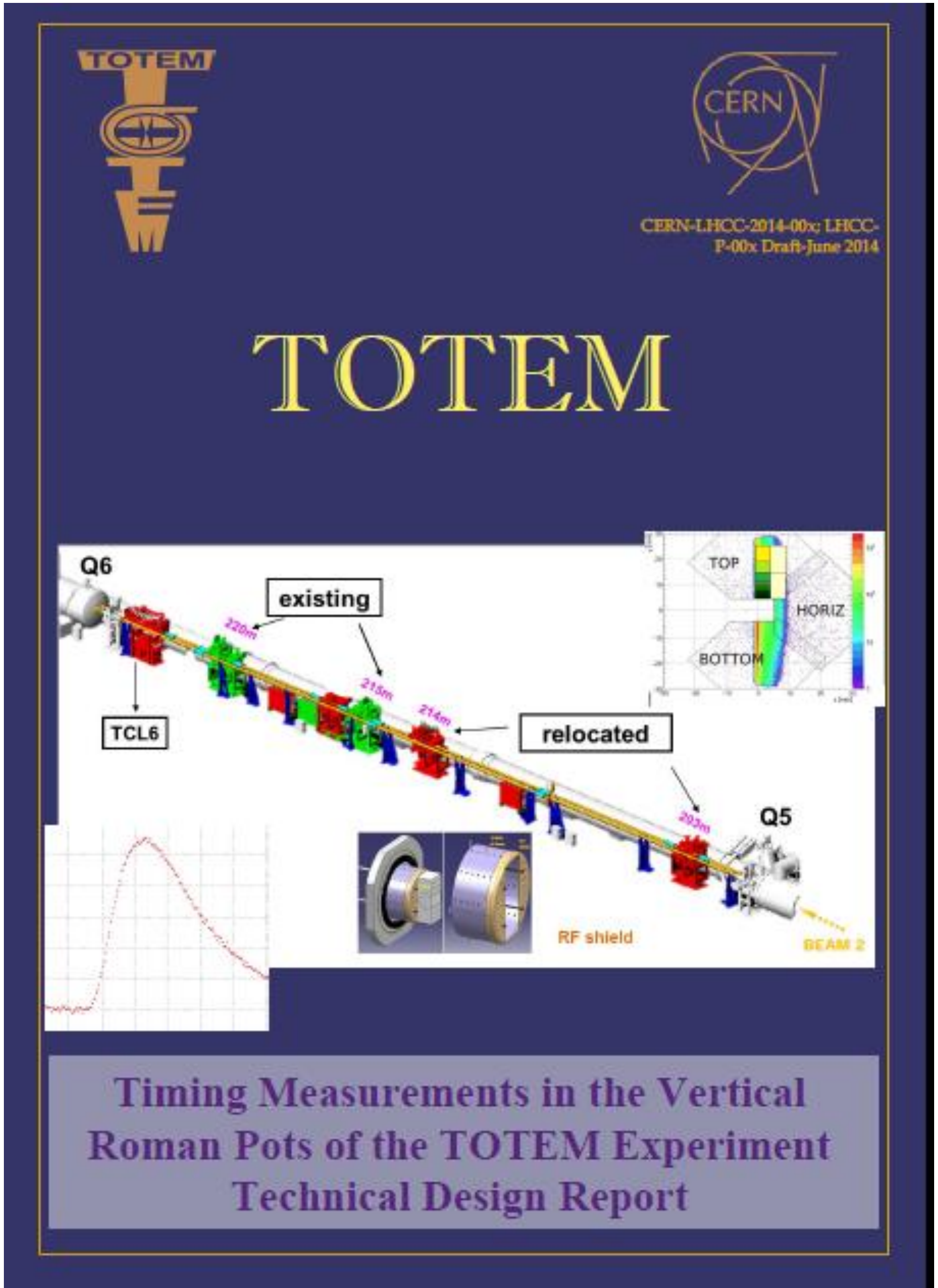




*new layout*:

- 147 m station relocated to 204 and 214 m (increased lever arm ⇒ better angular resolution)
- RPs at 214 m rotated by 8° ⇒ multi-track capability
- ≈ 216 m new two horizontal RPs for timing detectors (improved proton left–right correlation)



# TDR – Timing Vertical RP Project




- TDR approved by LHCC on November 2014

- Test beam campaigns during winter spring (Desy, PS, SPS) all requirements for physics met

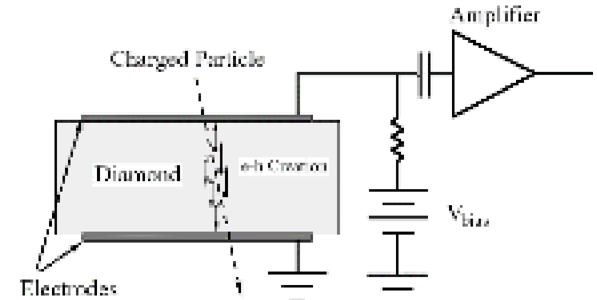
- Construction in progress.

# Vertical RPs Timing Detectors

- Solid state detectors only (limited space in old pots boxes)
  - Diamond detectors
    - Rad hard
    - Easy pixelization
    - Limited channel number (12 per plane)
    - Discrete components amplifiers
    - Low signal to noise
  - Silicon detectors
    - Large signal to noise
    - Large pixels have charge collection time skew
    - Necessity to have large number of pixels
    - Need for special ASICs development.

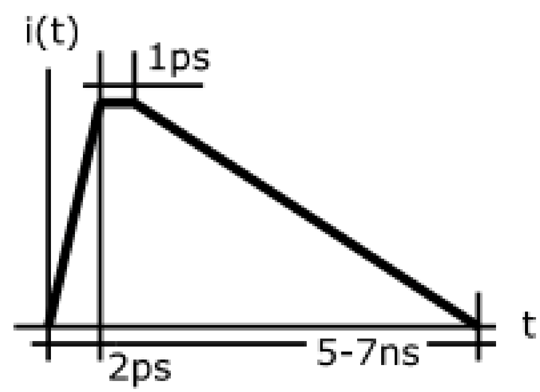
# Diamond detector - signal

- Charged particle crossing the detector release electron/hole pairs, Landau distributed with <Charge> ~18Ke$^-$~3fC




- A bias, 800V, is applied on top and bottom of the electrodes and allows the primary charge to drift toward the electrodes (higher electron mobility wrt silicon both for holes and electrons).

- A current pulse is given by the Shockley–Ramo theorem:
  tr = 2 ps (rising edge)
  ts = 1 ps (sustain)
  tf = 5 .. 7 ns (falling edge)
  Imax = 0.5 µA

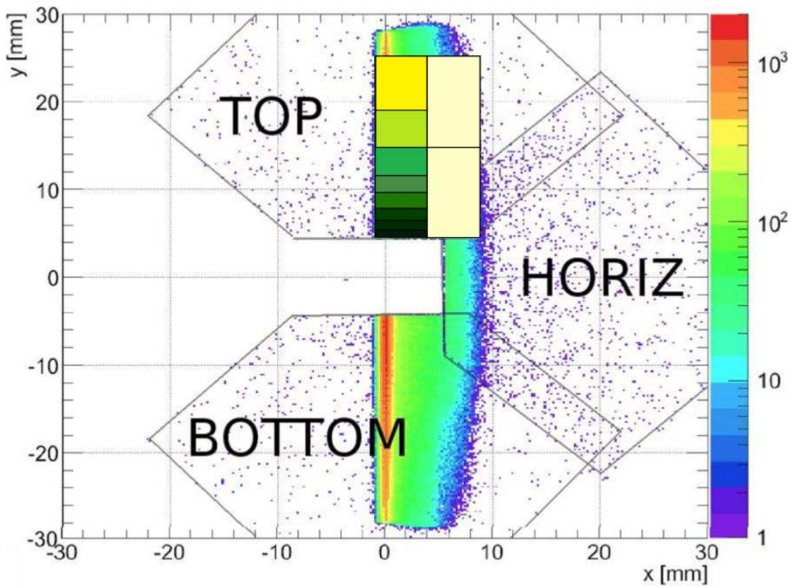


# Vertical RPs Timing Detectors

Optimization driven by physics and technical choices

- Minimize number of channels without compromising the physics program
  - Map plane with different size pads with same occupancy
  - Minimum number optimized with simulation

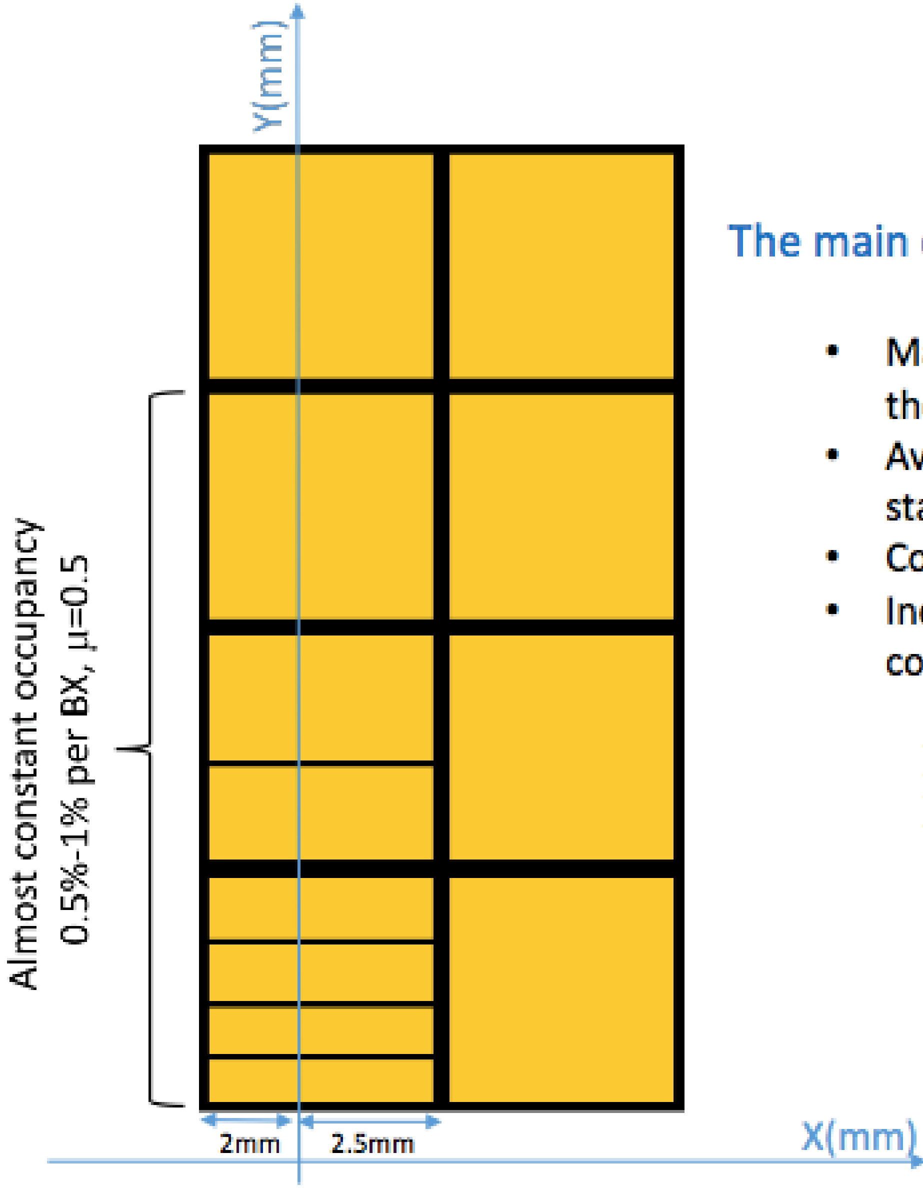
- Detector
  - Dimensions:  10mm X 20mm
  - 10 pixels with dimensions adapted to track density
  - A stack of 4 Planes improves the single plane timing resolution (1/2)
  - Available on the market is 4.5x4.5 mm 500 μm thick
  - Diamond




- Timing Specifications
  - Measure time of arrival of proton with a resolution better than 50ps (100ps/plane)

# Detector Layout

Most probable installation of timing detectors: 220 N



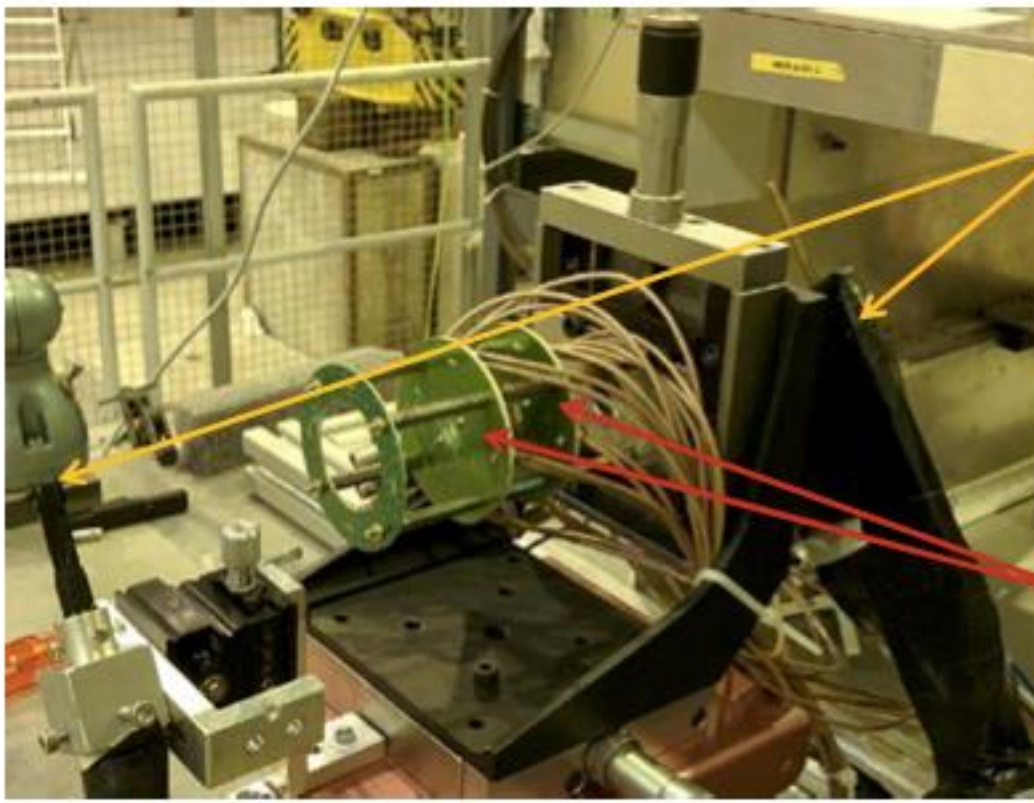

The main constraints driving the layout optimization are:

- Max number of channels that can be equipped inside the hybrid board (12).
- Available diamond sizes in the market (Element 6 standard diamonds are 4.5mmx4.5mmx0.5mm).
- Cost (1.9Keuro for each E-grade scCVD pixel).
- Inefficiency loss due to double hit (negligible in this configuration) and metalization dead regions.

  - ➢ Better to have small pixels close to (X=0,Y=0)
  - ➢ This will assure better time resolution for an higher number of track

We started last summer with commercial Cividec detectors and amplifiers, but th
resolution was ~300ps (Oscilloscope)
We took advantage from Hades@GSI experience on diamond detectors.

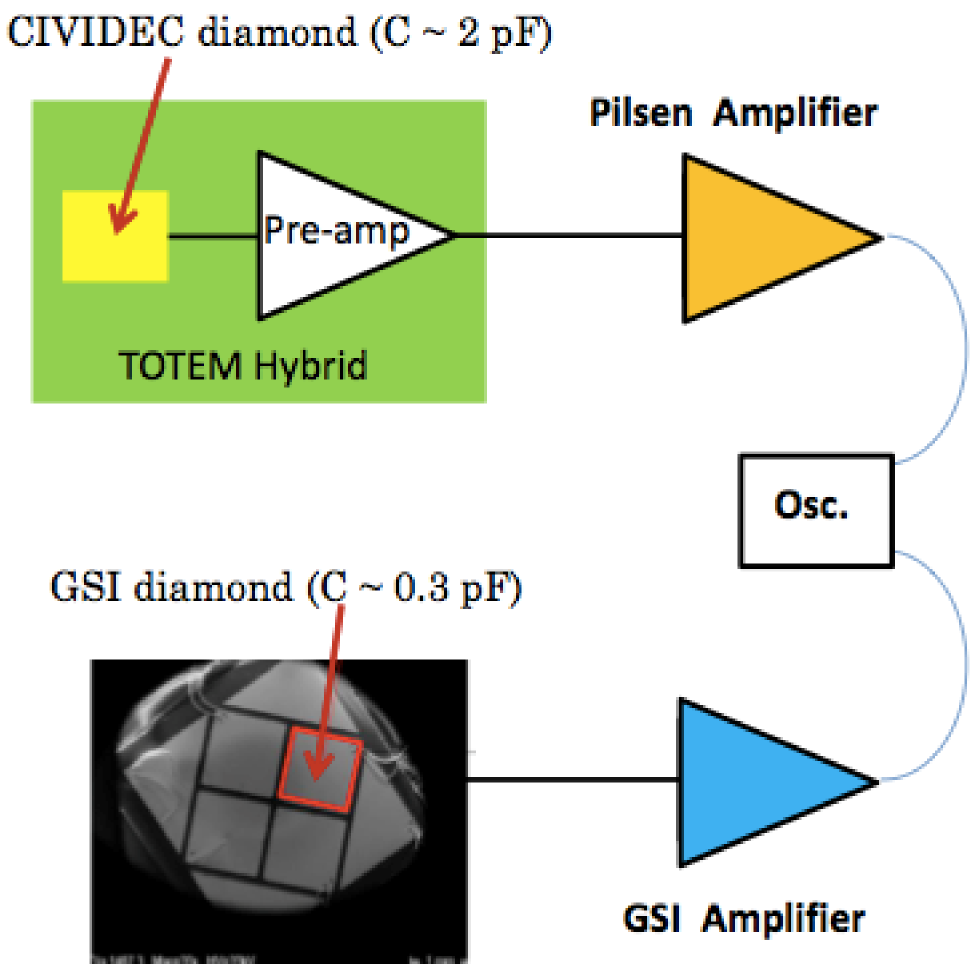
GSI detector has been tested and timing resolution well below 100 ps was proved.



Front and back scintillator + anticoincidence

GSI diamond detector (2 plane, 8 pixel/plane)

# First test with custom hybrids




We developed a simple hybrid with a preamplifier stage and external amplification boxes developed in Pilsen (West Bohemia University)

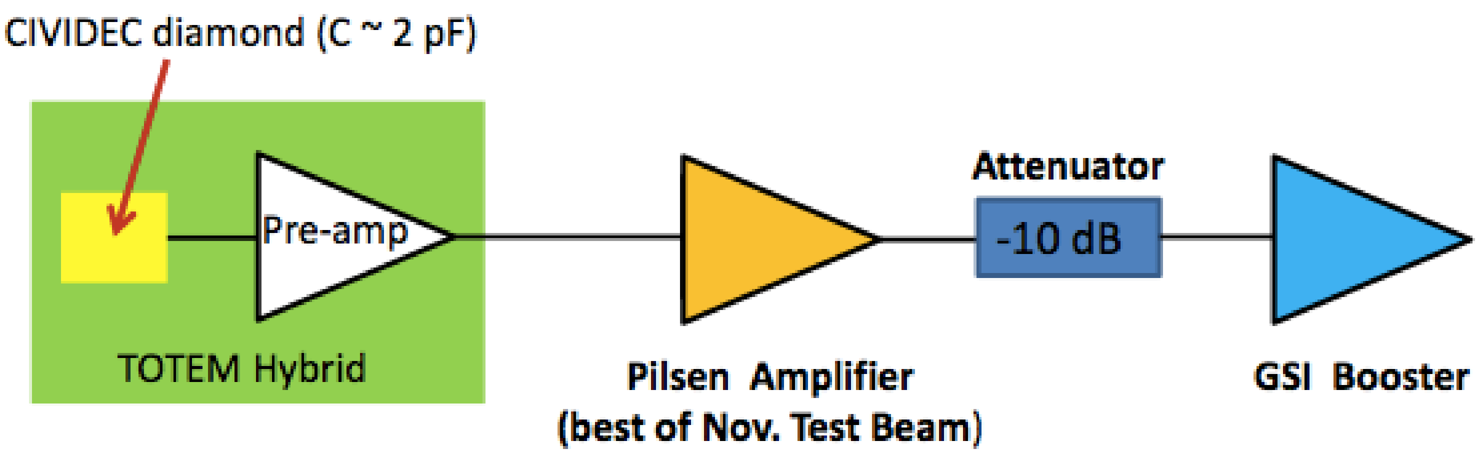
The detector is 5x5mm 500µm thick single pixel

We got 150ps resolution

Thanks to Hades@GSI for the test telescope as reference

The test beam work focused on the amplification chain and finally we got the resolution that was required by the project <100ps (signal sampled by a 10Gs Agilent Oscilloscope)

Many GSI/Pilsen mixed configuration tested during December test-beam. One of them proved effective.

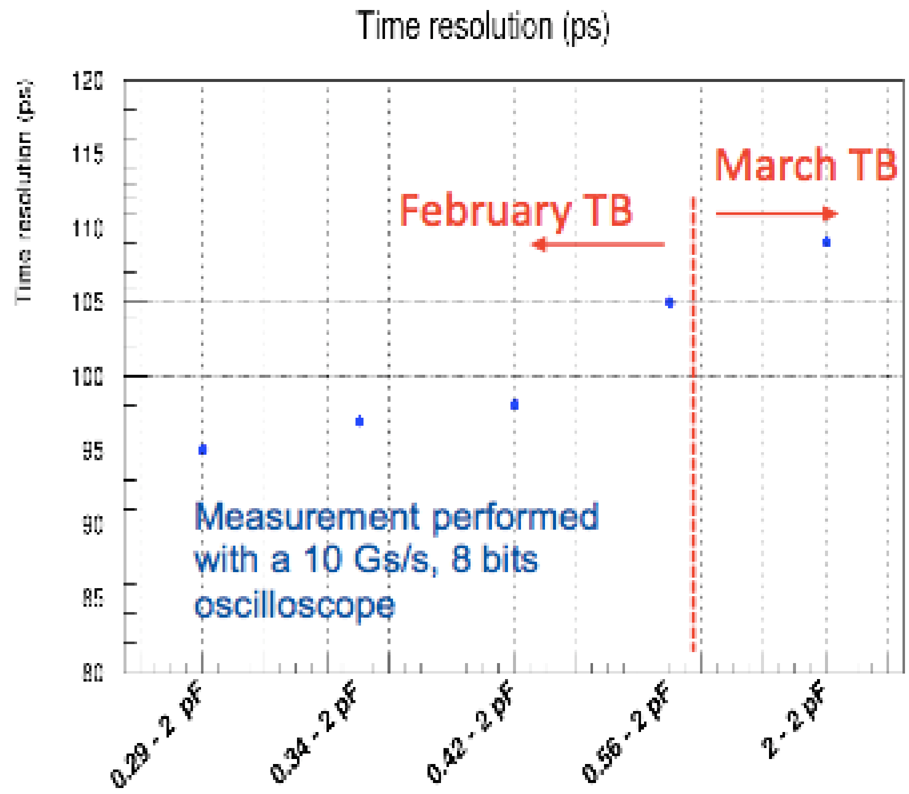


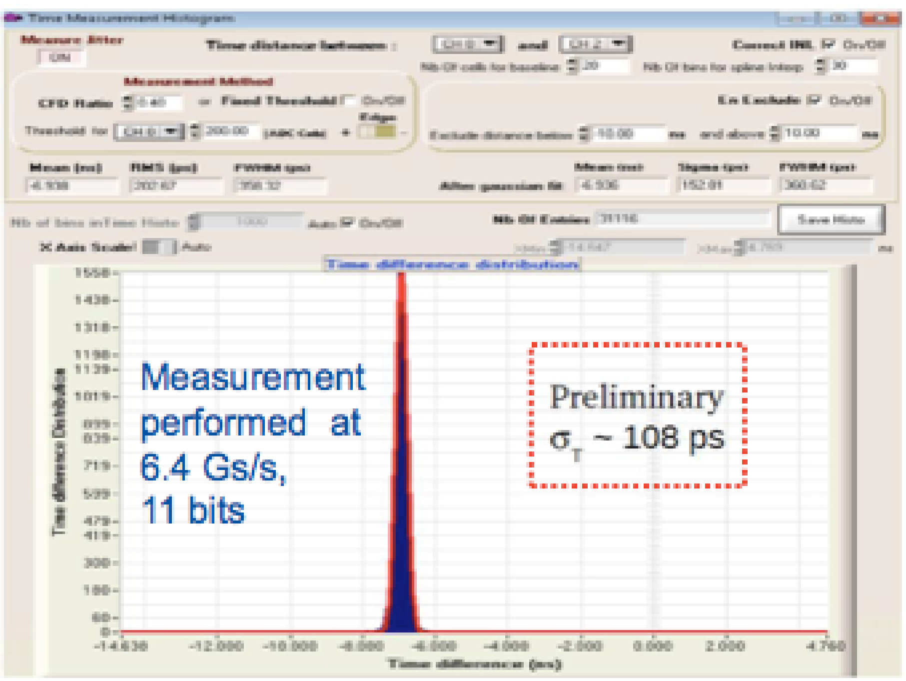

-10dB attenuator added to prevent signal saturation in GSI Booster

GSI perform not only amplification but also signal shaping

# Timing measurements

- The time resolution is found to slightly increase with the capacitance.
- The rise time of the diamonds are about 2-2.2 ns.
- The S/N is found to be > 25 (strips) and 18 (plane sensor)

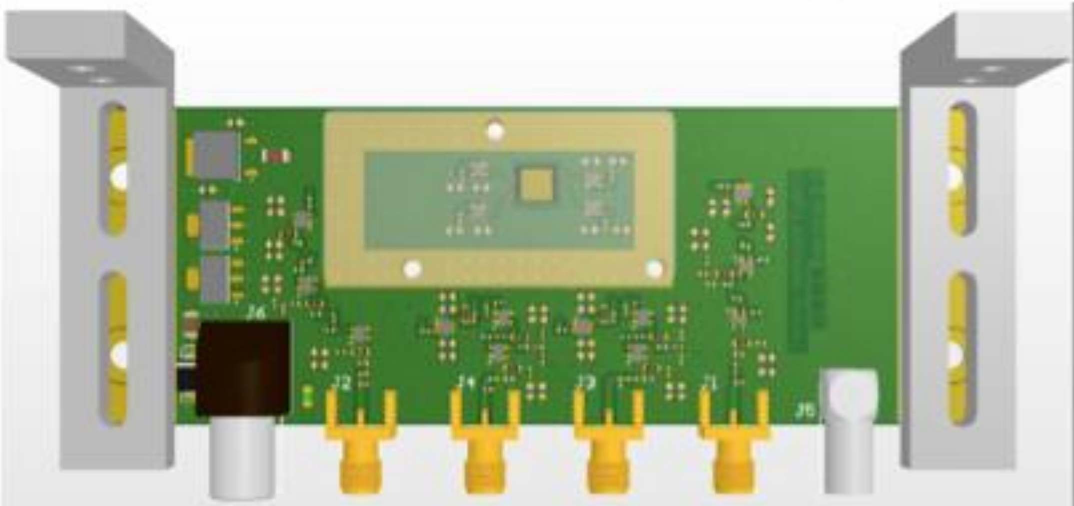



2pF vs 2 pF measurement obtained with the SAMPIC (waveform digitizer)

<u>Important: time resolution has not been degraded by the waveform digitizer.</u>

# Second Hybrid prototype with the final full ampification chain

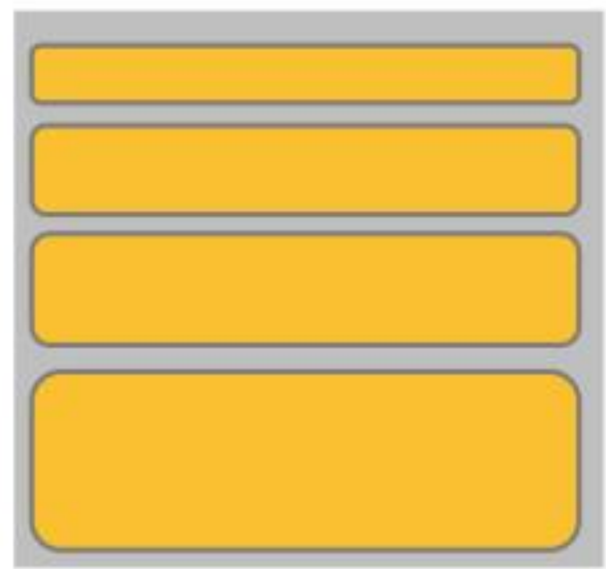


Amplification chain validated in December fully integrated in the new hybrid board.

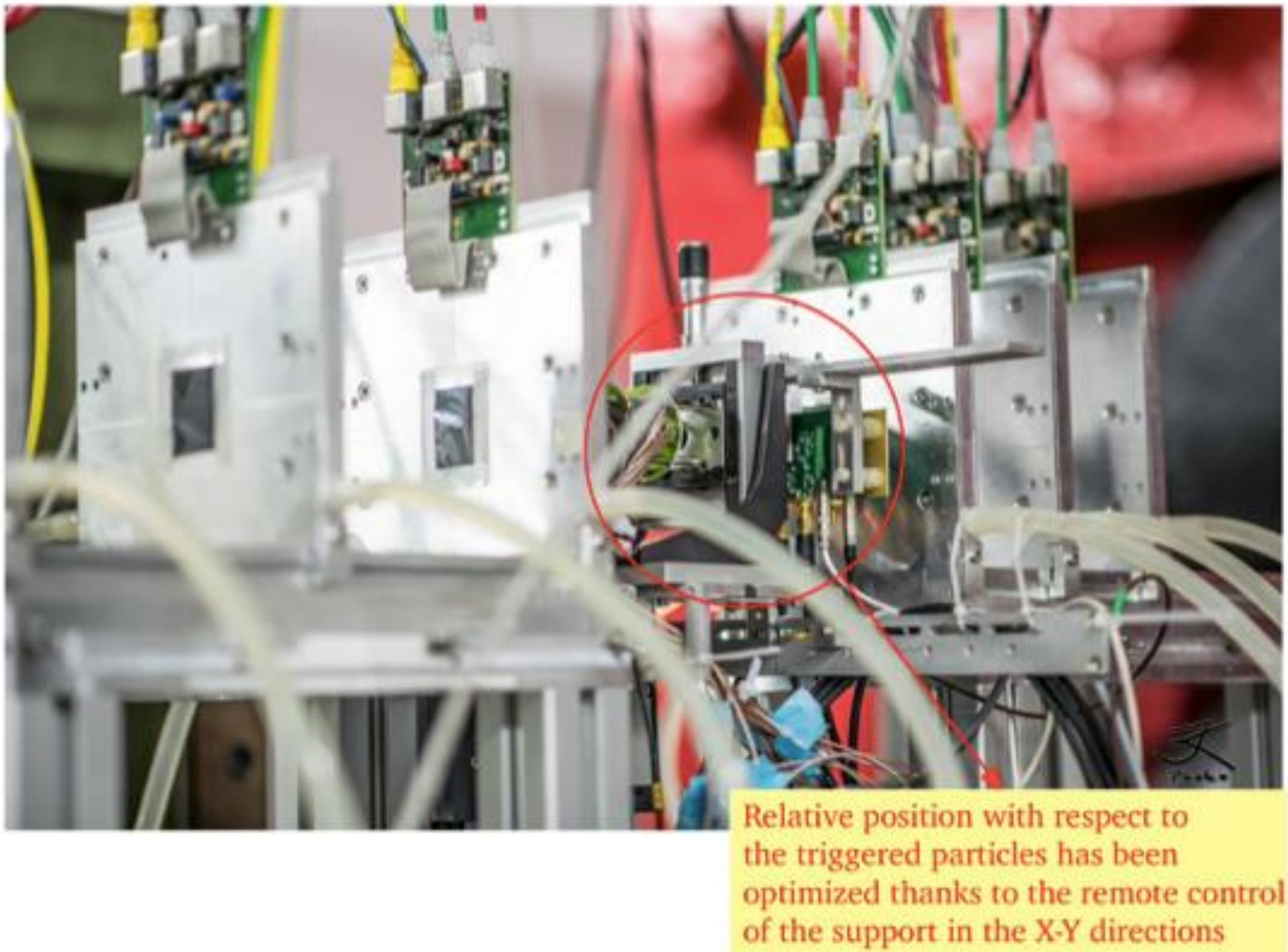
4 readout channels available

Diamonds available (all mounted in new boards):

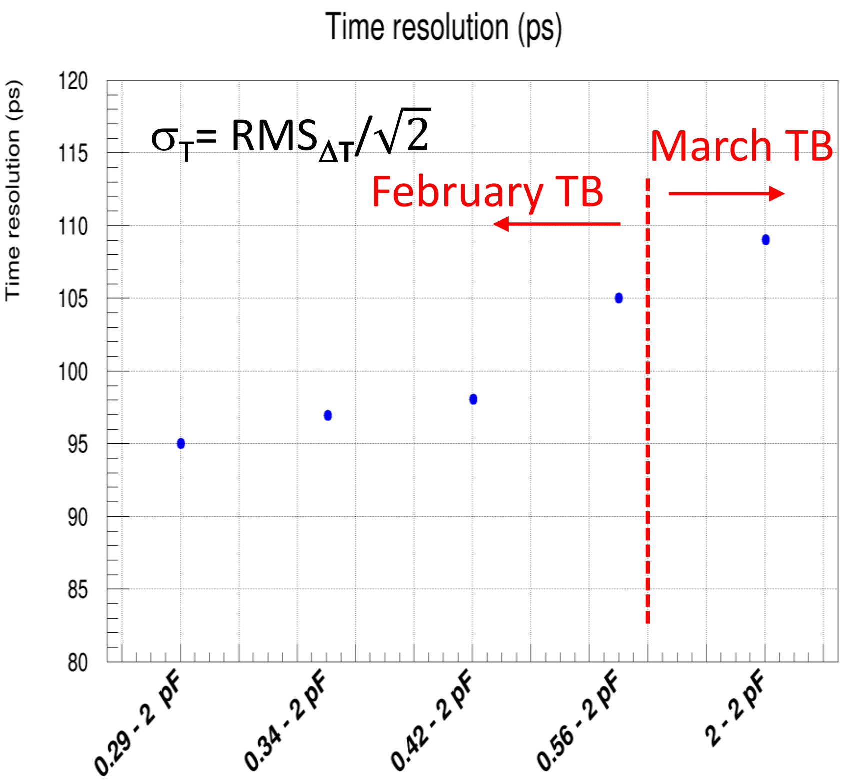
- CIVIDEC diamond (full pad)
- Brand new diamond from E6:
  - Full pad metalization made @GSI and Princeton
  - Strip metalization @ GSI →

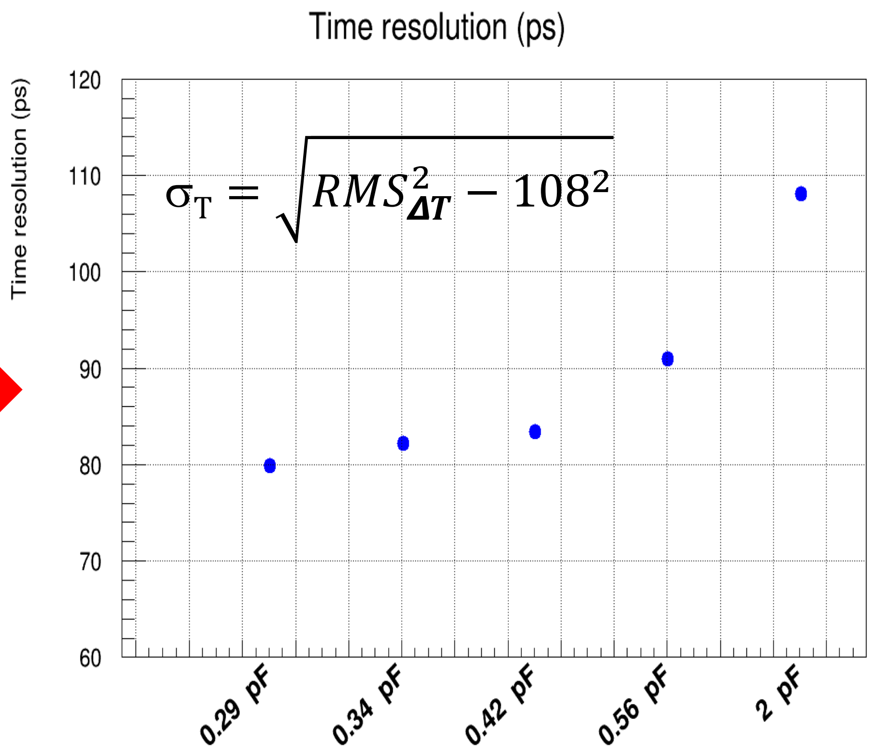


DESY Test beam setup with the new hybrids.
2 hybrids with 4 nominal pixel detector and a 5x5mm single pixel detector were tested with a silicon tracker in front for efficiency measurements



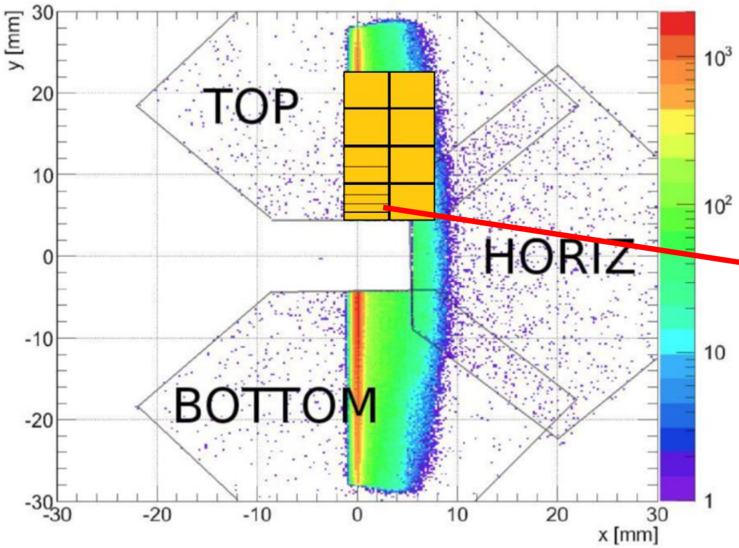
# Summary on the Timing measurements at the Test beams

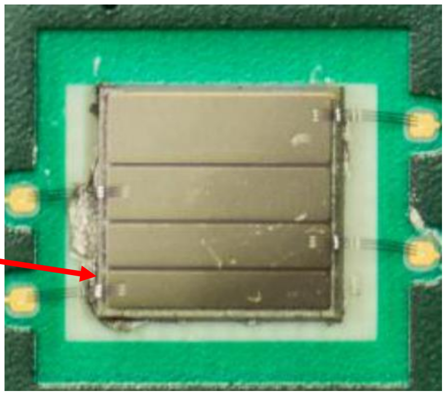


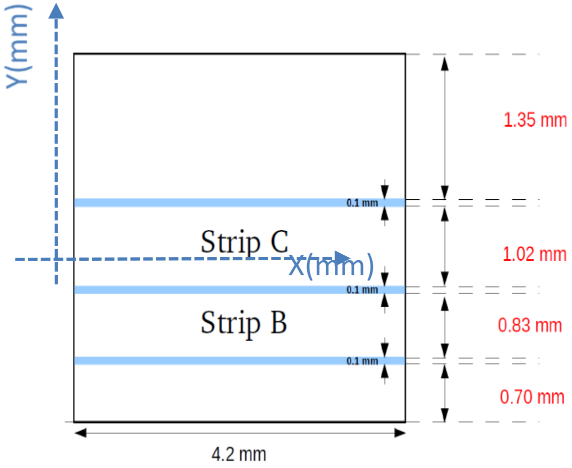



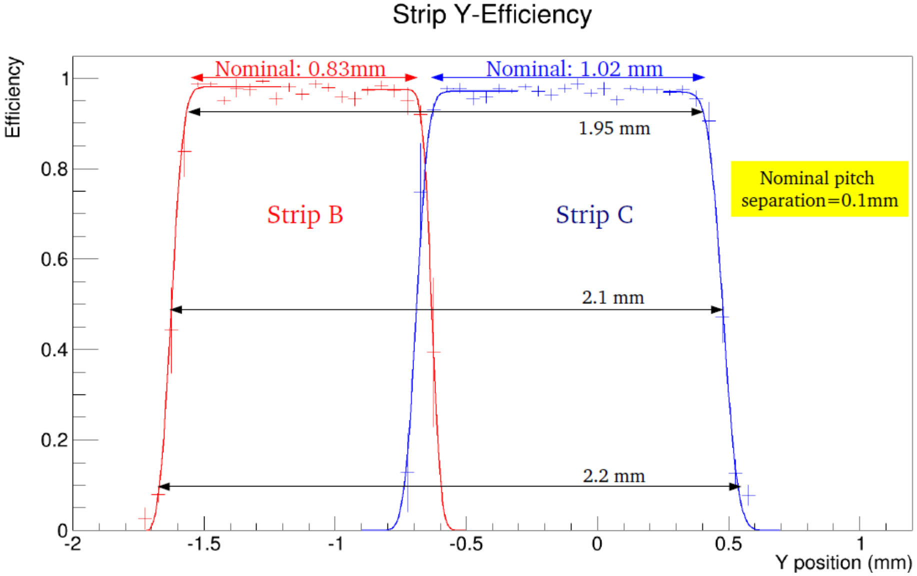
# Efficiency measurement

- Measurement of the inefficiency induced by the 100 $\mu$m unmetalized region between the strips.



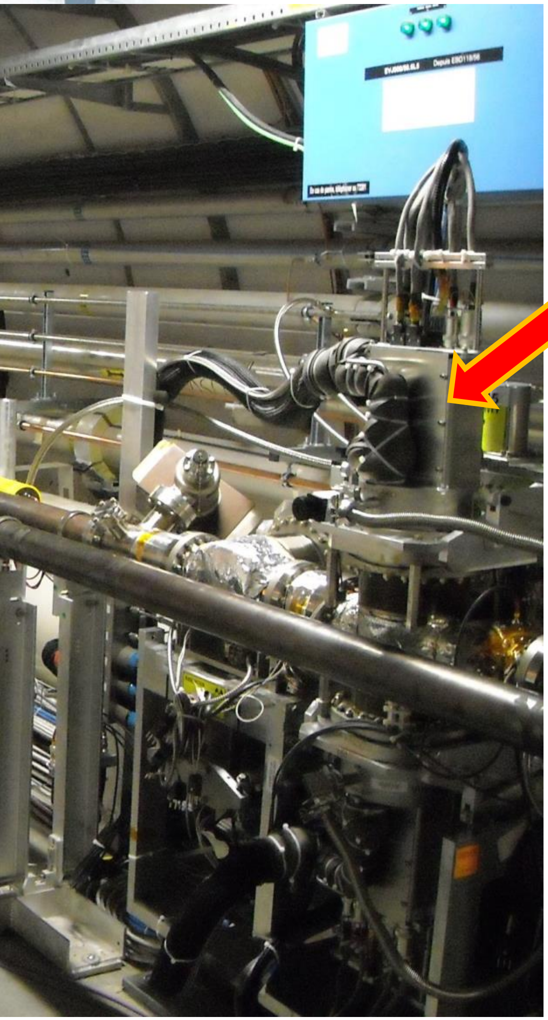


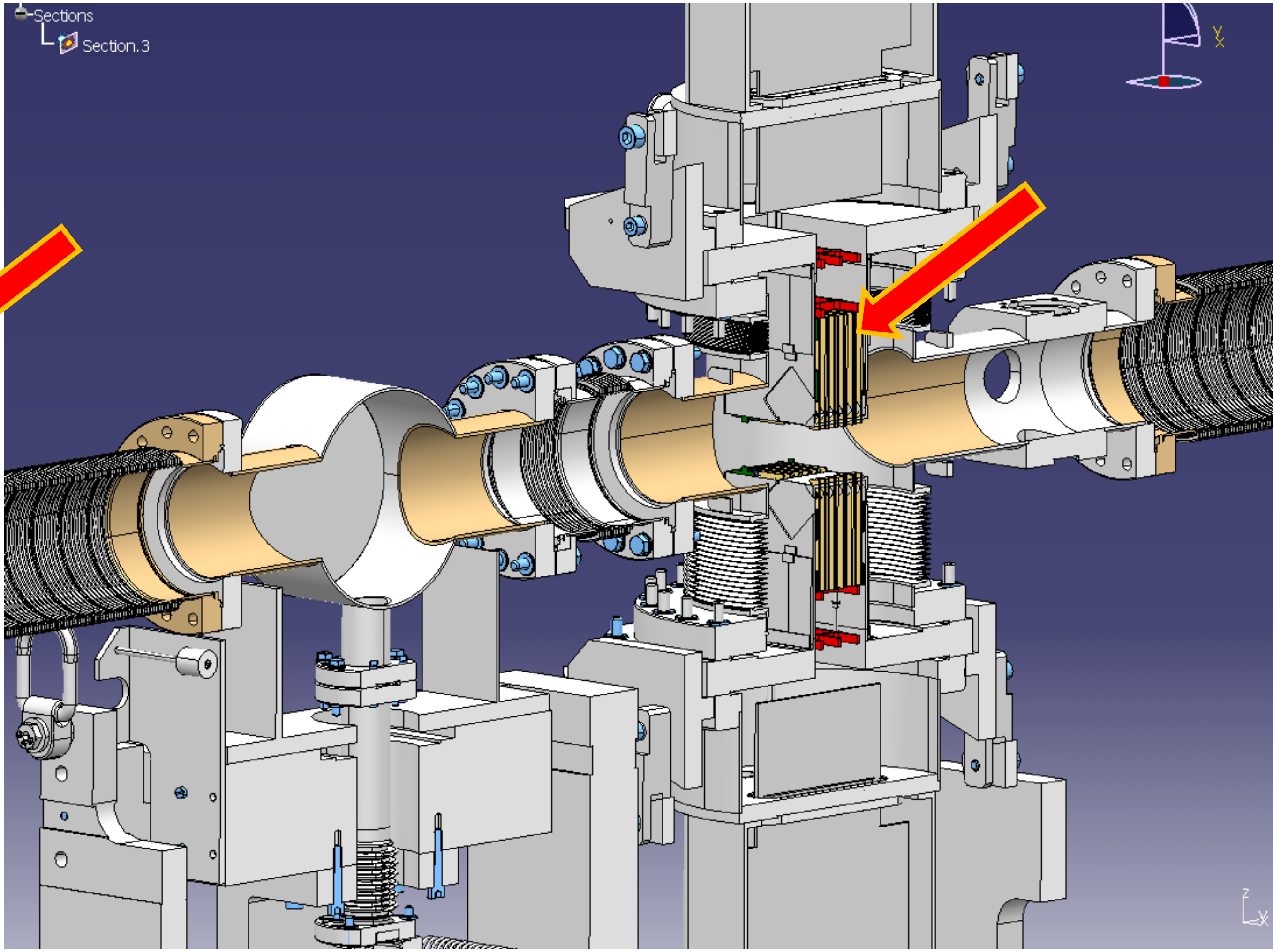




- In the geometrical area of the metallization an efficiency larger than 98% is obtained (residual inefficiency can be explained in terms of PU and Multiple scattering). The S/N is: 20 < S/N < 25.

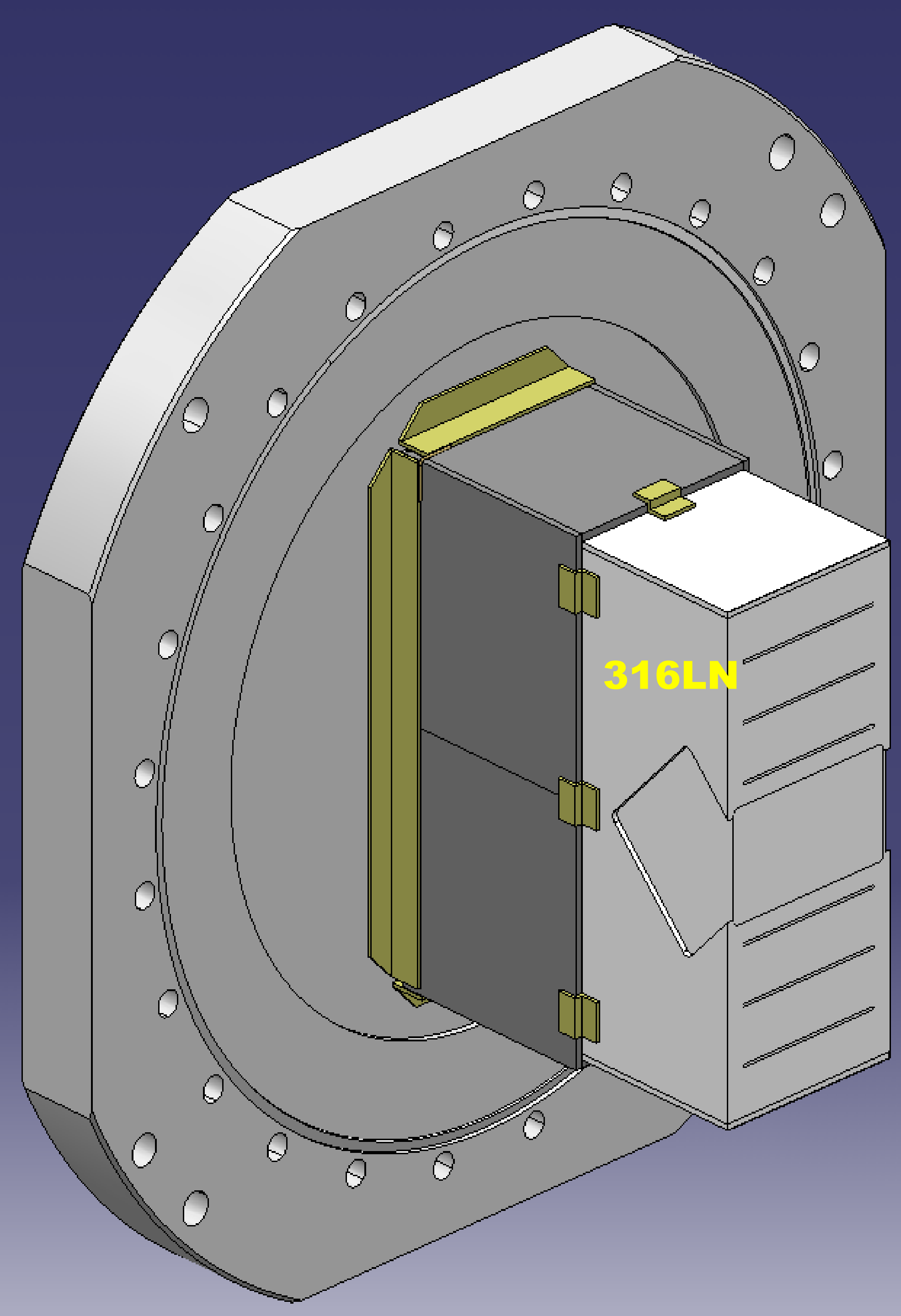
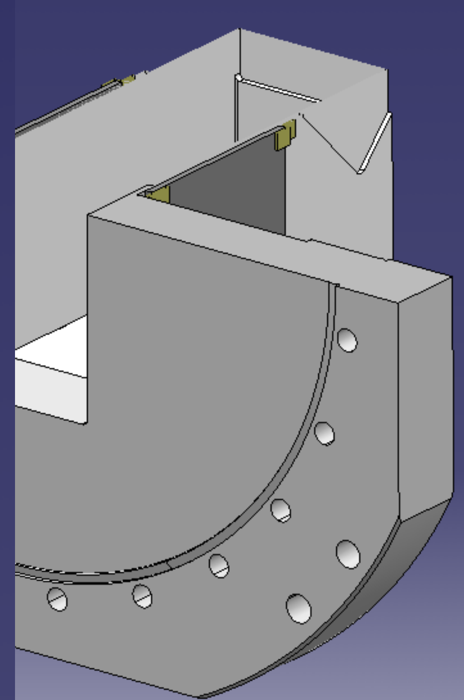
- An efficiency larger than 80% was found even in the unmetallized area (but here S/N and $\sigma_T$ degradation has been observed)

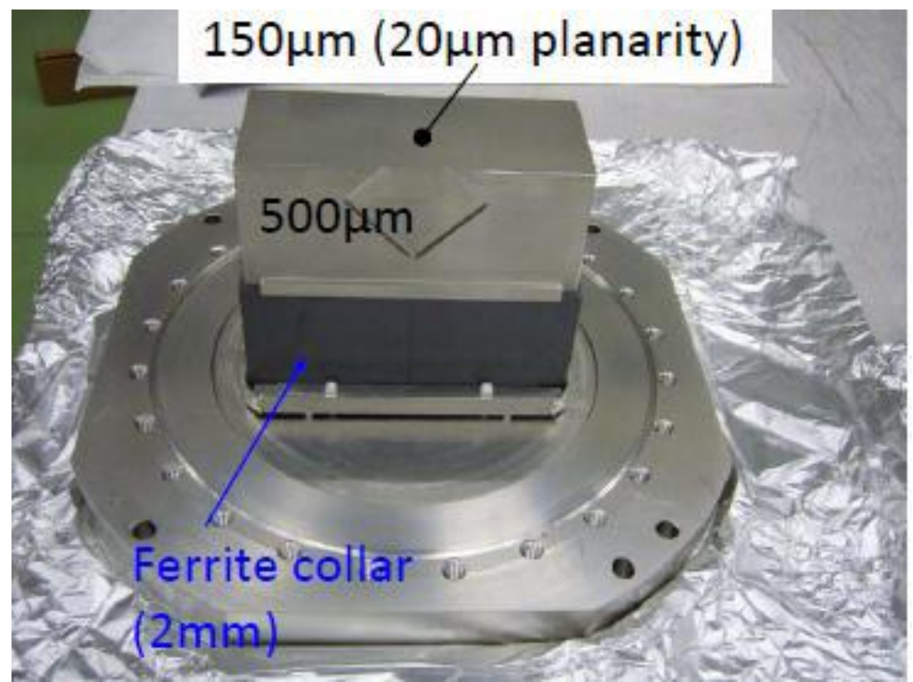
Replace one of present vertical detectors (Si-microstrip) with the diamond (timing) detector.



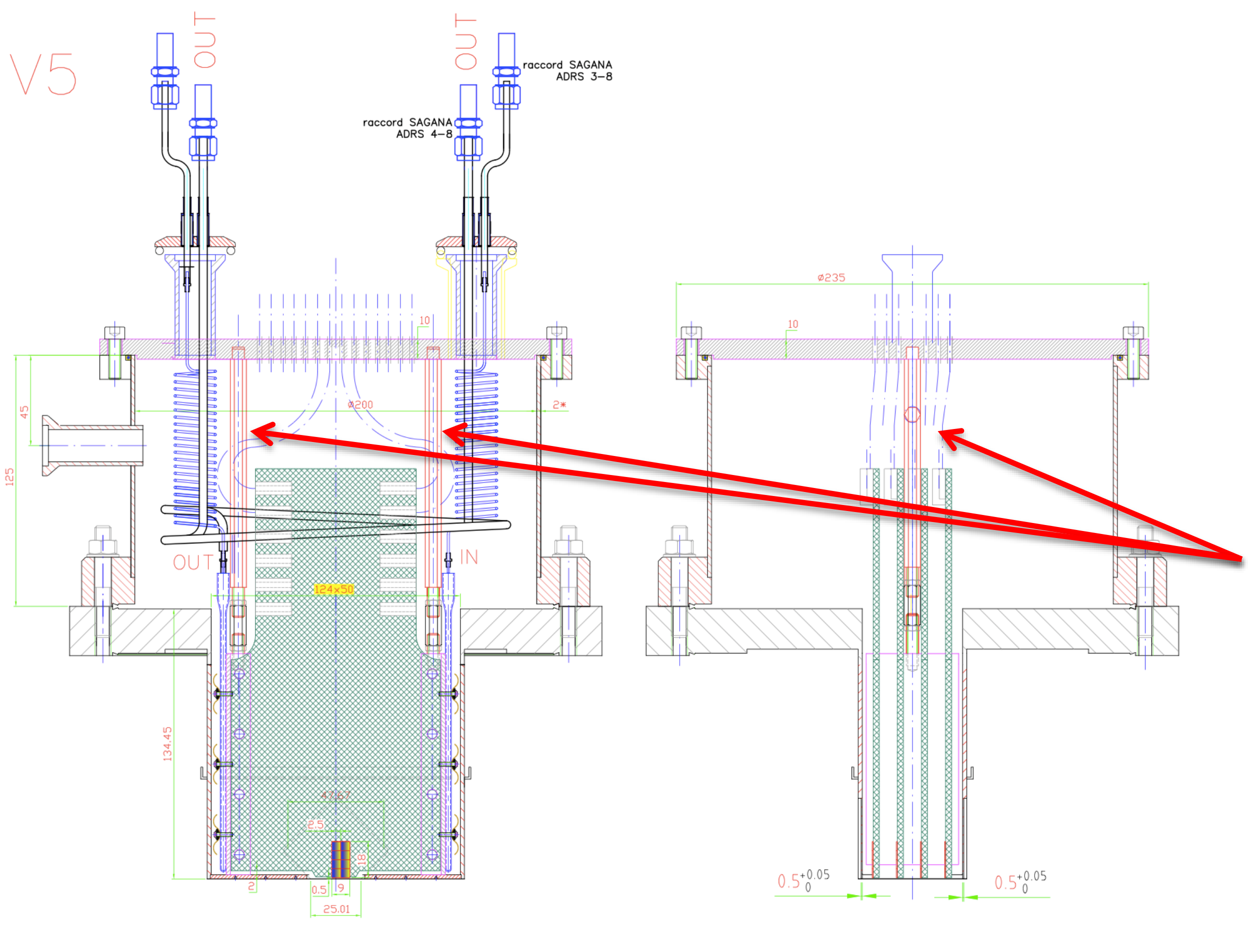



**Vertical Roman Pots (220Near)**


316LN


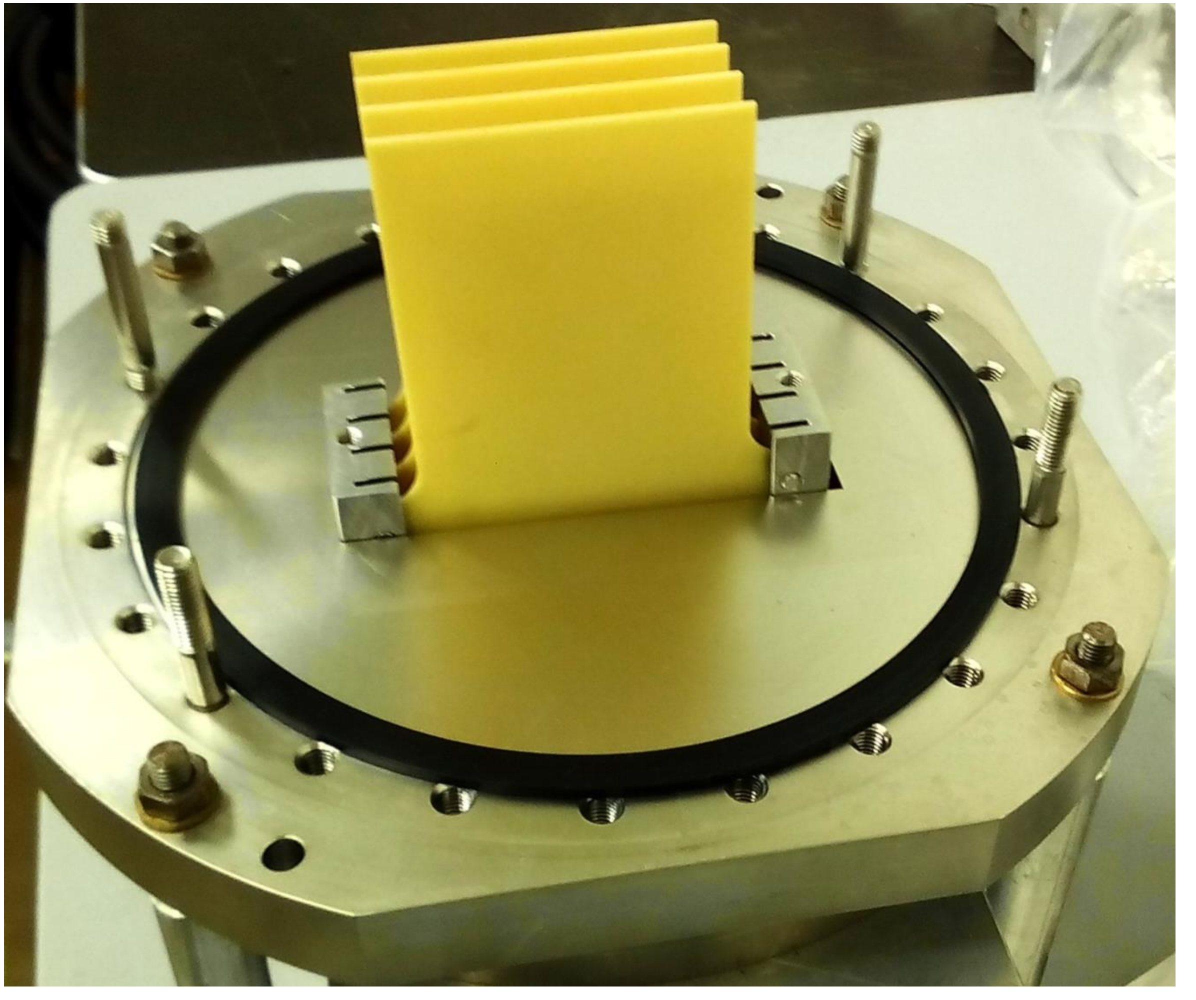
150µm

150µm (20µm planarity)
500µm
Ferrite collar
(2mm)

# Mechanics

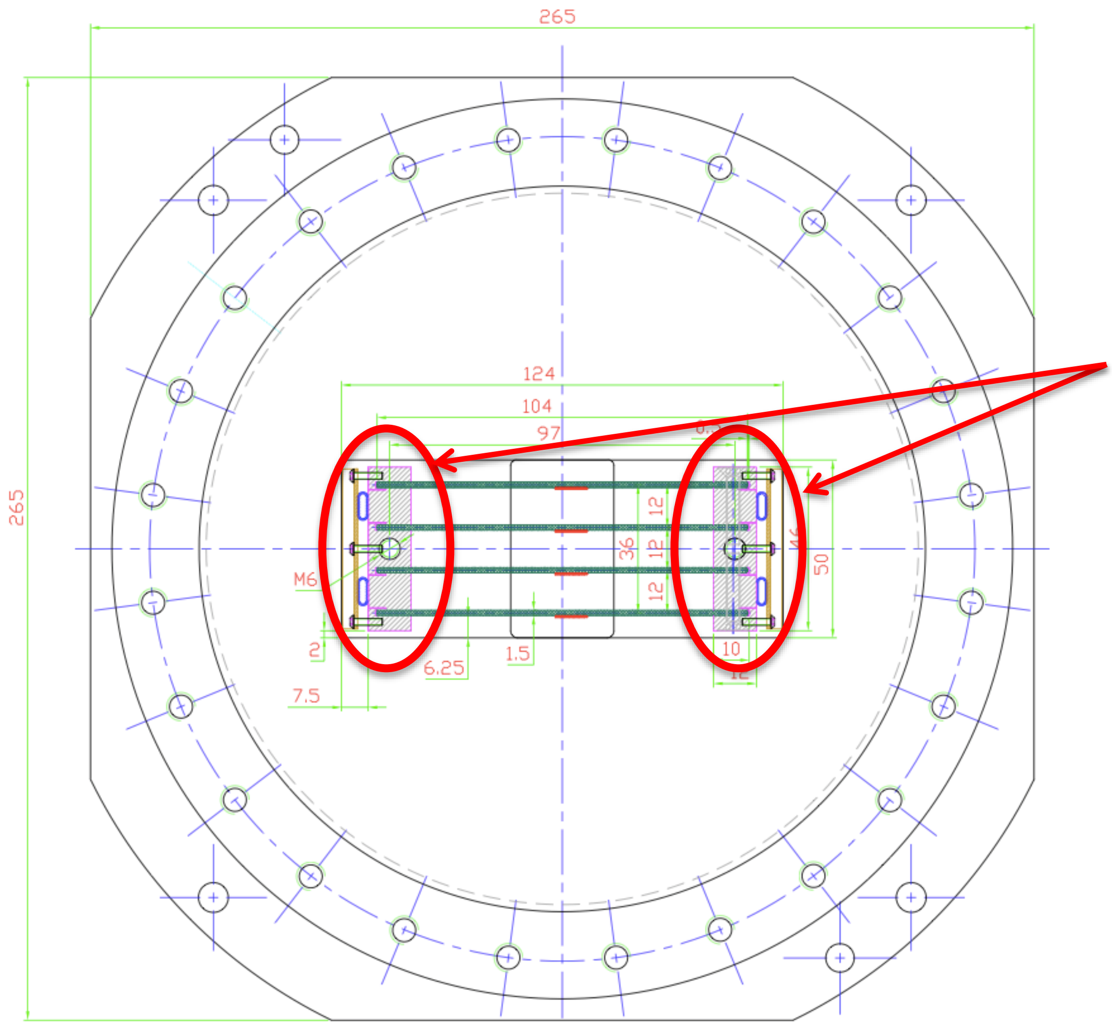



The “champignon” is based on the old pots basic structure.
The evaporative cooling is the same.
Two adjustable bars are used to precise positioning of the package in the pot.

# Full-scale mock-up

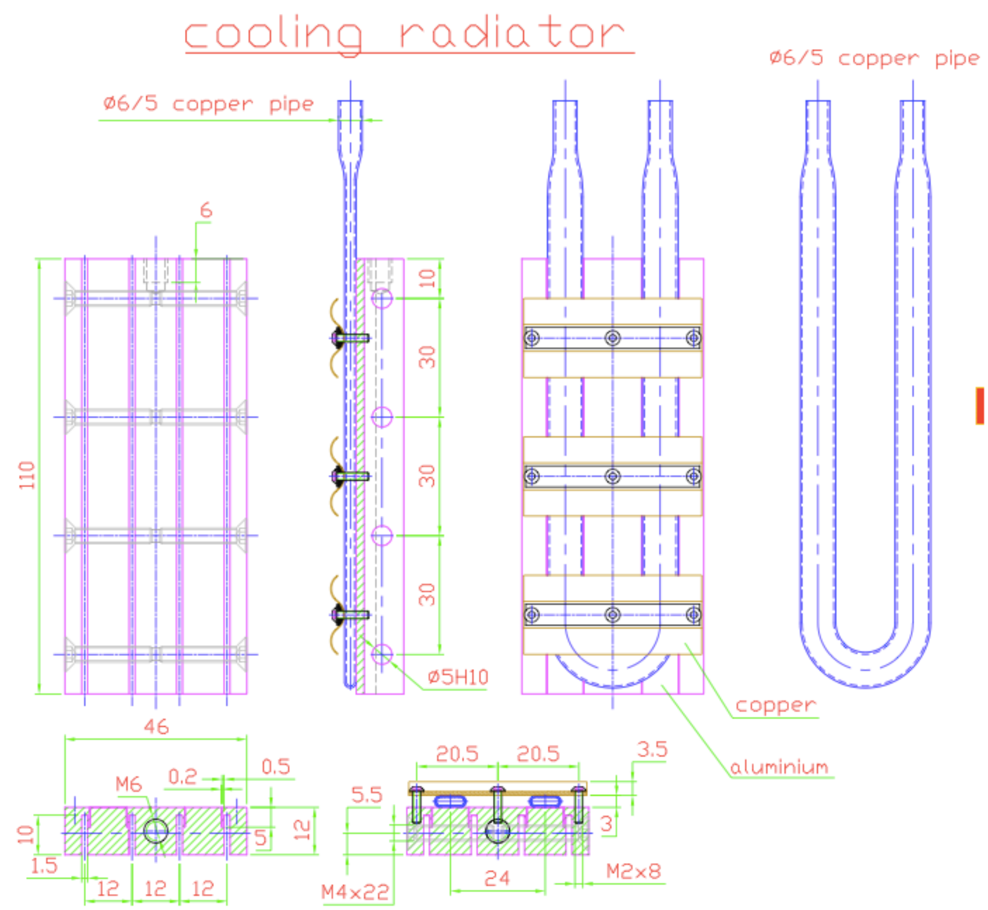


# Mechanics



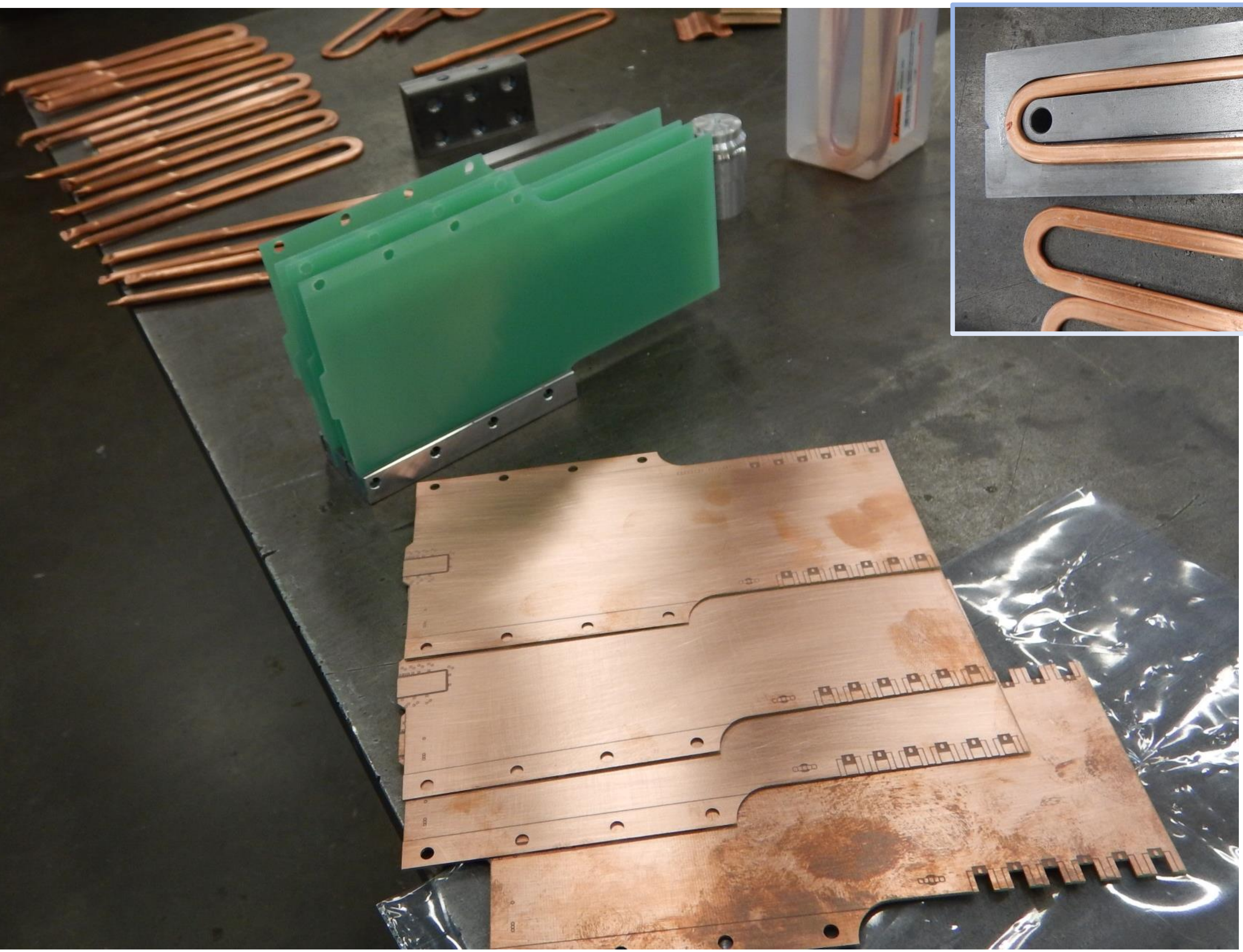

Two lateral, cold, aluminum holding bars are the main structure. The Hybrids are hold into large grooves to enhance heat transfer from the board to the bars.

# Cooling

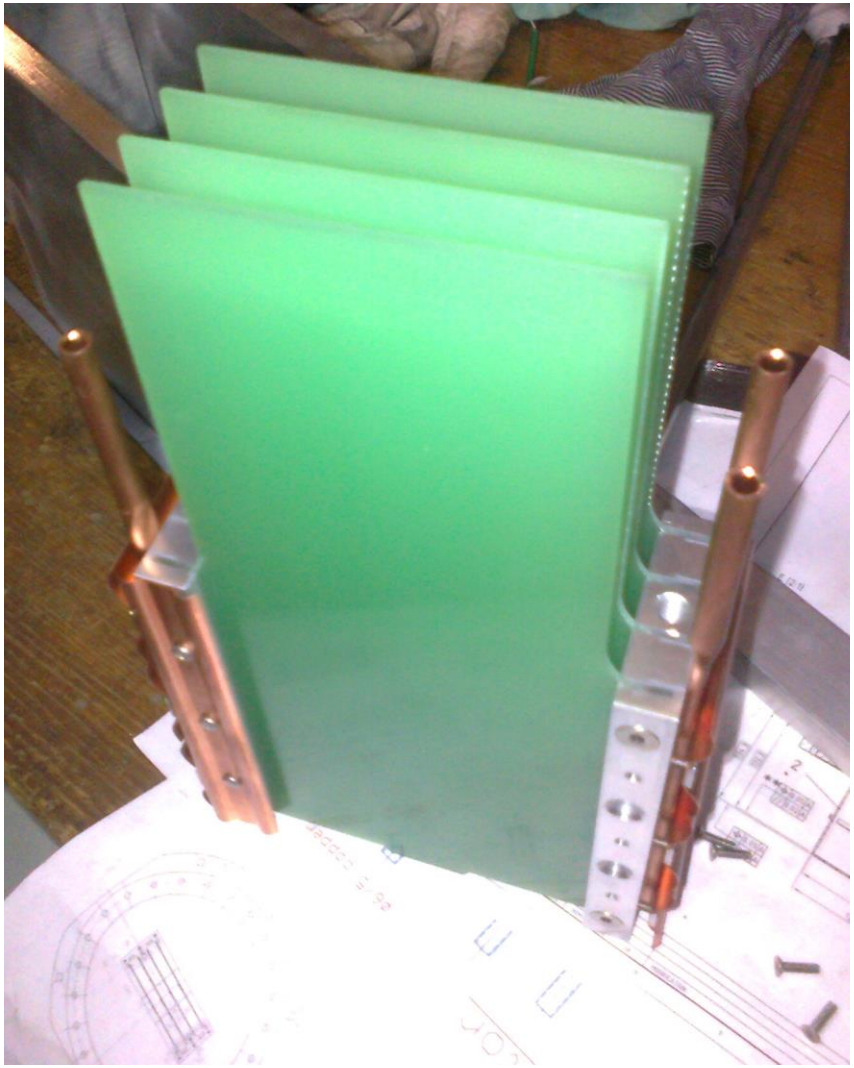



The two lateral aluminum holding bars are cooled by an ovoidal copper pipe to enhance the heat transfer from the aluminum to the fluid. A thermal connection of the pipes with the wall pots is foreseen.

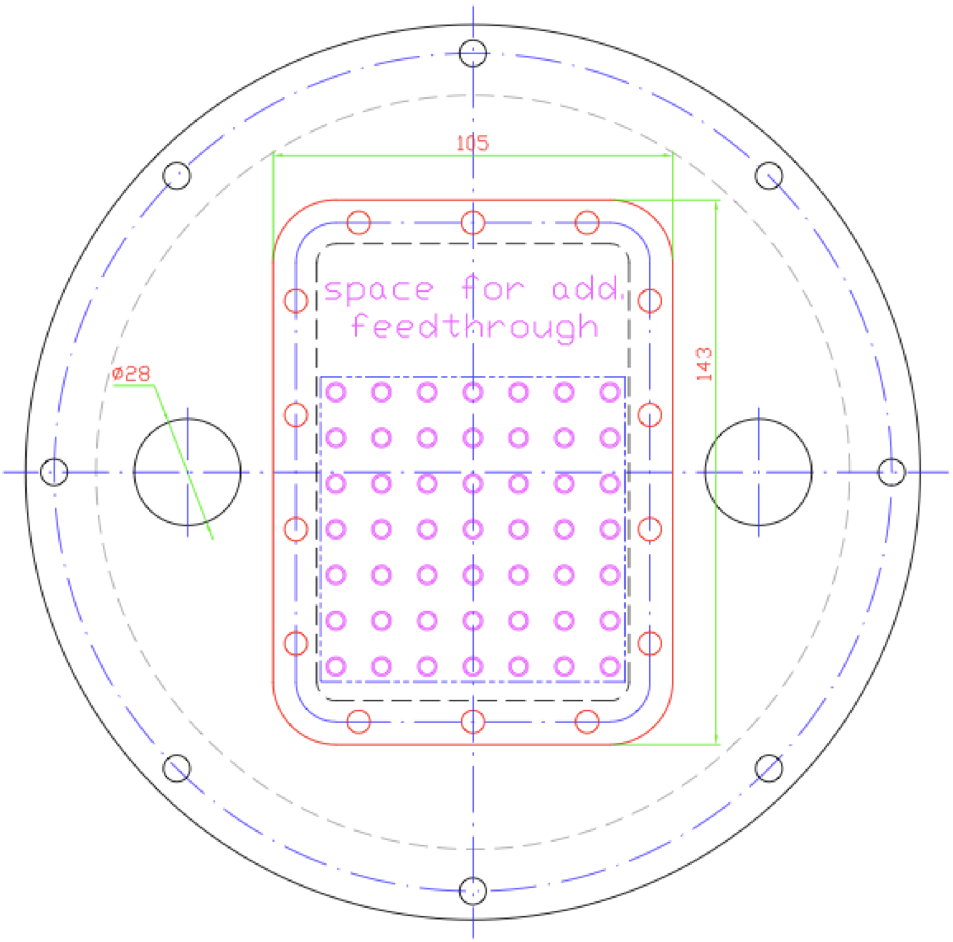
# Cooling lines



# Cooling test assembly



# Mechanics



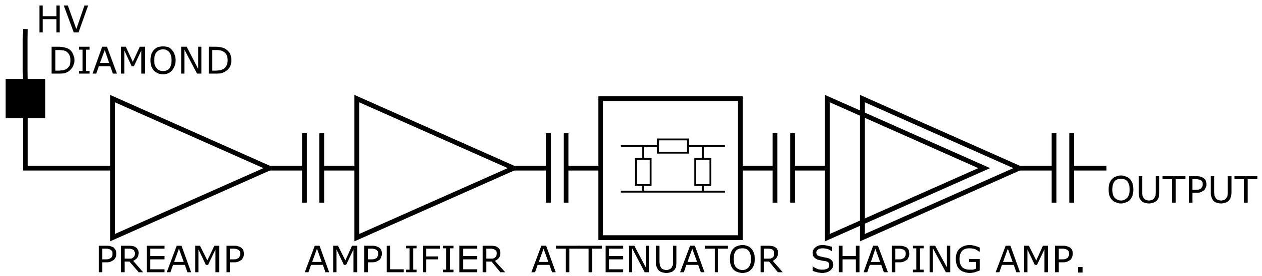

Feedtrough for high frequency RF connectors. We found a company that does this and it will be available by august.

# The Hybrid

- The hybrid has been designed by Richard Linhart from University of West Bohemia (Pilsen)
- The PCB is made with ROGER substrate for better impedance matching.
- The first prototype has been tested at Pilsen and now is at CERN.
- In the next weeks it will be tested at SPS test beam area.

# The Configuration

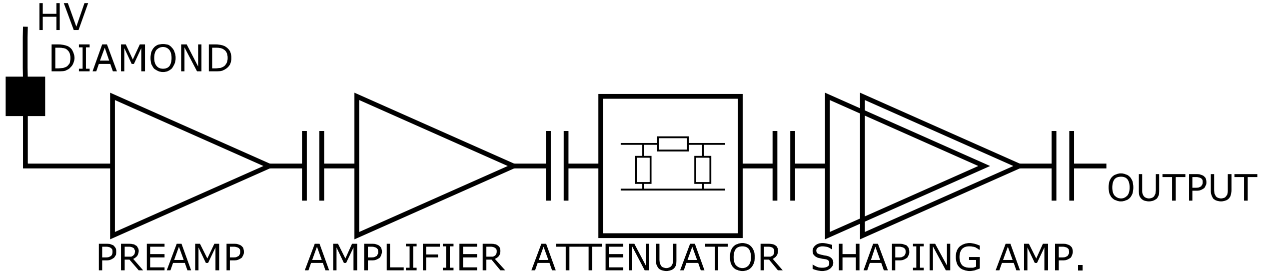
- Preamplifier
  - 1 stage BFP840ESD, robust SiGe BJT with low-C feedback
  - Gi = 31 dB (Gu = -4 dB)  F = 0.6 dB
- Amplifier
  - MMIC ABA-53563, near linear phase, absolute stable amplifier
  - G = 22 dB  F = 3.5 dB




AMPLIFIER CHAIN BLOCK DIAGRAM

# The Configuration

- Attenuator
  - G = -10 dB, for matching the next stage and for amplitude adjustment
- Shaping amplifier
  - 2x BFG425 Si BJT matched amplifier for shaping the signal
  - G = 50 dB
- SUM G = 93 dB (taken as current transfer rat. from diamond to output)



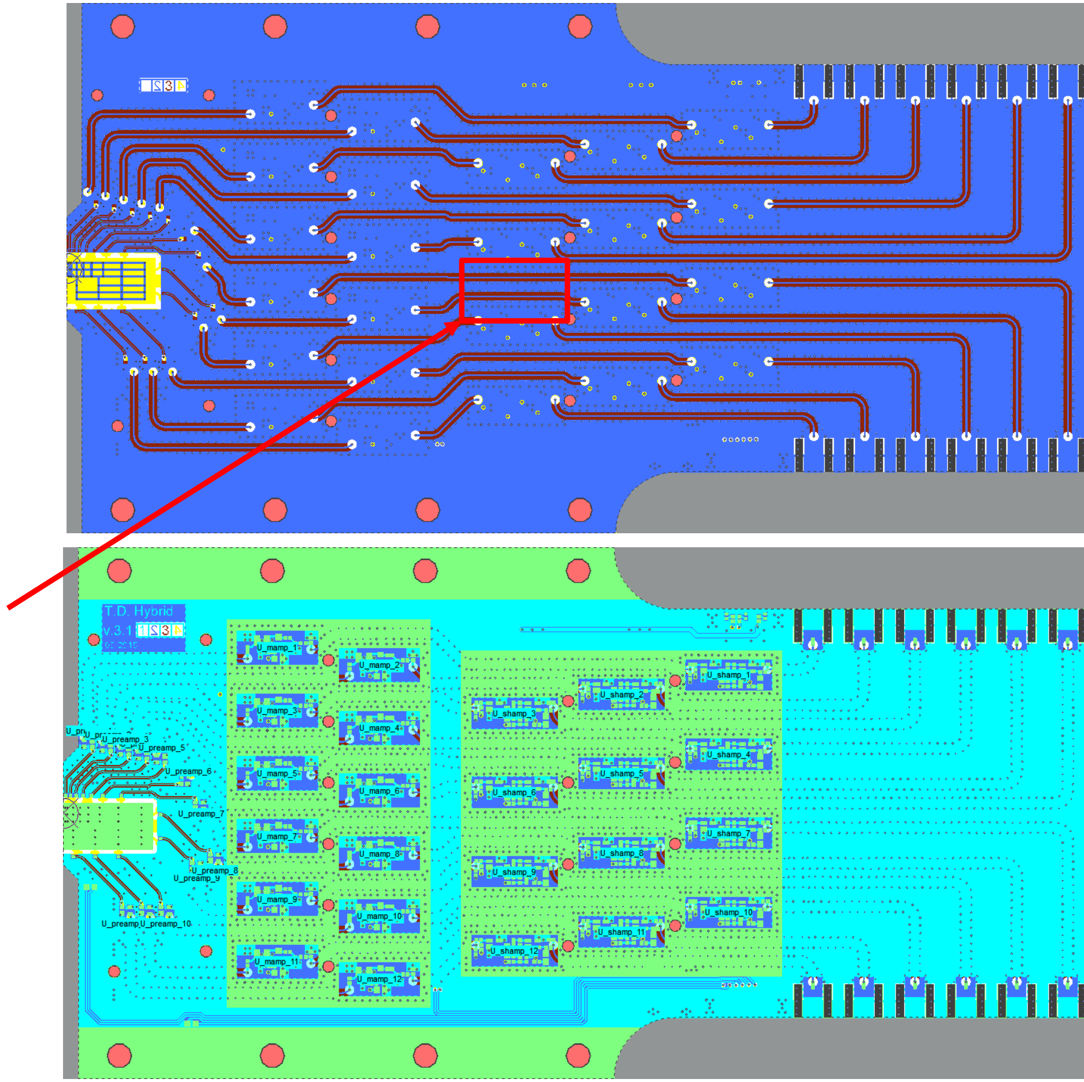

AMPLIFIER CHAIN BLOCK DIAGRAM

# The Electromagnetic Shielding

- Signal traces = stripline

(Inside the board between two ground planes without any gaps.)

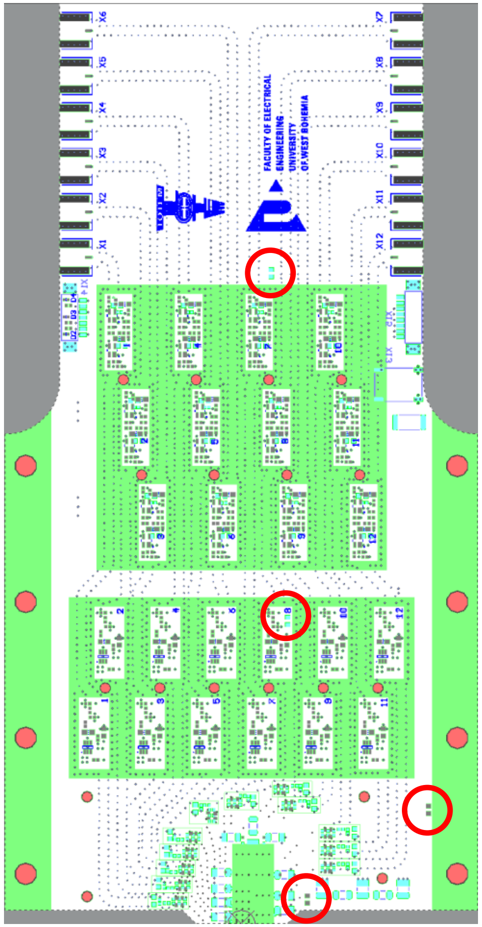
- At least 2 via fences between traces, or between trace and circuit
- Crosstalk rejection between 2 parallel lines was approx. 100 dB in simulations
- Via density depends on signal bandwidth and propagation velocity
- Shielding metal boxes on circuits



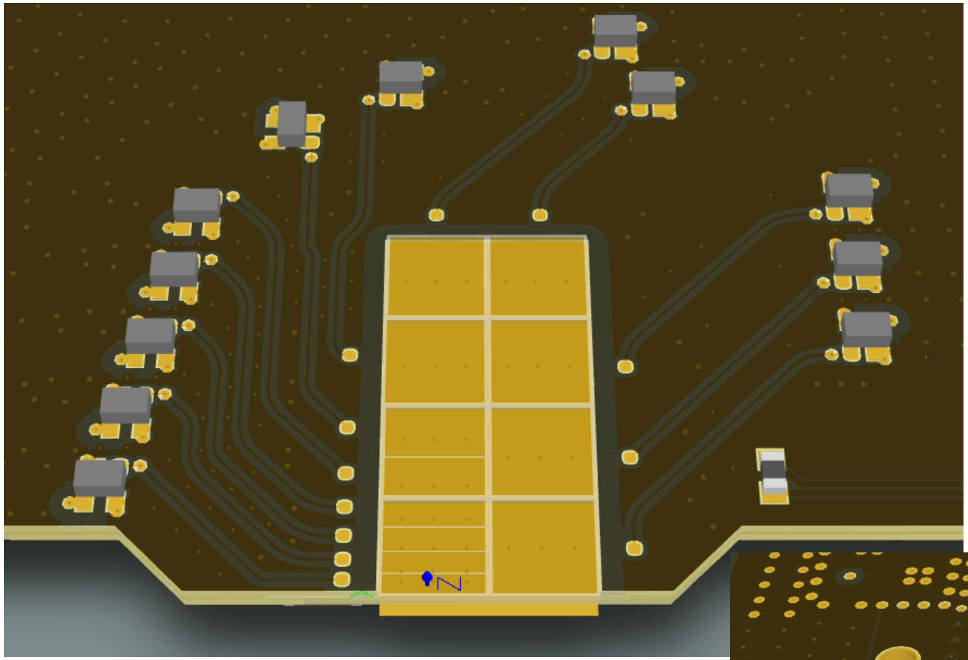
# Thermal Analysis & Diagnostics

- Power loss – 0.307 mW / channel ; 3.7 W total
- PCB thermal conductivity 37 W/mK
- Previous work on 4 channel hybrid
  - 2D thermal model in vacuum
  - Basic test in vacuum chamber
- Current tests for 12 channel hybrid
  - Board Mockup used for test
  - Cooling system test with board mockups
- In operation diagnostics
  - 4x PT-100 temperature sensors

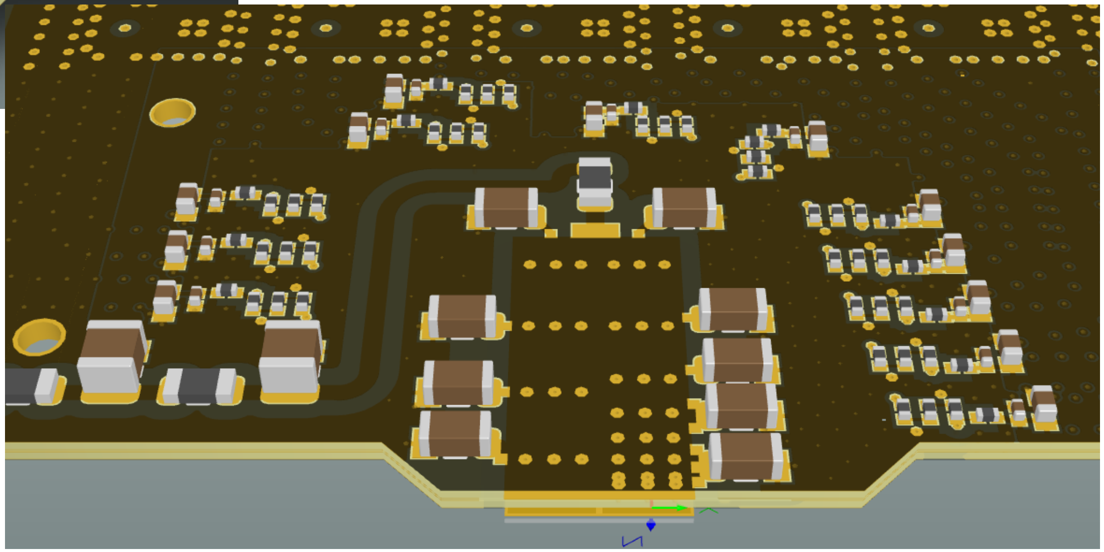
  (Diamond, Heat Sink, Main Amplifier, Board)



# Board Preview – Diamond

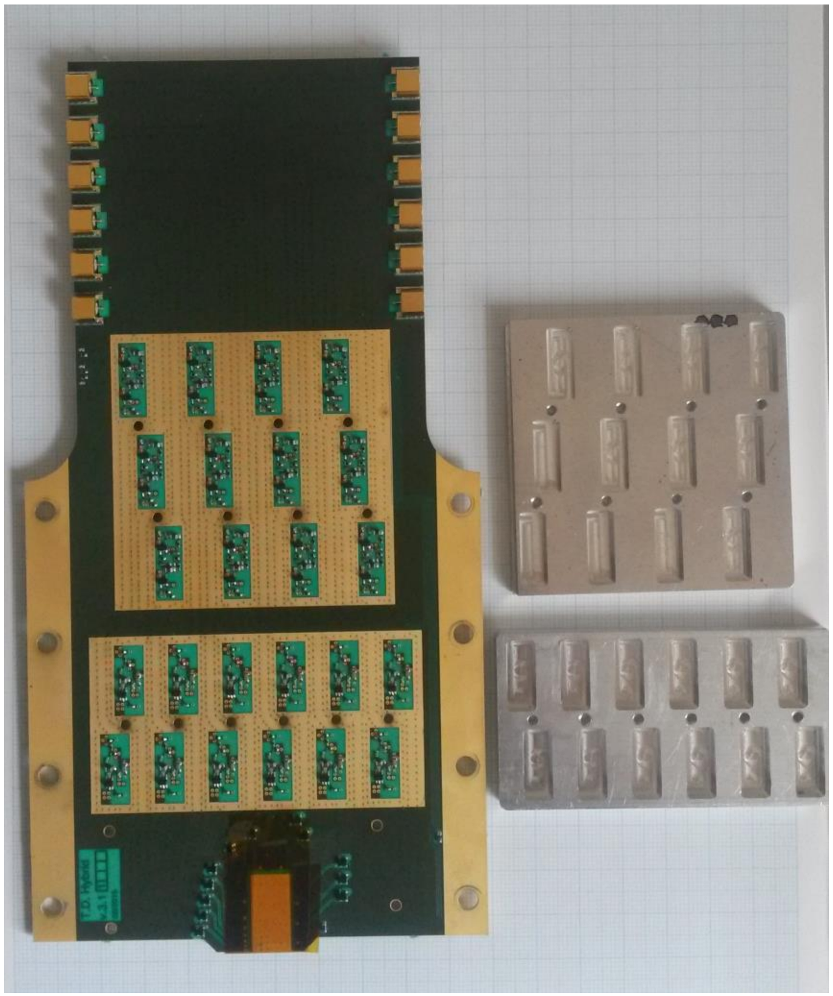


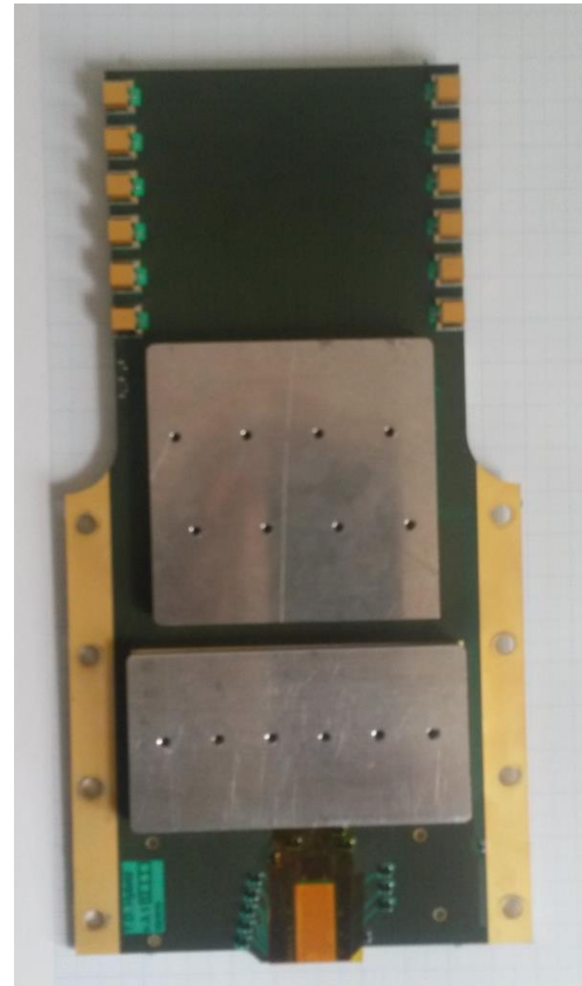
The top view of the diamond and preamplifiers



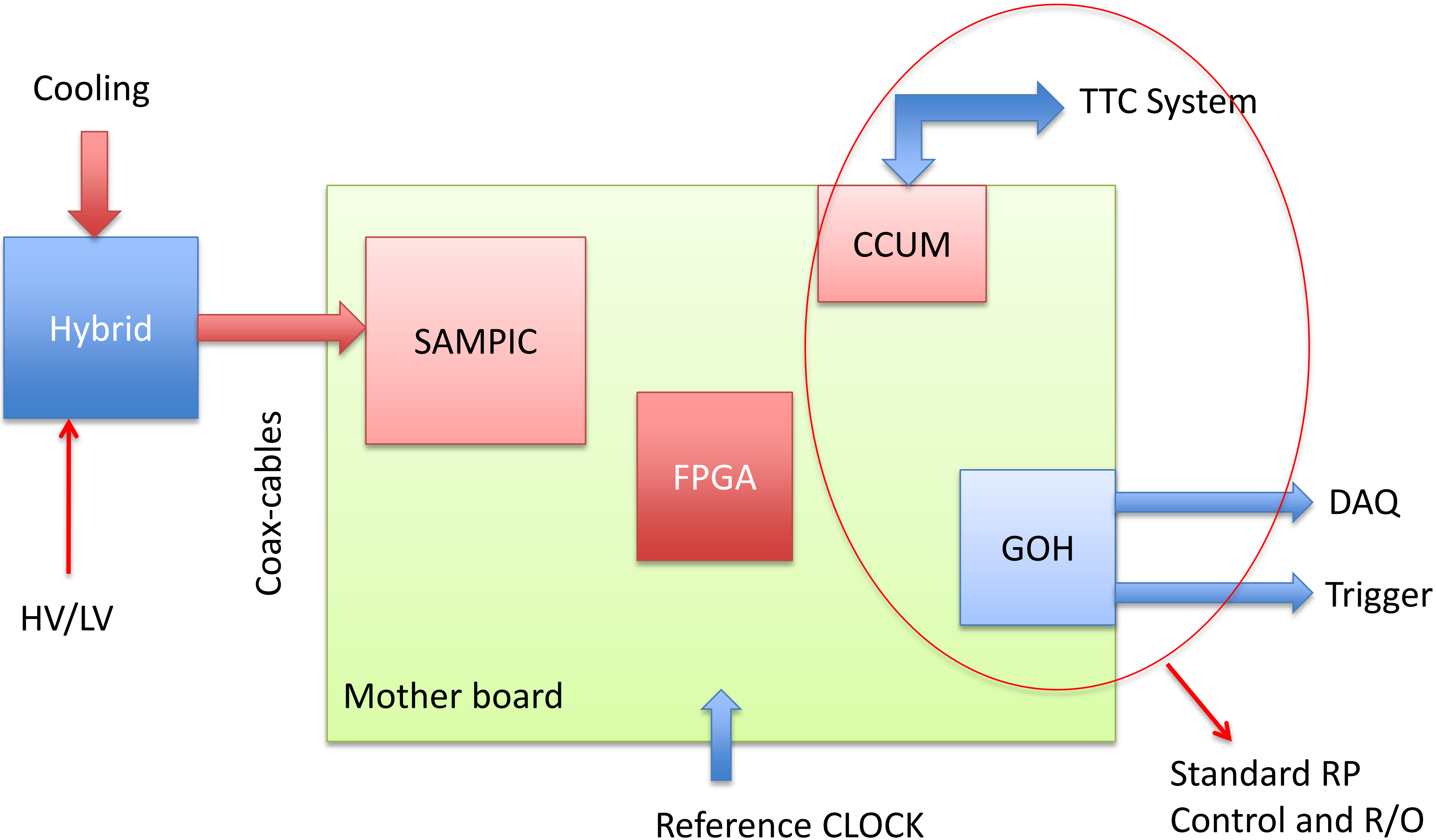
The bottom view of the diamond and preamplifiers

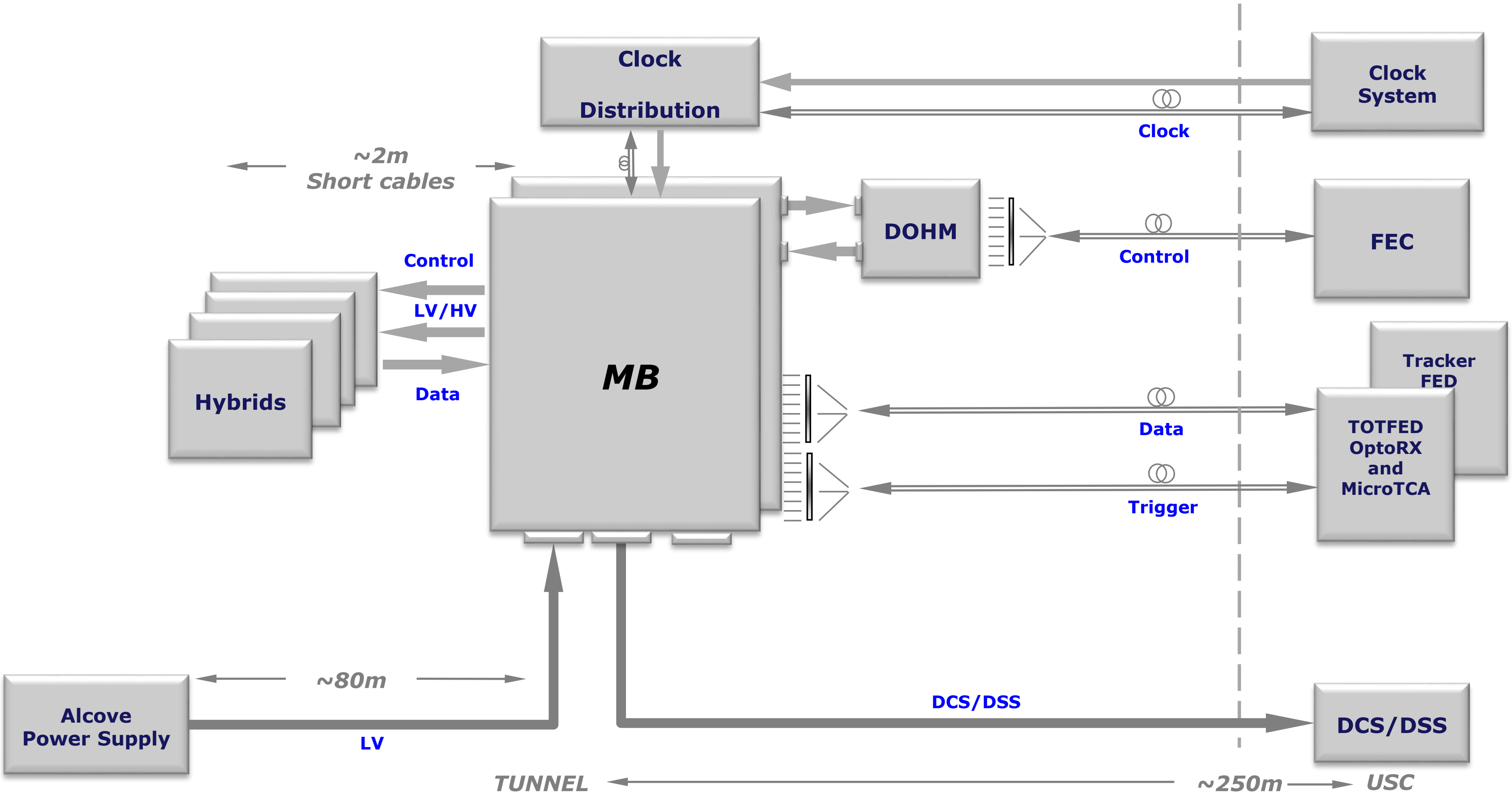
# First Prototype





# Digitization and data acquisition





Clock
Distribution
Clock
System
Clock
~2m
Short cables
DOHM
Control
FEC
Control
LV/HV
Hybrids
Data
MB
Tracker
FED
Data
TOTFED
OptoRX
and
MicroTCA
Trigger
~80m
DCS/DSS
Alcove
Power Supply
LV
DCS/DSS
TUNNEL
~250m
USC

# The Sampic Chip

Matthias Saimpert, D. Breton, E. Delagnes, J. Maalmi, C. Royon
CEA Saclay - Irfu/SEDI,SPP ; CNRS Orsay - IN2P3/LAL

**SamPic** is a CMOS chip designed to read the forward timing detectors of ATLAS. **Sam**pler for **Pic**osecond time pick-off.

R&D financed by P2IO

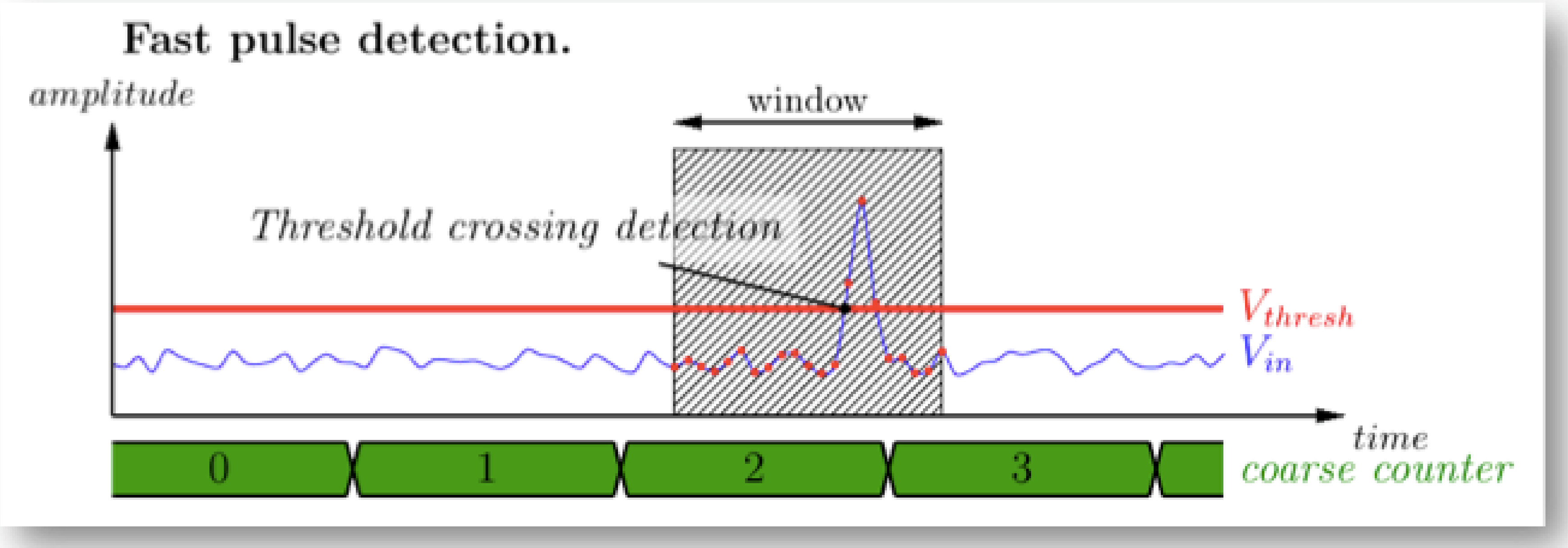
**Goals:**

- Technology evaluation (IBM 0.18μm)
- Tests of design choices (DLL & SCA architecture)
- Simultaneous Read&Write
- Creating a multi-channel chip easily integrable in large-scale experiments (ATLAS).

# The Sampic Chip

**Detection of 'Event of interest' above threshold.**

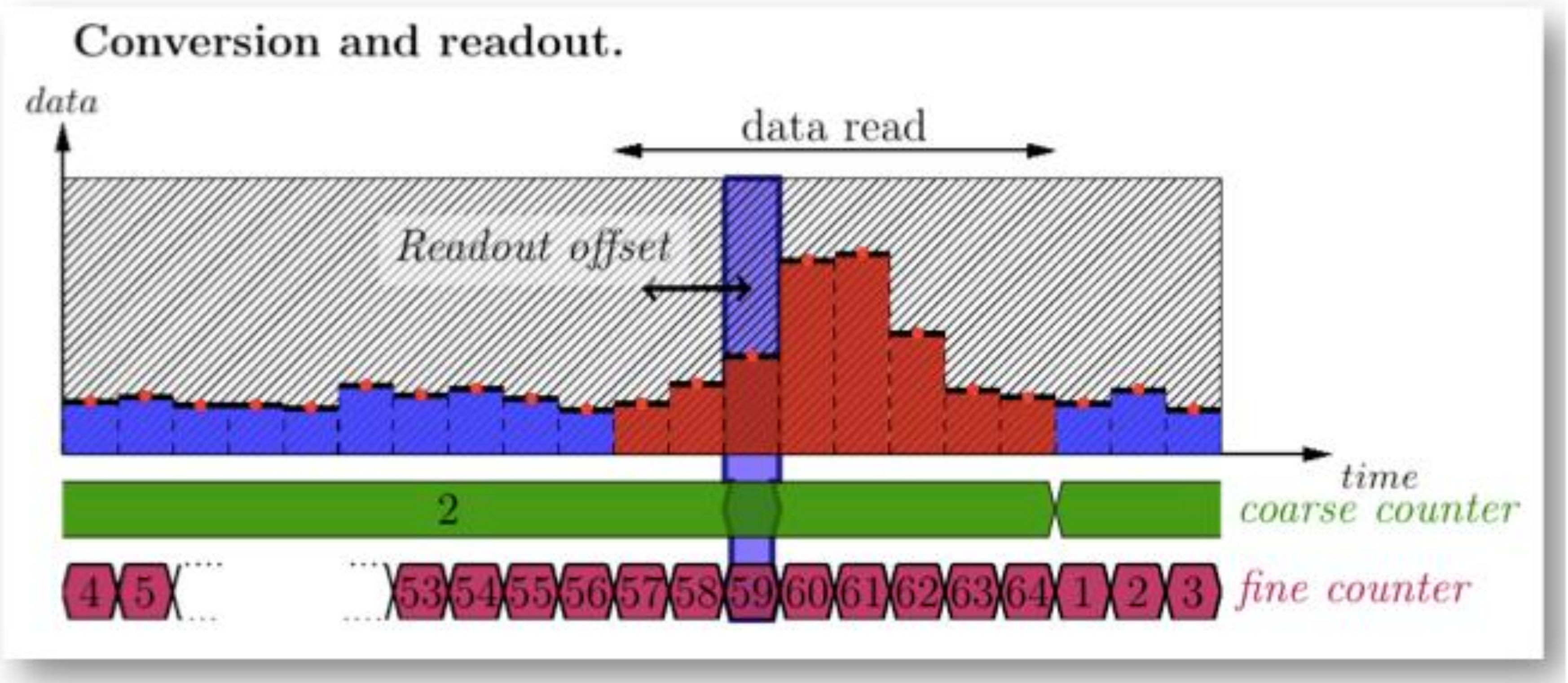
- Adjustable threshold (DAC).
- Pulse polarity (rising or falling edge).
- Additional post-trigger delay.



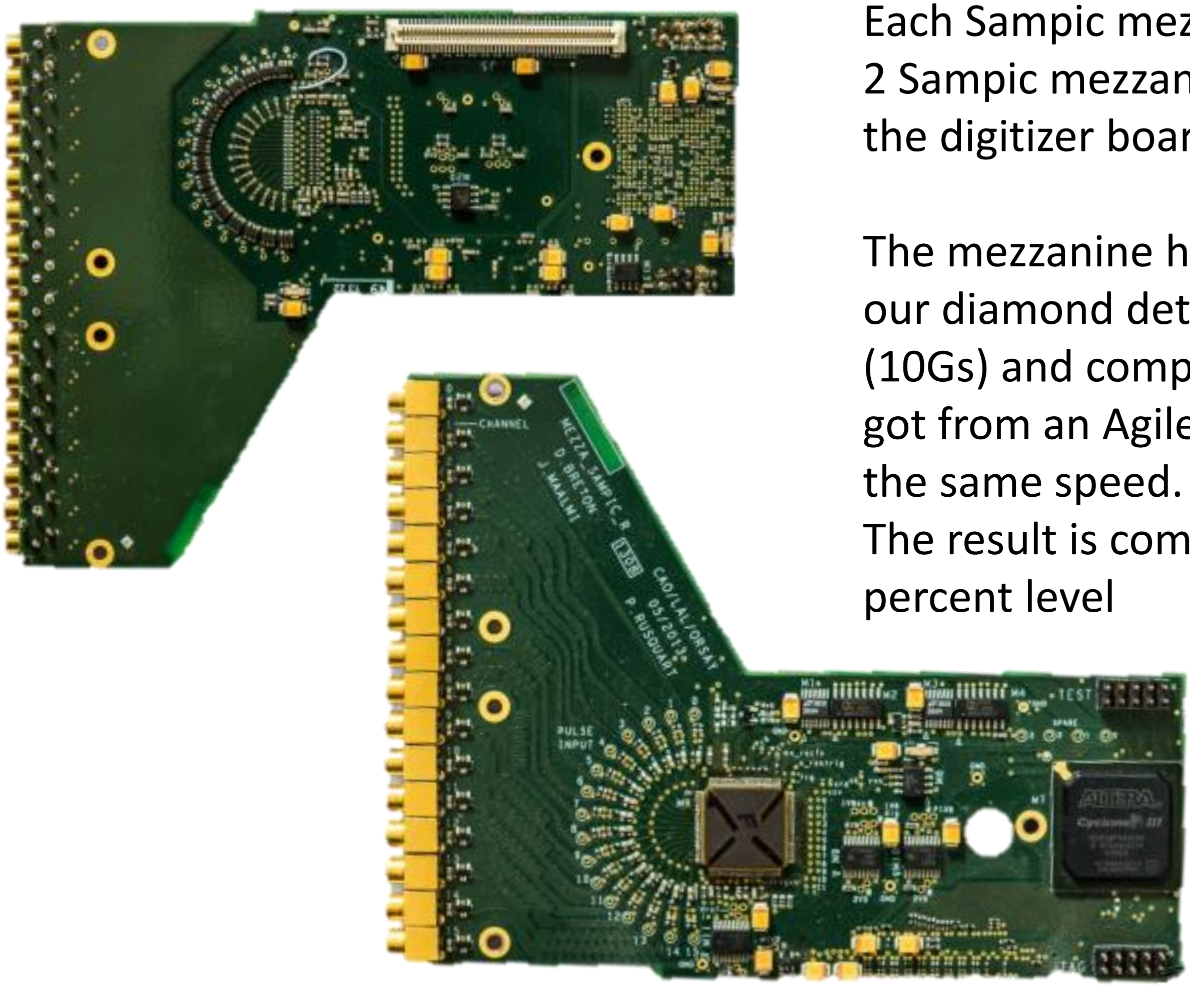
# The Sampic Chip

## Conversion and readout.

- Wilkinson 11 bits - 2GHz.
- Region of interest readout LVDS 400MHz.



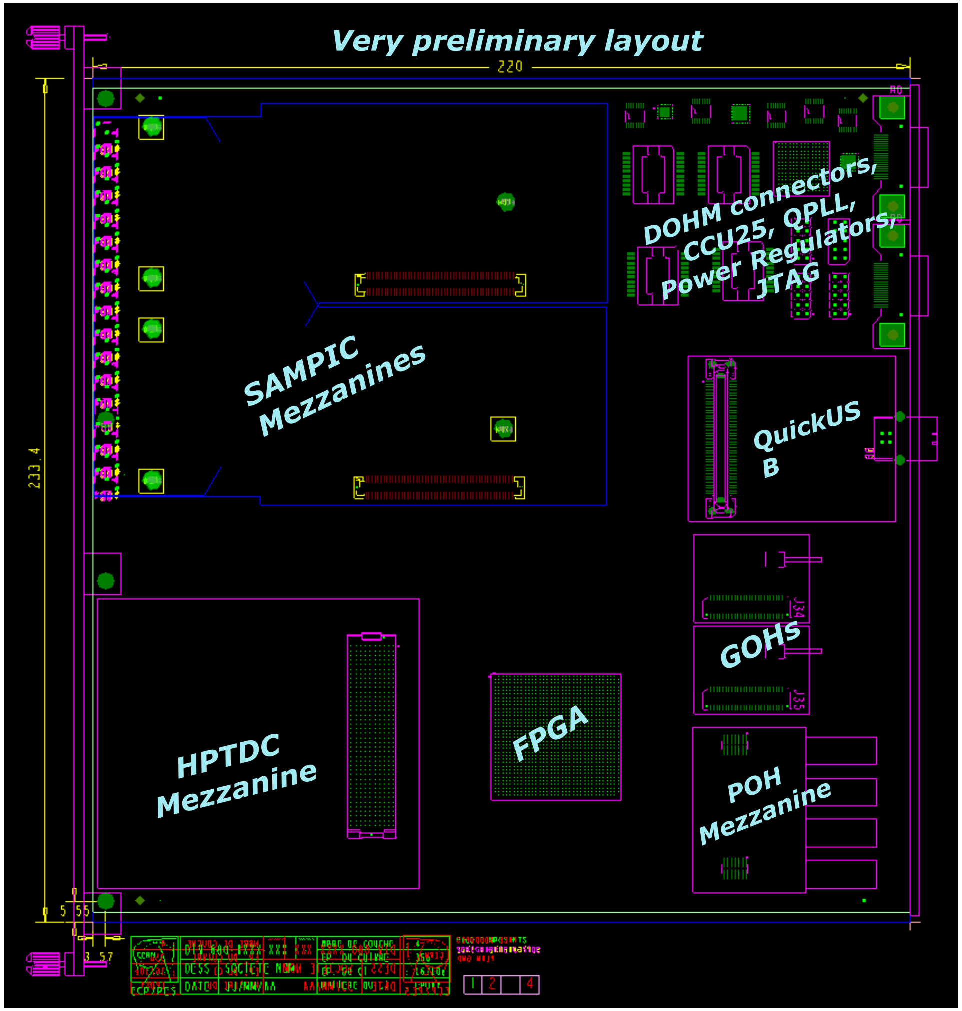
# Sampic Mezzanine

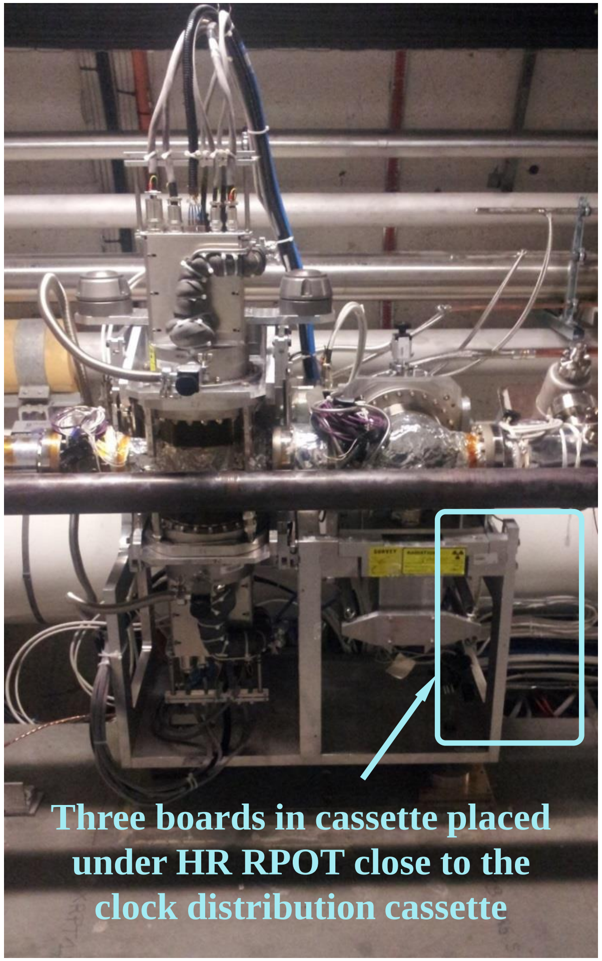



Each Sampic mezzanine has 16 inputs.
2 Sampic mezzanine will be hosted in the digitizer board.

The mezzanine has been tested with our diamond detectors at full speed (10Gs) and compared with the result got from an Agilent Oscilloscope at the same speed.
The result is comparable at the percent level

# Digitizer board



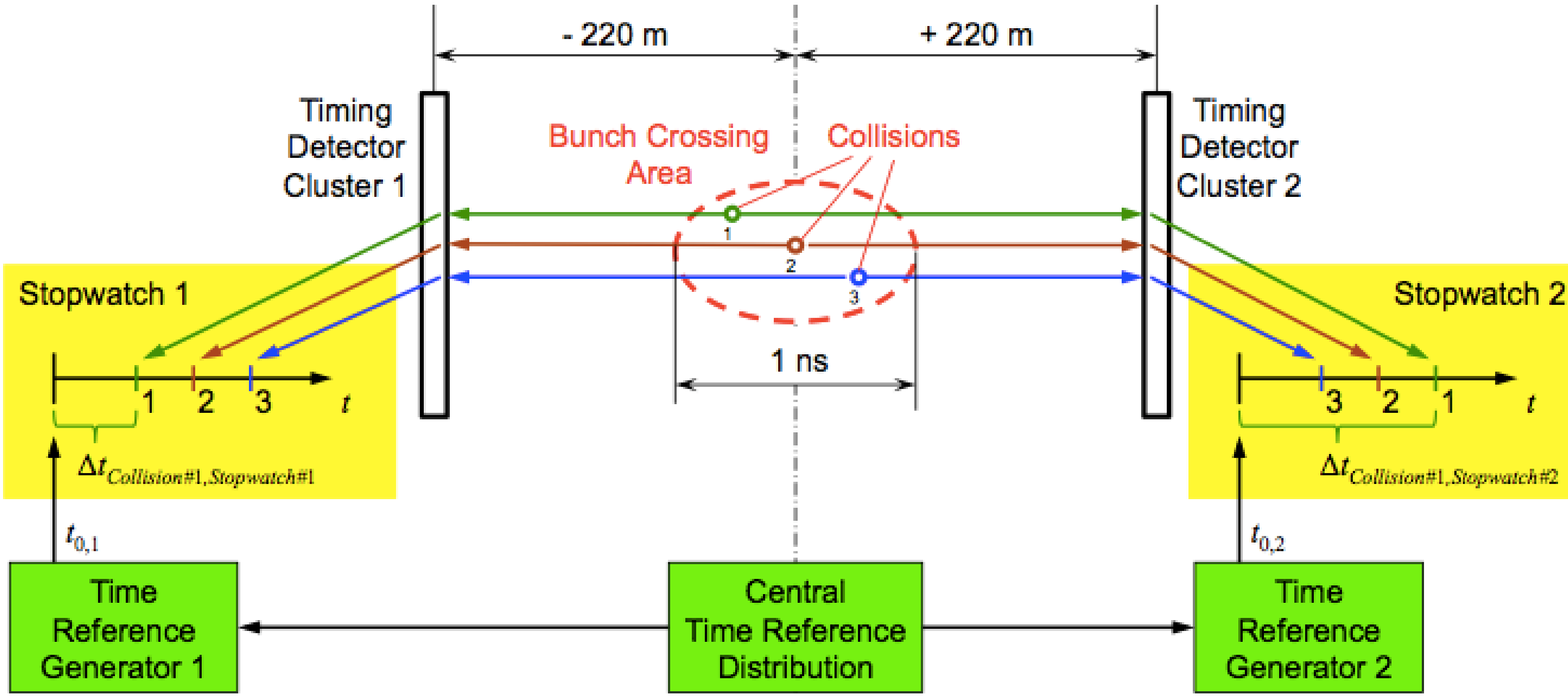



# The clock distribution

- We are adapting M. Bousonville, "*Universal Picosecond Timing System*", developed for FAIR at GSI.
  - M. Bousonville and J. Rausch. *Universal picosecond timing system for the Facilityfor Antiproton and Ion Research*. Phys. Rev. ST Accel. Beams, 12 (2009), p. 042801 (http://link.aps.org/doi/10.1103/PhysRevSTAB.12.042801 ).
  - P. Moritz and B. Zipfel. *Recent Progress on the Technical Realization of the Bunch Phase Timing System BuTiS*. Conf.Proc., C110904 (2011), pp. 418-420.
- This system strengths:
  - It is scalable. In principle 128 clocks can be transmitted on a single fiber.
  - It uses robust industrial standards used for communication on fibers, like DWDM (*Dense Wavelength Division Multiplexing*);
  - Can be monitored.
  - It has been already installed and used.


48

# Timing Requirements of TOTEM




$$\text{Position of Collision 1} = f(\Delta t_{Collision\#1,Stopwatch\#1}, \Delta t_{Collision\#1,Stopwatch\#2})$$

# Design Parameters for a Starting Point Provider

- Timing Offset
  - Must not be equal

    => $|\varphi_1-\varphi_2| = \Delta\varphi \neq 0$ is ok
  - But should be constant for small time periods

    => $\Delta\varphi$ = constant

    with a drift tolerance < 1 ps/min

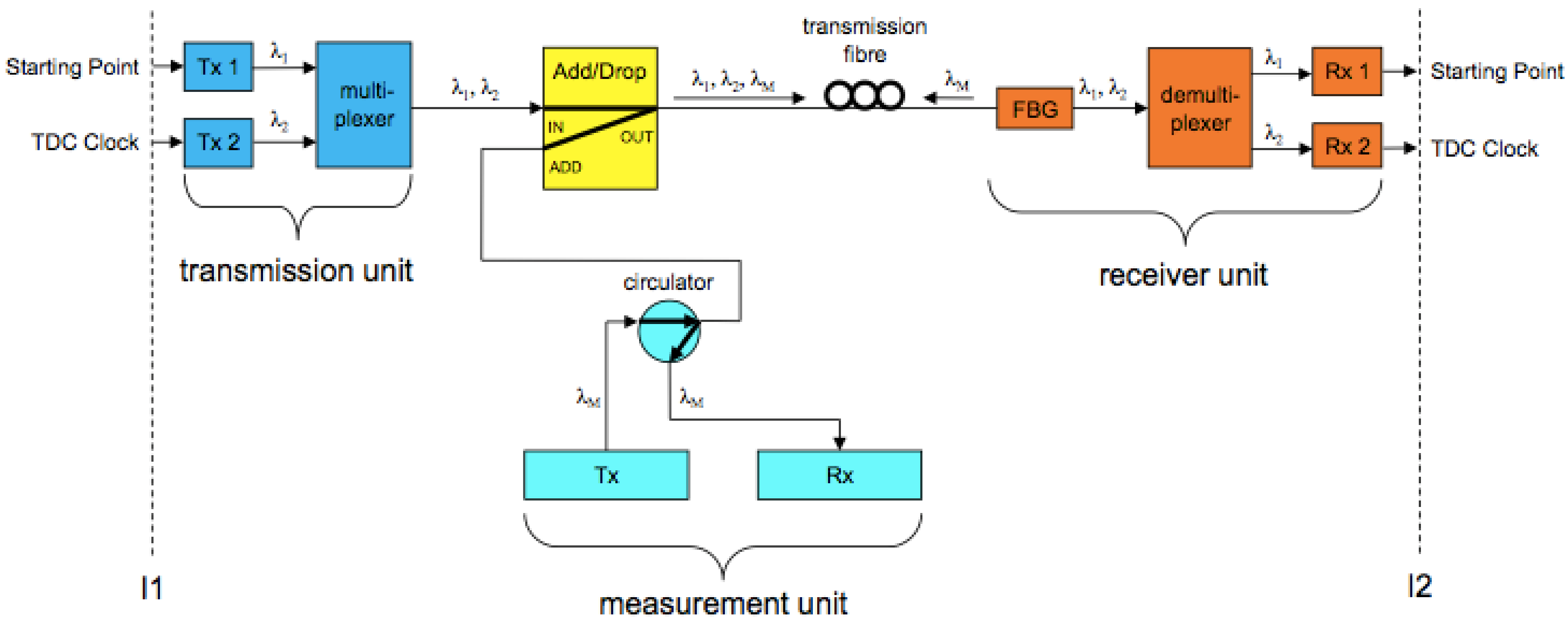
    Remark: $\Delta\varphi$ can be calculated out of the measurements in 10 minutes
- Jitter
  - Standard deviation

    $\sigma_{Ref} < 10$ ps

# Design Concept for TOTEM Timing

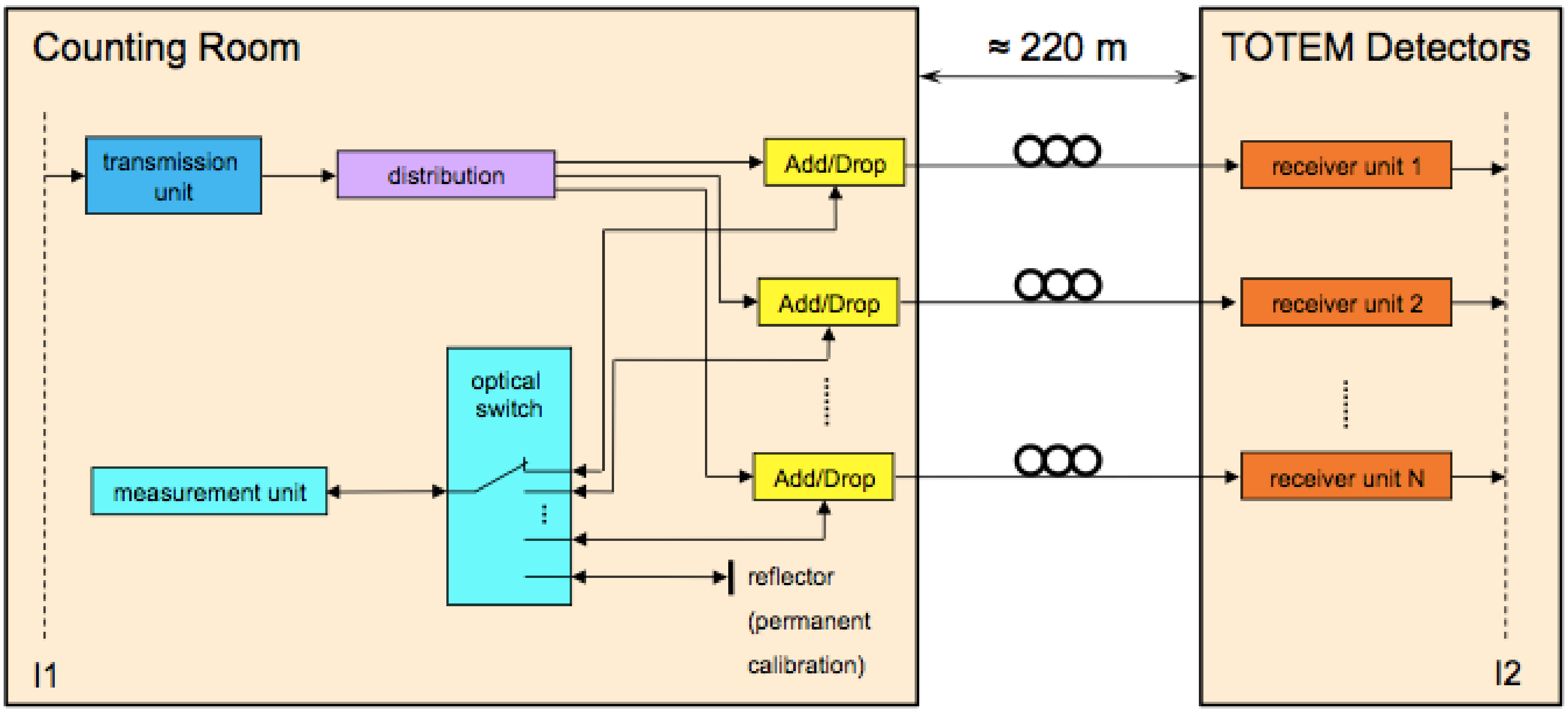
## System setup

- Configuration of one transmission branch



# Design Concept for TOTEM Timing

- System setup
  - Star-shaped distribution of the starting points to the TOTEM detectors
  - with locations

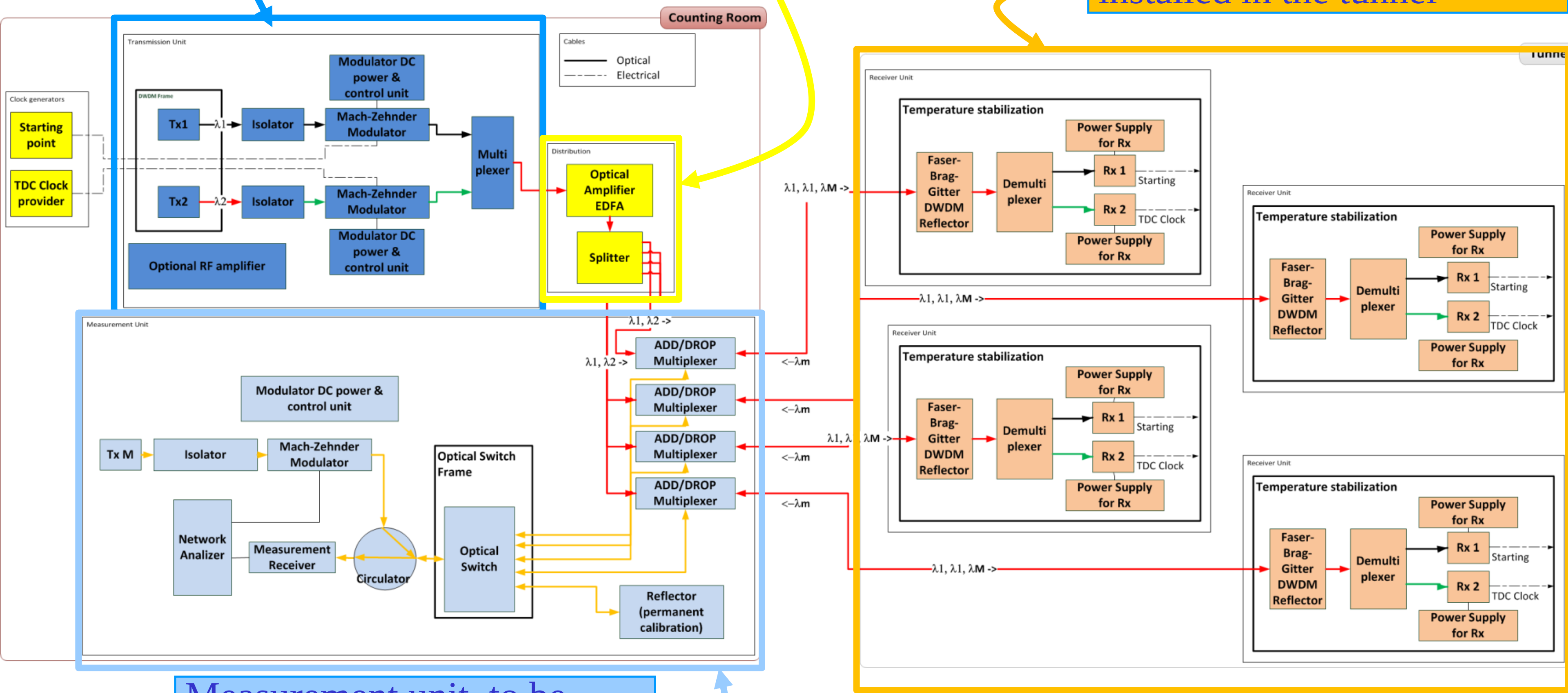


# The full system view

Transmission unit, to be installed in UCS

Distribution unit, to be installed in UCS

Receiving units, to be installed in the tunnel

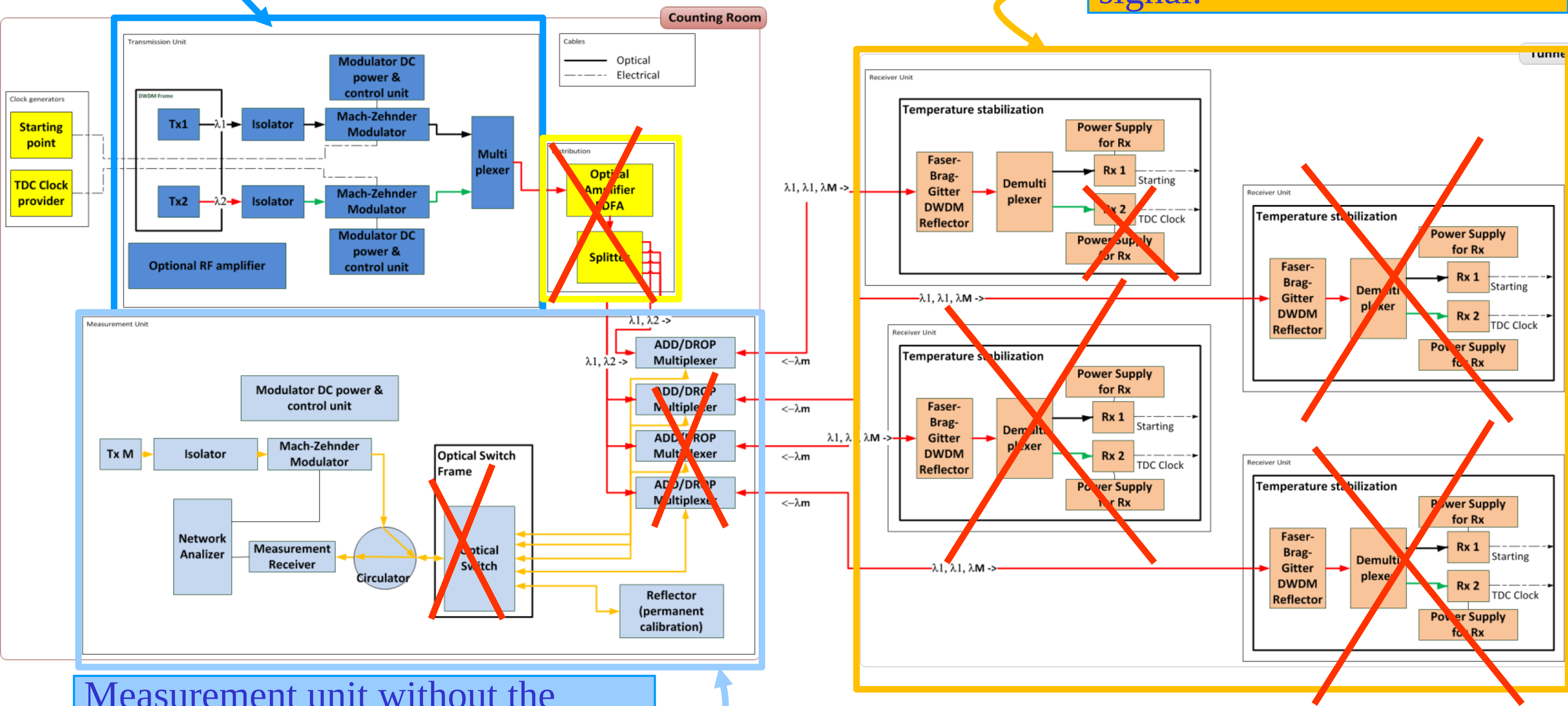



Measurement unit, to be installed in UCS

# The first test configuration

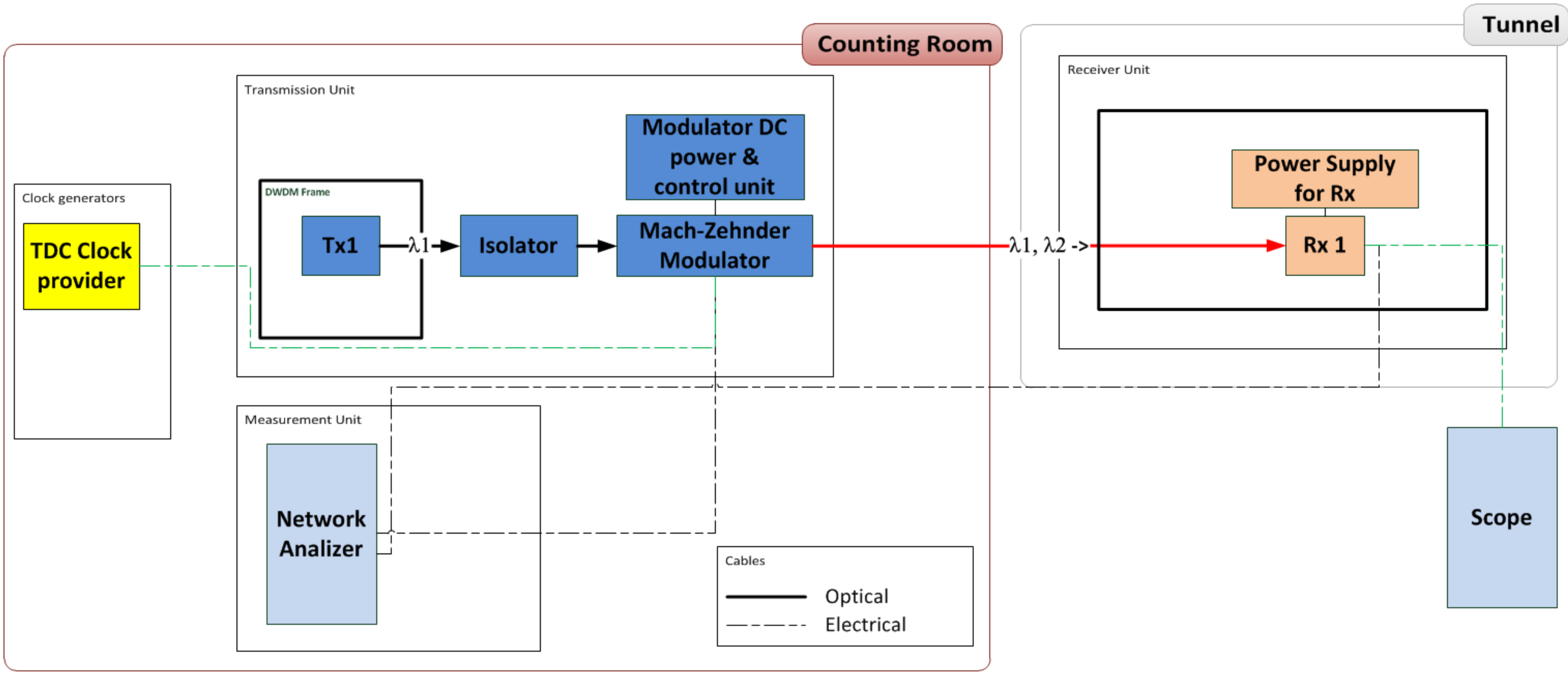
A full transmission unit

One receiving unit with one signal.

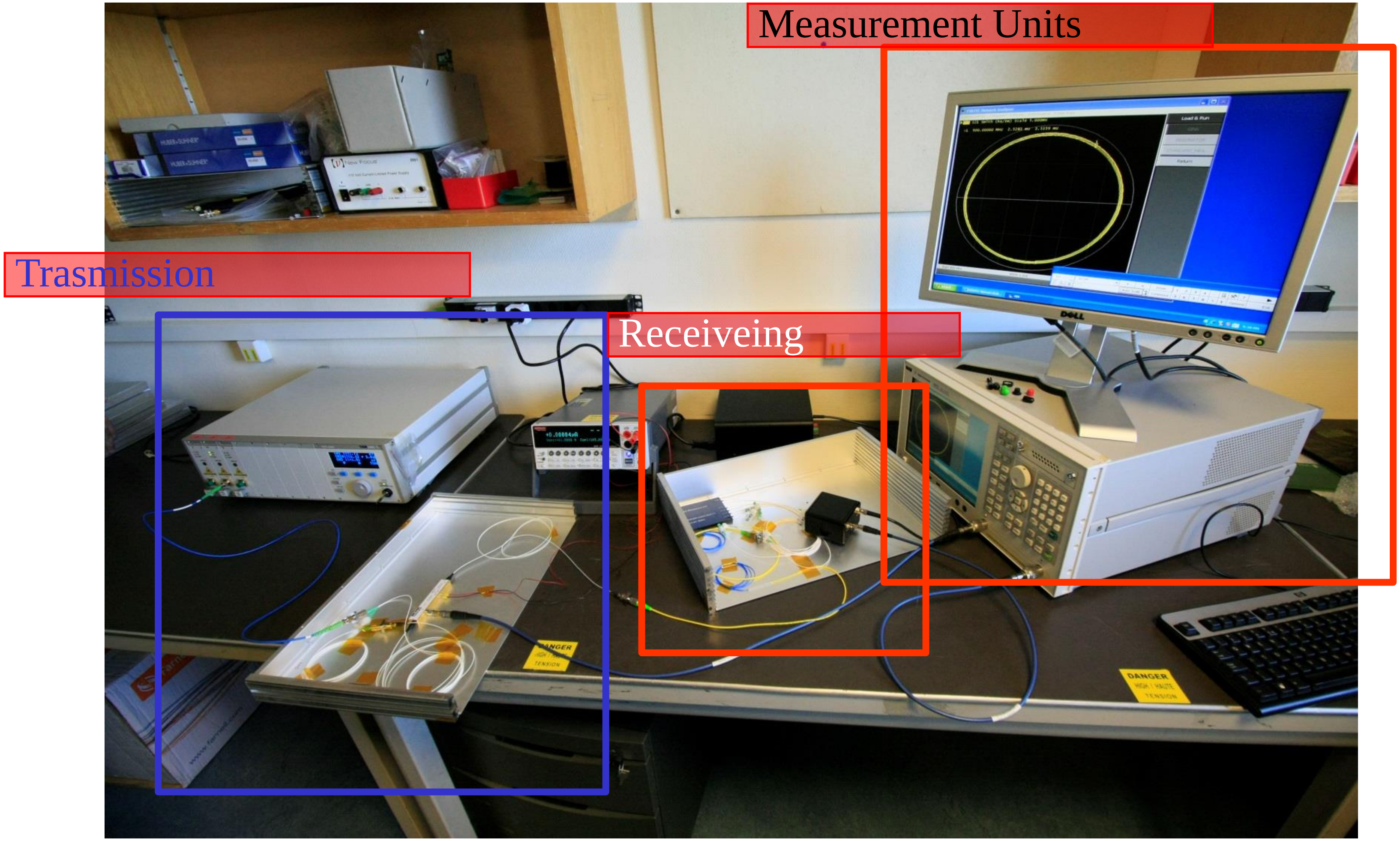



Measurement unit without the network analyzer.

# First test Setup



# First test Setup

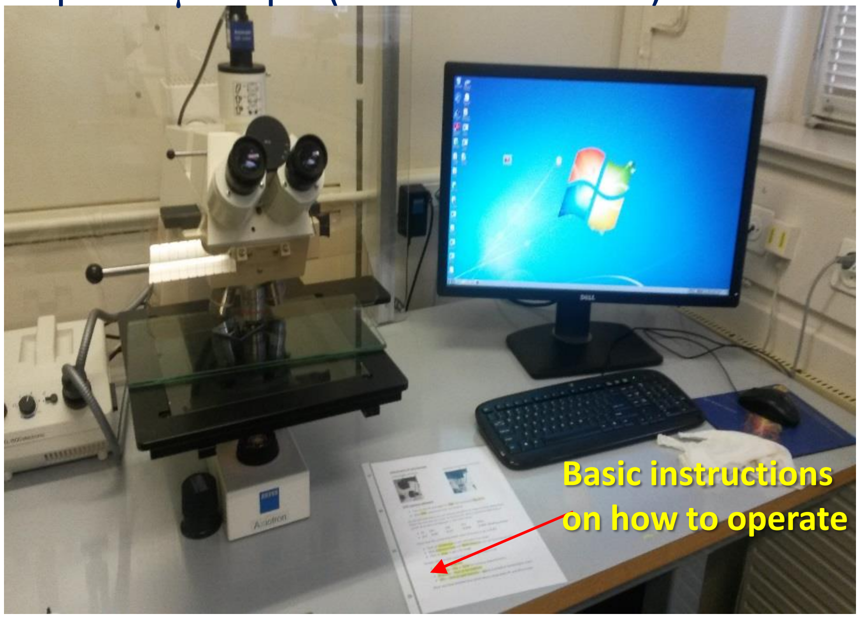


# Diamonds

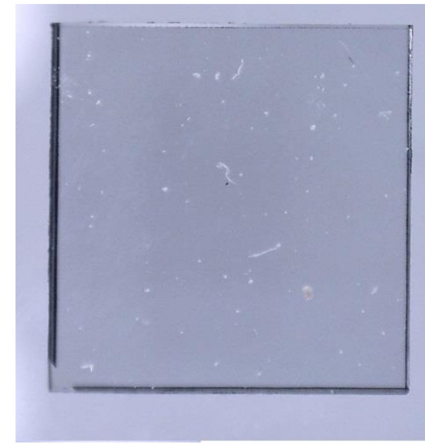
- A full set of 60 diamonds has already bough from Element6.
- Test are undergoing to evaluate the detectors.
  - Optical test (defects detection)
  - Metallization (Princeton)
  - Full electrical test with a source

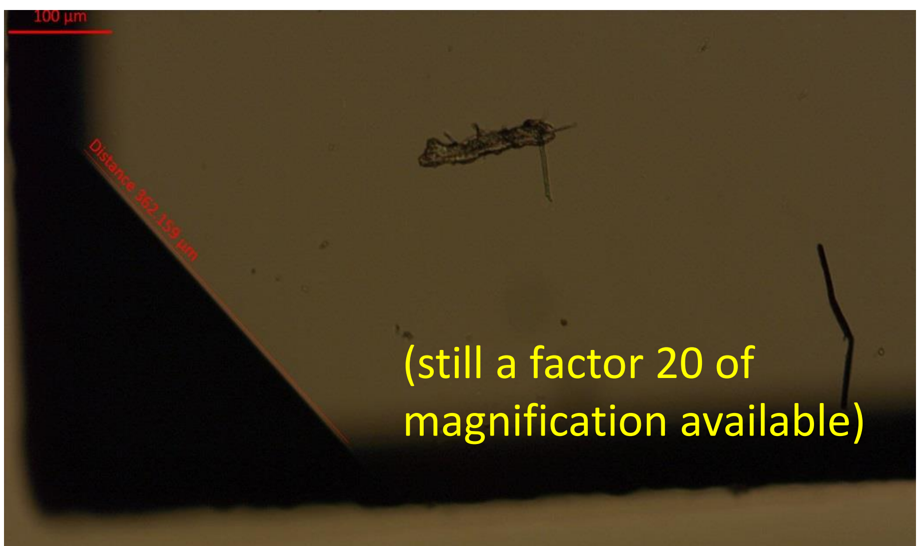
# Optical test setup

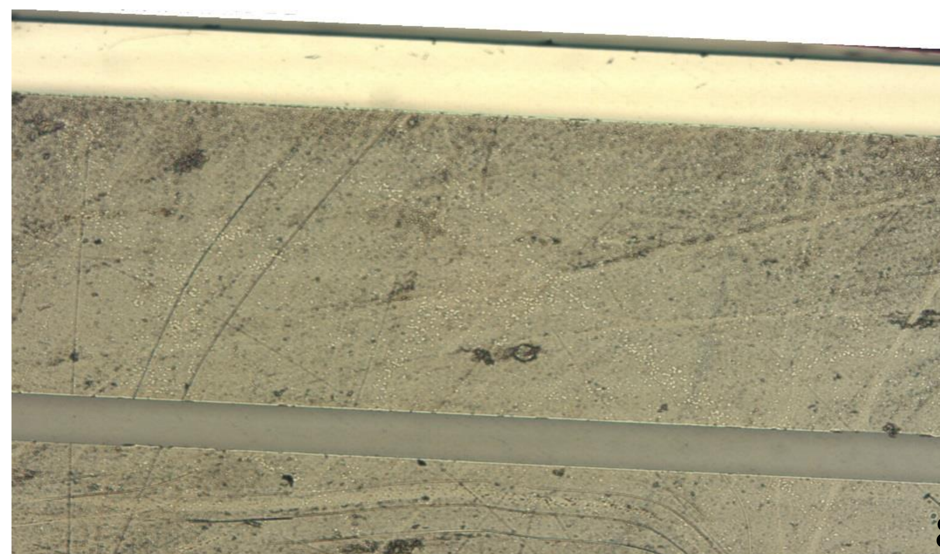
## Optical $\mu$scope (down to 200nm) with CCD




Diamonds have to be cleaned in advance (cleaning materials available in the laboratory)

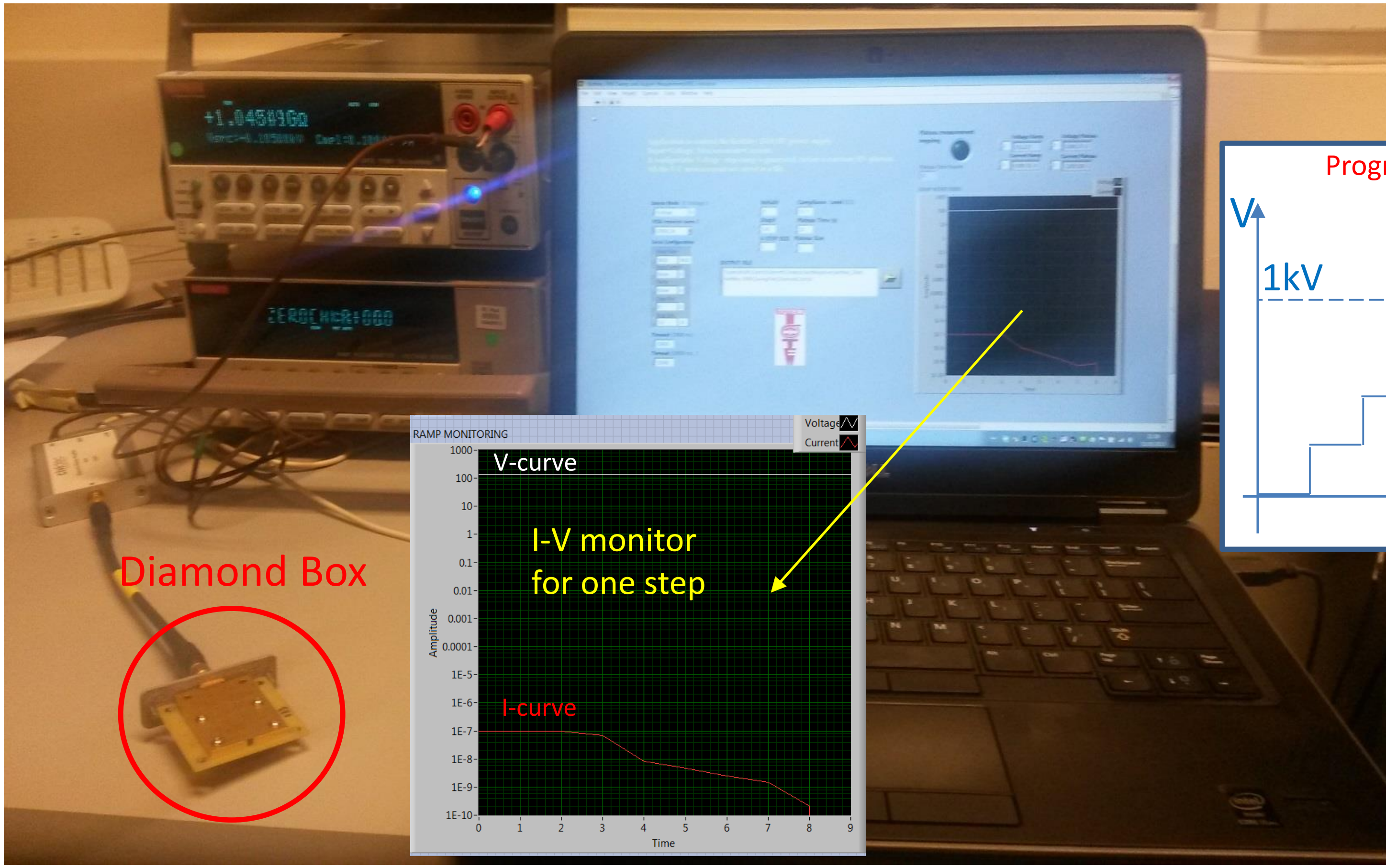


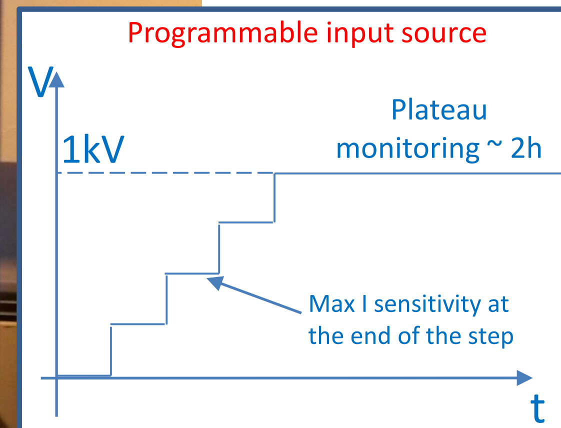


# Electrical test with a source

- A Labview program has been developed to systematically measure the IV curve (needed by the vendor as replacement condition)

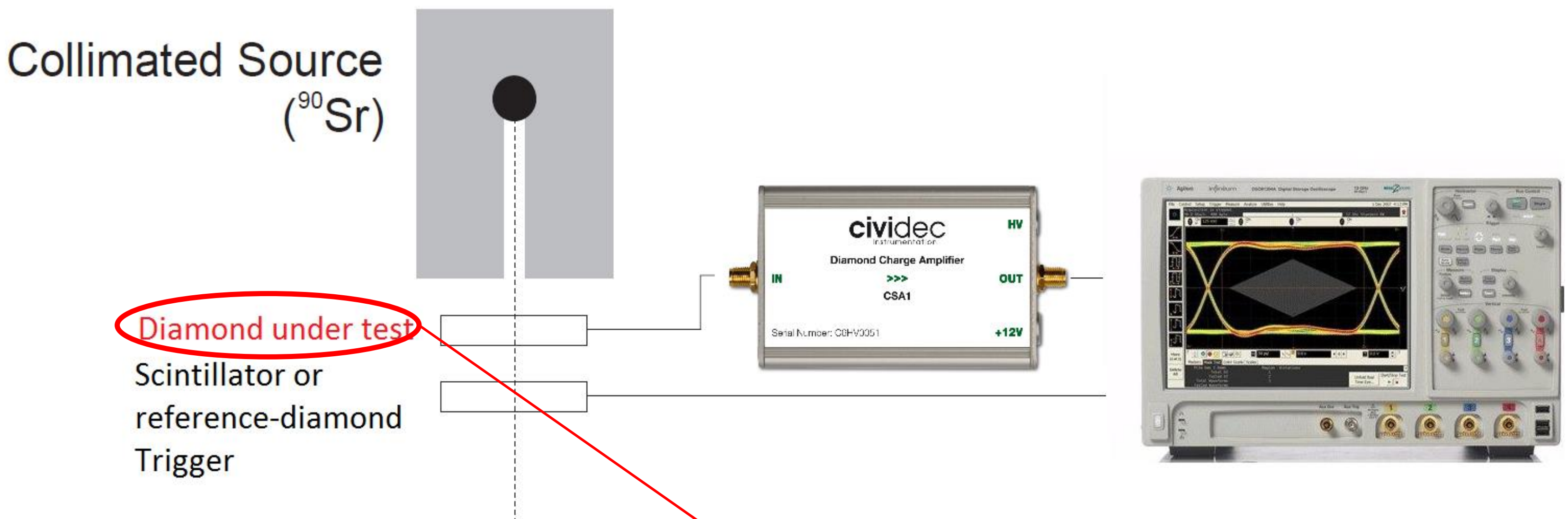


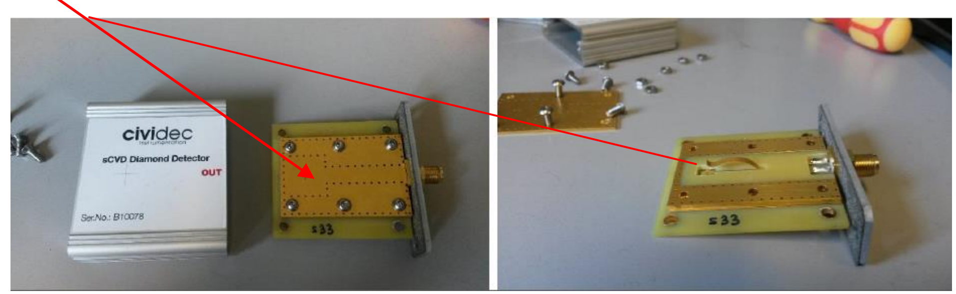

- The full IV curve resulting from a raising V-stair is saved in a file. At 1KV, a good diamond should have a leakage current of about  1nA

# Electrical test with a source

- We have obtained a new stronger radioactive source (Sr-90 - 36.56 MBq) from the RP
- Diamond passing the HV test should have a S/N ratio compatible with the one of the reference diamond
- This source will be also used to make a stability test on the S/N under “high” rates




Verification at the μscope that the metalization is not ruined by the metallic contact:

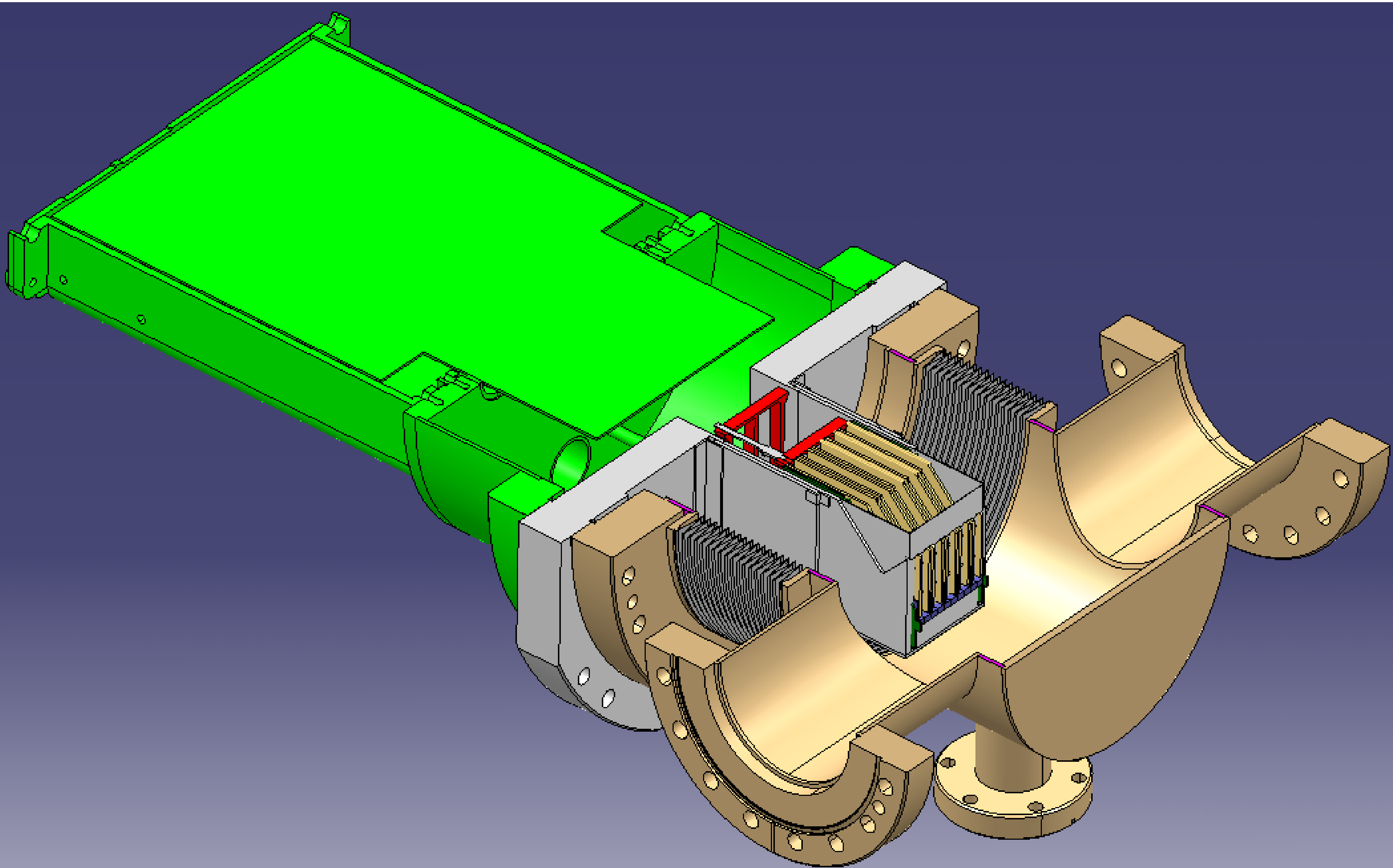


# Conclusions

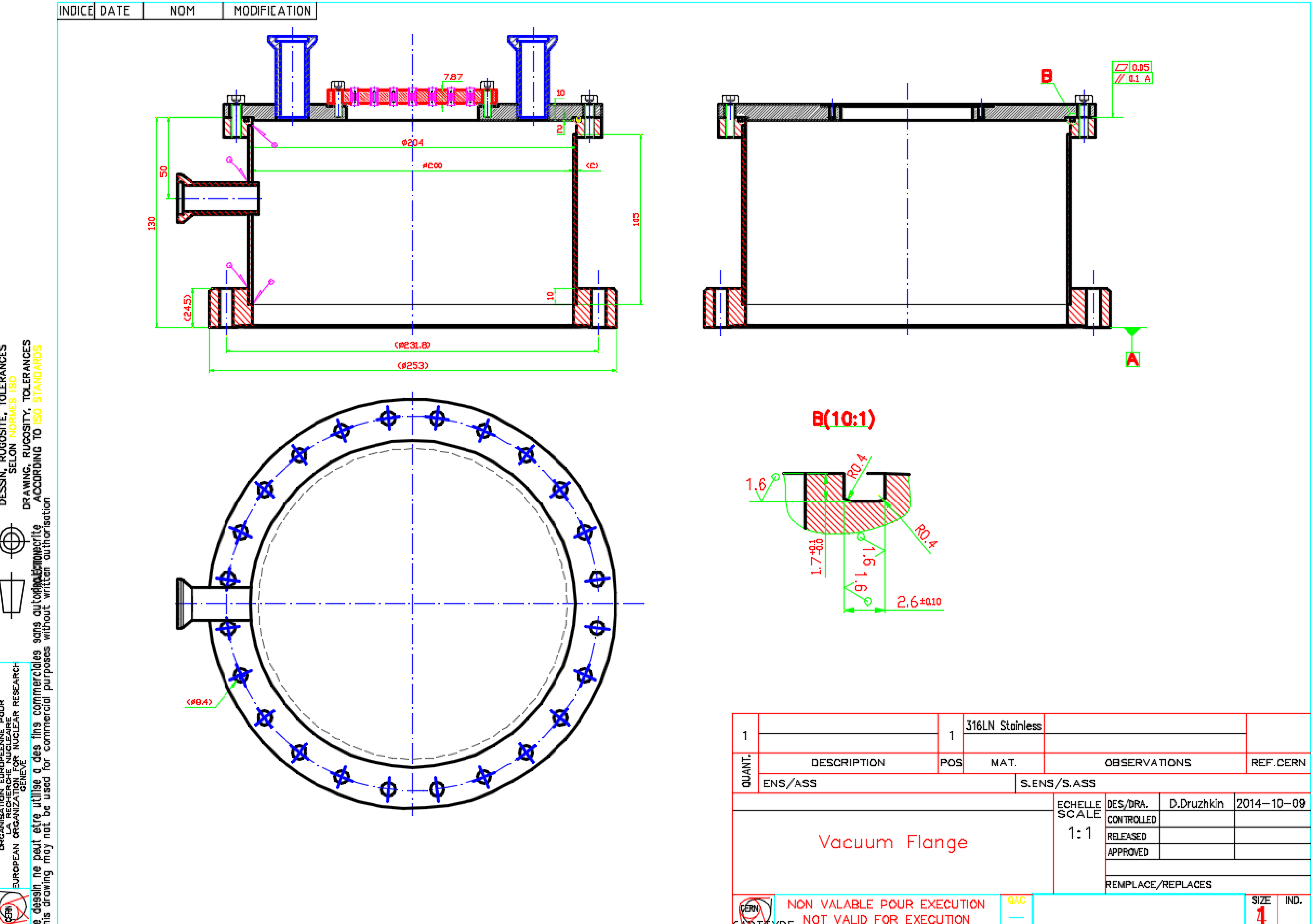
- The TOTEM diffractive physics program, in order to get rid of the pileup at higher luminsity, requires a time of flight measurement of the scattered protons.
- The time of flight measurement of the protons impinging in the Roman Pots area with a time resolution of 50ps, together with the improved track measurement allows to reach moderate luminosities with a pileup of the order of $\mu$~1.
- We have developed a detector based on diamond sensors with a special front-end electronics that have a time resolution from 80ps to 110ps depending to the pixel capacitance.
- We are in the process to build a full timing telescope with 4 layers that will be installed between 2015/2016.
- Next year we will request a special high beta run with the largest bunch intensities and ~1000 bunches to fulfill our physics requirements.

# Backup

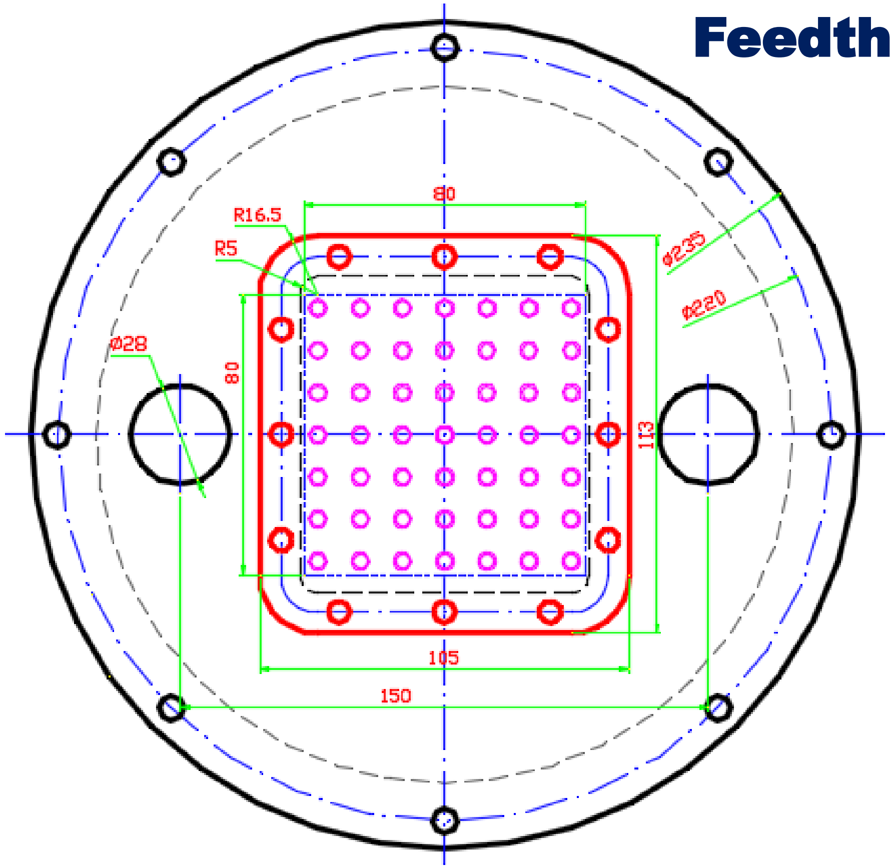
# Present design (rectangular housing) in the “garage” position

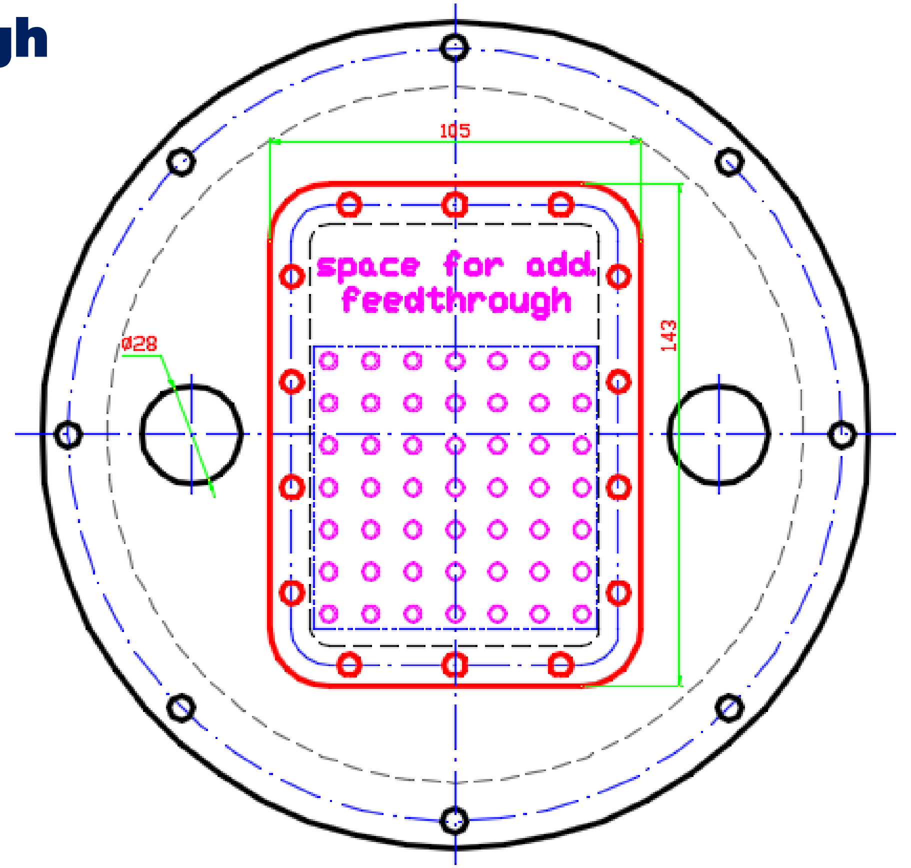


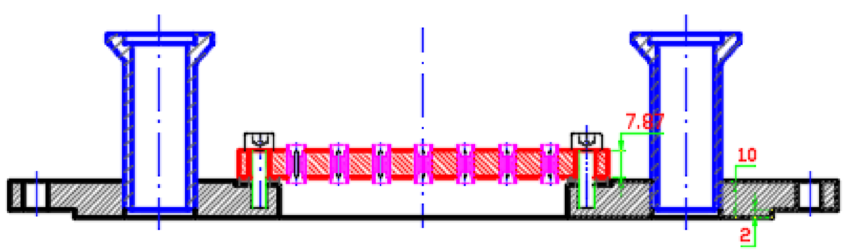
# Vacuum Cup

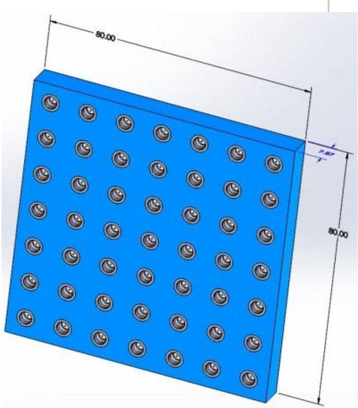

INDICE DATE NOM MODIFICATION
7.87
10
2
ø204
ø200
(2)
50
130
105
(24.5)
10
(ø231.8)
(ø253)
B
0.05
0.1 A
A
B(10:1)
1.6
R0.4
R0.4
1.6
1.6
2.6±0.10
(ø8.4)
1
1
316LN Stainless
QUANT.
DESCRIPTION
POS
MAT.
OBSERVATIONS
REF.CERN
ENS/ASS
S.ENS/S.ASS
ECHELLE SCALE
1:1
DES/DRA.
D.Druzhkin
2014-10-09
CONTROLLED
RELEASED
APPROVED
Vacuum Flange
REMPLACE/REPLACES
NON VALABLE POUR EXECUTION
NOT VALID FOR EXECUTION
CARTTYPE
SIZE
IND.
4
DESSIN, RUGOSITE, TOLERANCES SELON NORMES ISO
DRAWING, RUGOSITY, TOLERANCES ACCORDING TO ISO STANDARDS
Ce dessin ne peut être utilisé à des fins commerciales sans autorisation écrite
This drawing may not be used for commercial purposes without written authorisation
ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE
EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
GENEVE

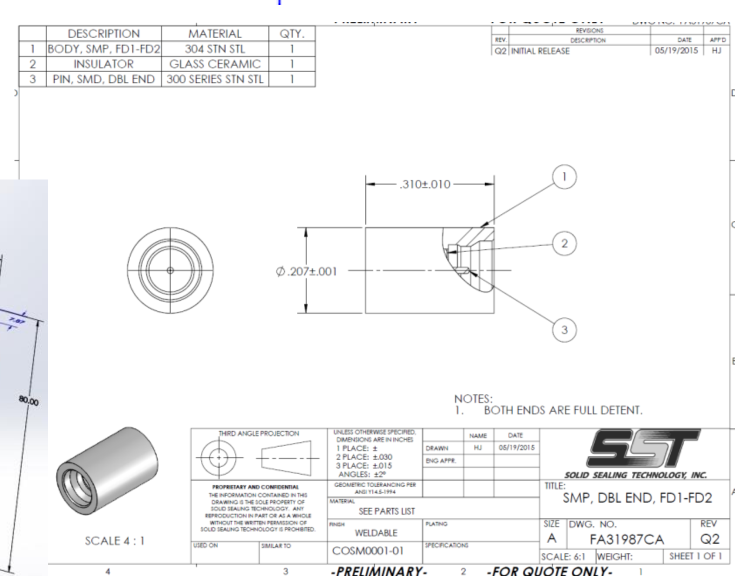
# Feedthrough



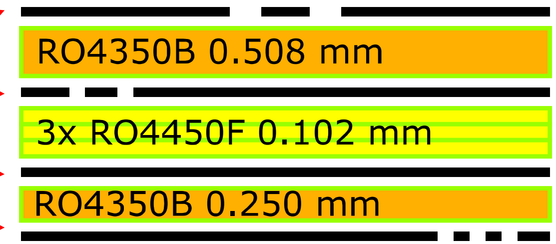



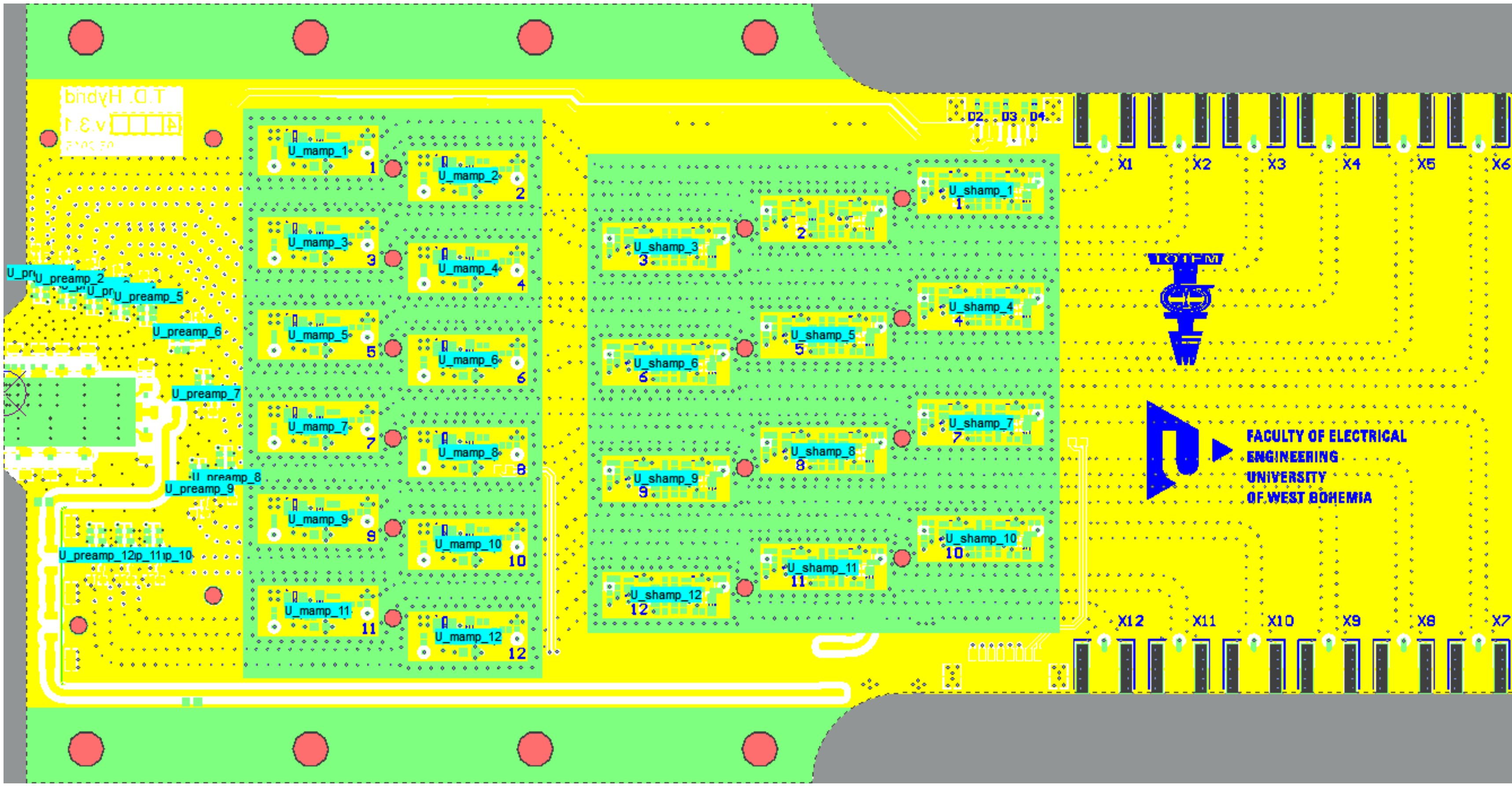
# The PCB Design

- 4 layers on RO4350B/RO4450F
  - TOP – ground plane + microstrip layer + components
  - IN2 – striplines + ground plane
  - IN3 – low impedance ground plane
  - BOTTOM – power distribution + HV + auxiliary traces



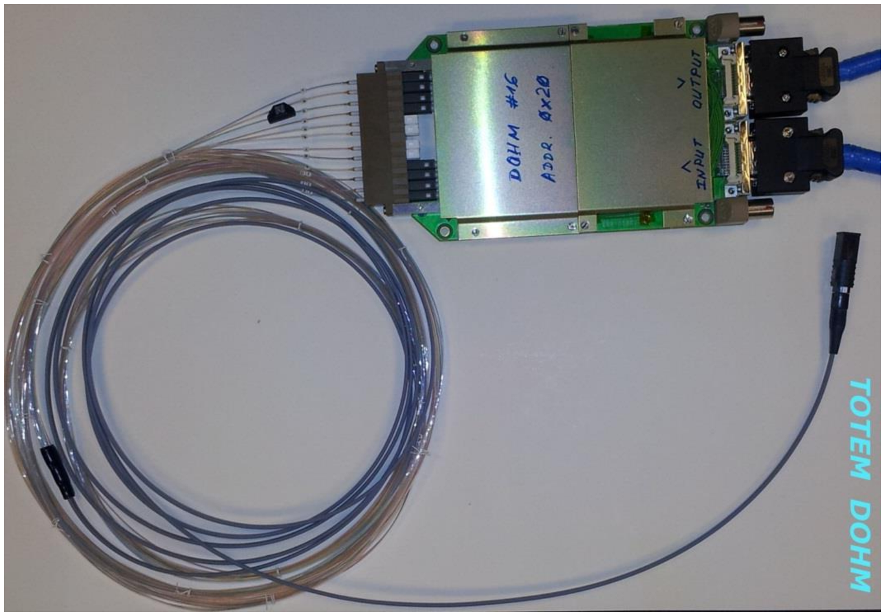

- Layer stack allows us
  - 10 mil offset striplines as 50Ω signal traces
  - 29 mil microstrips for 50Ω
  - Highest impedance 5 mil, near 150Ω microstrips (diamond)
- Board layout and transmission block placement
  - Preamps – near the diamond as possible
  - Main amps + attenuators – in configuration 2 x 6 under metal box
  - Shaping amps – in configuration 3 x 4 under metal box
  - Voltage regulators – not on the board (lower power loss and board heat)

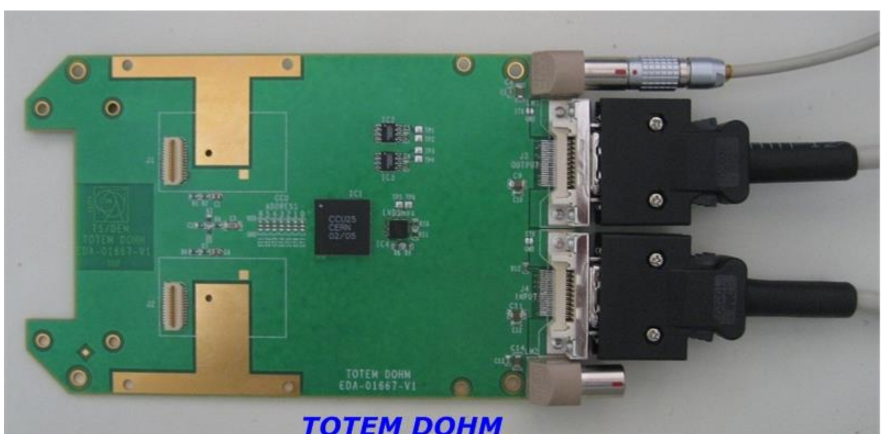
# The Board Layout

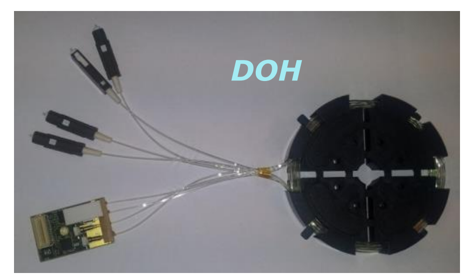



Blue numbers denotes channels.

# DOHM mezzanine



# The Sampic Chip

- Internal discriminators on all channels (with indiv. thresholds).
- 64 fully recorded samples (no dead zone).
- High bandwidth design.
- Reset before write (ghosts pulses removal).
- Gray code ADC conversion (limitation of metastability errors).
- Wide sampling range (Fast and Slow DLL modes).
- Fully configurable by serial link.

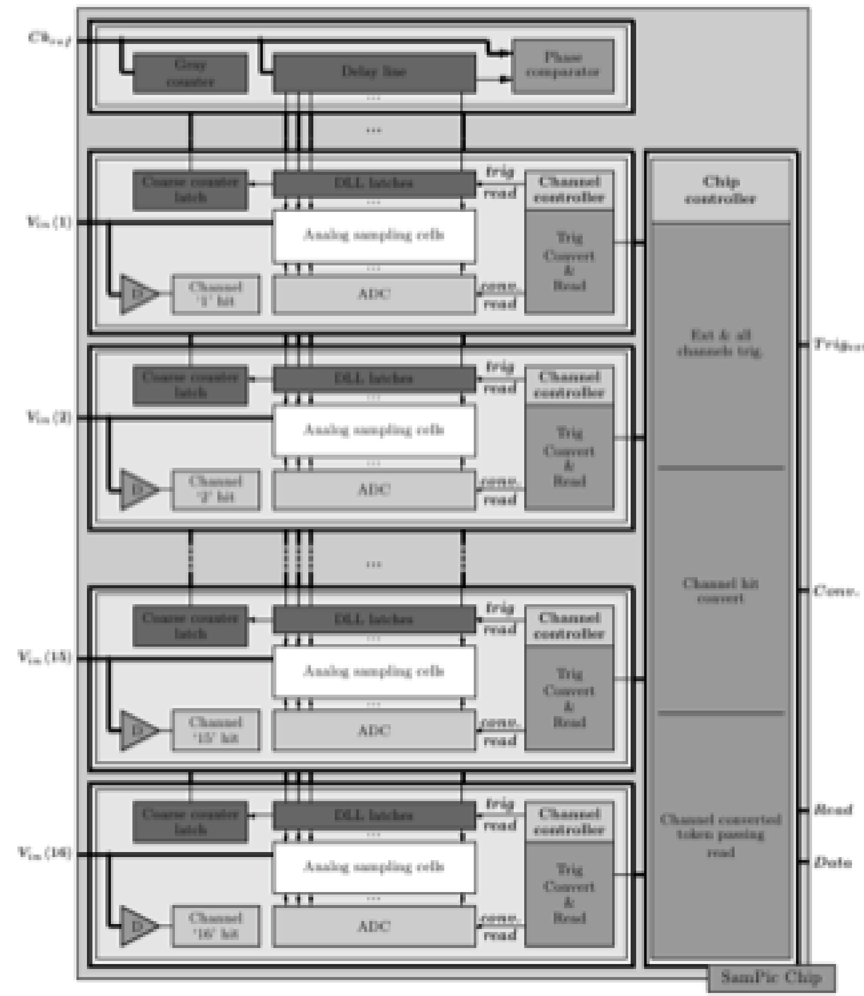



Figure 1 – Top level bloc diagram of the SamPic chip.