RPC 2018
XIV Workshop on Resistive Plate Chambers and related detectors, Puerto Vallarta, Jalisco State, MEXICO, Feb 19-23/2018

The BIS78 Resistive Plate Chambers upgrade of the ATLAS Muon Spectrometer for the LHC Run-3

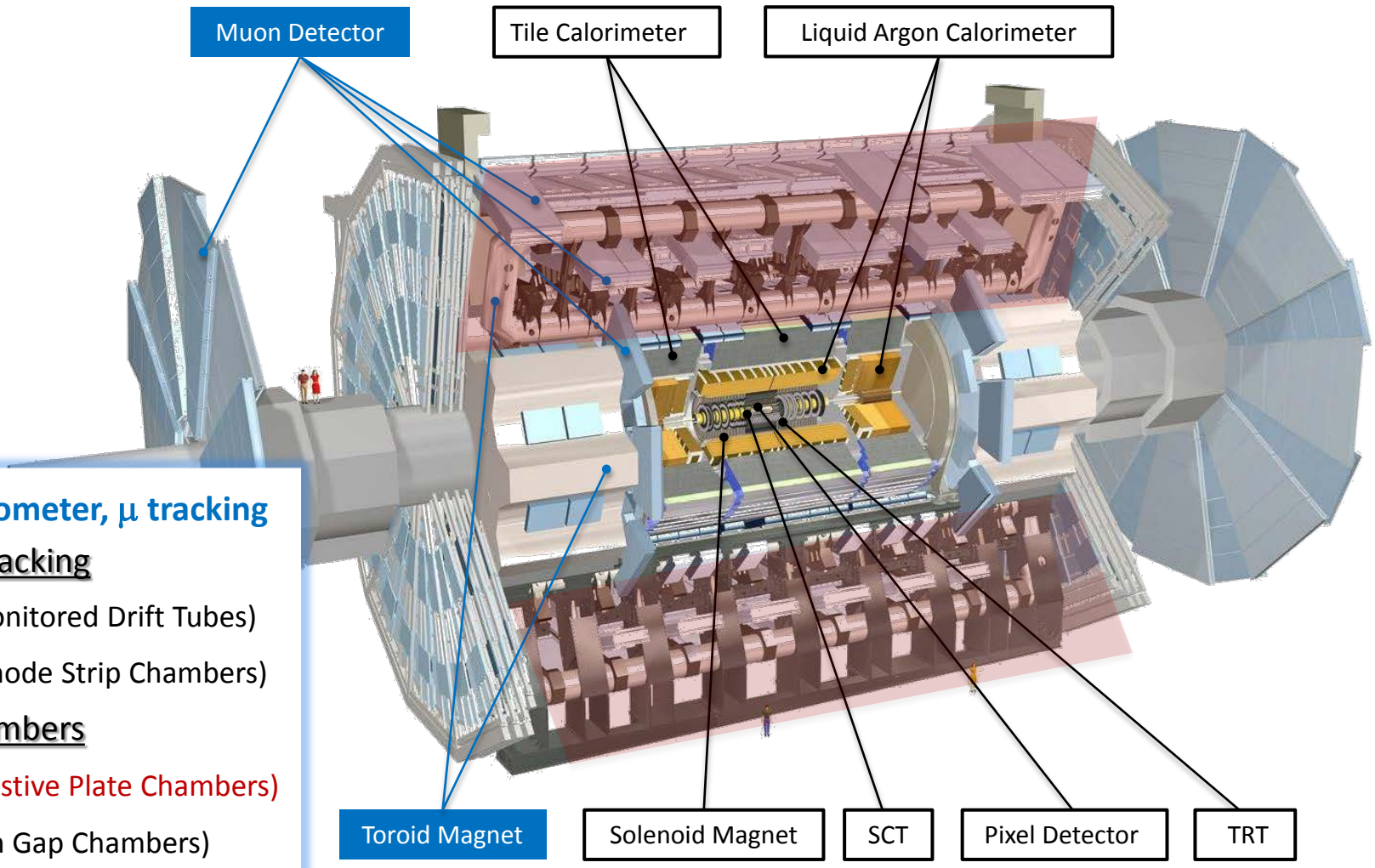
A. Polini (INFN Bologna)

on behalf of the ATLAS RPC/LVL1 Community

Outline:

- Introduction
  - ATLAS, Upgrade
- BIS78 Chambers
  - R&D towards the final prototypes,
  - chamber design, tests, electronics, DAQ,
  - preparations, installation, schedule
- Conclusions and Outlook

The ATLAS Detector

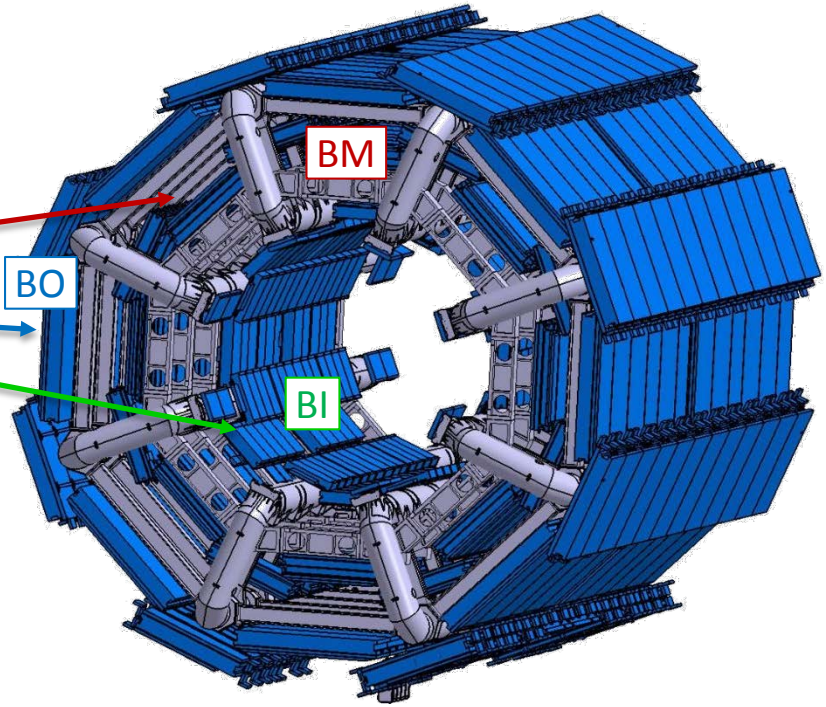


Muon spectrometer, μ tracking

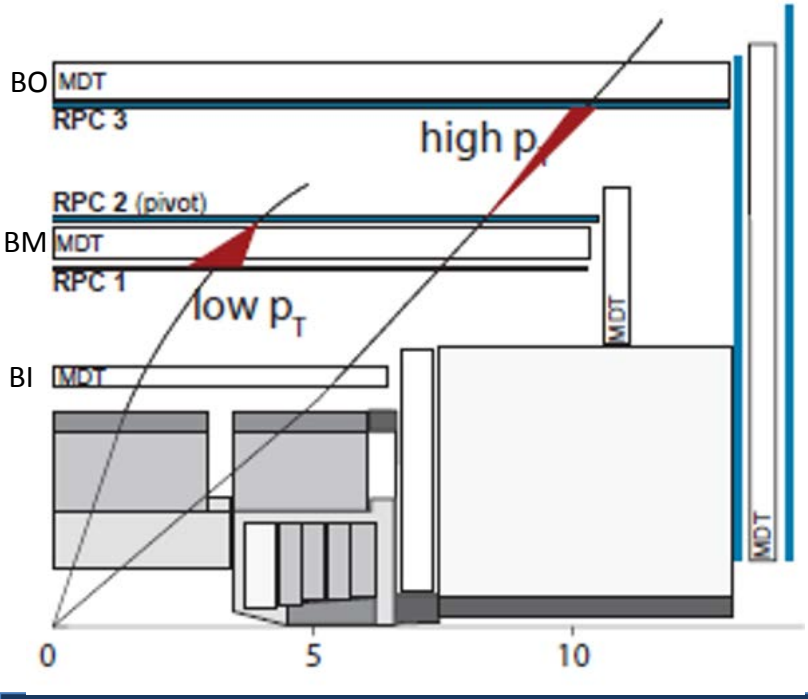
- Precision tracking
  - **MDT** (Monitored Drift Tubes)
  - **CSC** (Cathode Strip Chambers)
- Trigger chambers
  - **RPC** (Resistive Plate Chambers)
  - **TGC** (Thin Gap Chambers)
- Toroid Magnets

Present RPC Trigger System

- RPC System Coverage |η|<1.05
  - Three Concentric Stations
    - 2 in barrel middle (BM) region
    - 1 in barrel outer (BO) region
    - No RPCs in barrel inner (only MDT)

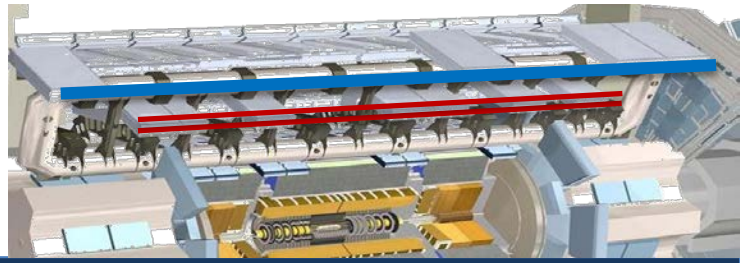


➔ Performance of existing RPCs in talks by G. Alberghi



Trigger algorithm based on RPC hit coincidence:

- **Low-p_T** trigger (p_T<10GeV) uses the two BM stations
- **High-p_T** trigger (p_T>10GeV) requires an additional confirmation on the BO station

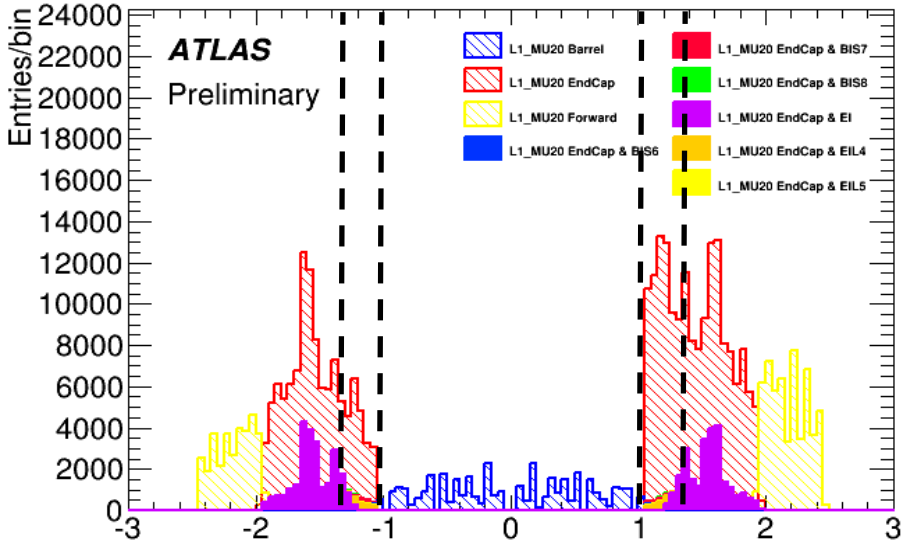


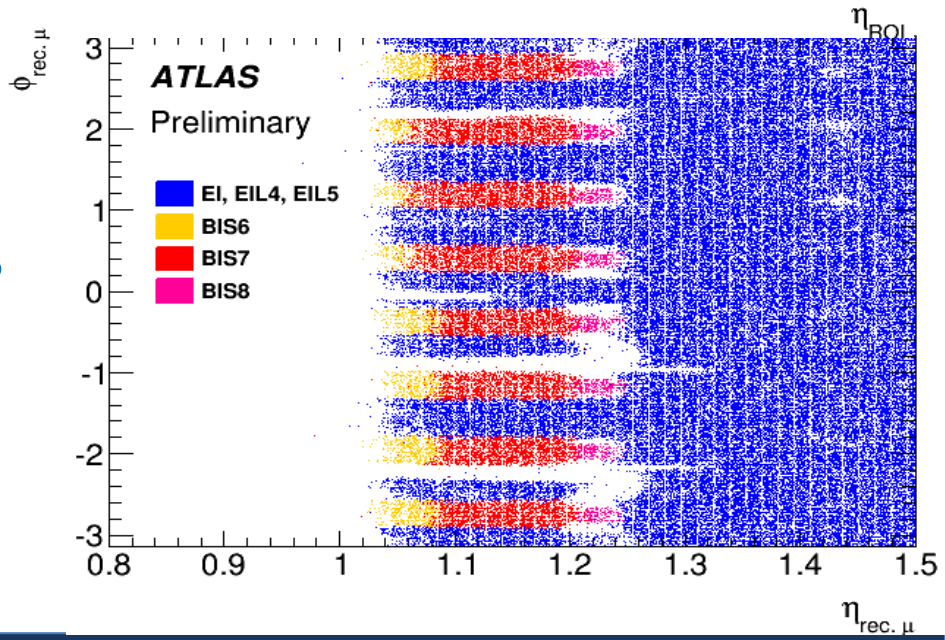
The BIS78 Project

- With the increased luminosity need to plan for a substantial reduction on fake rate in the Barrel-Endcap transition region
- Another Phase-I Upgrade (New Small Wheel, not described here) covers the region (1.3<|η|<2.7), while the existing muon big endcap wheel covers (1.0<|η|< 2.7)
- Half of the azimuthal region 1.0<|η|<1.3 is covered by the existing (EIL4) TGC end-cap trigger detectors

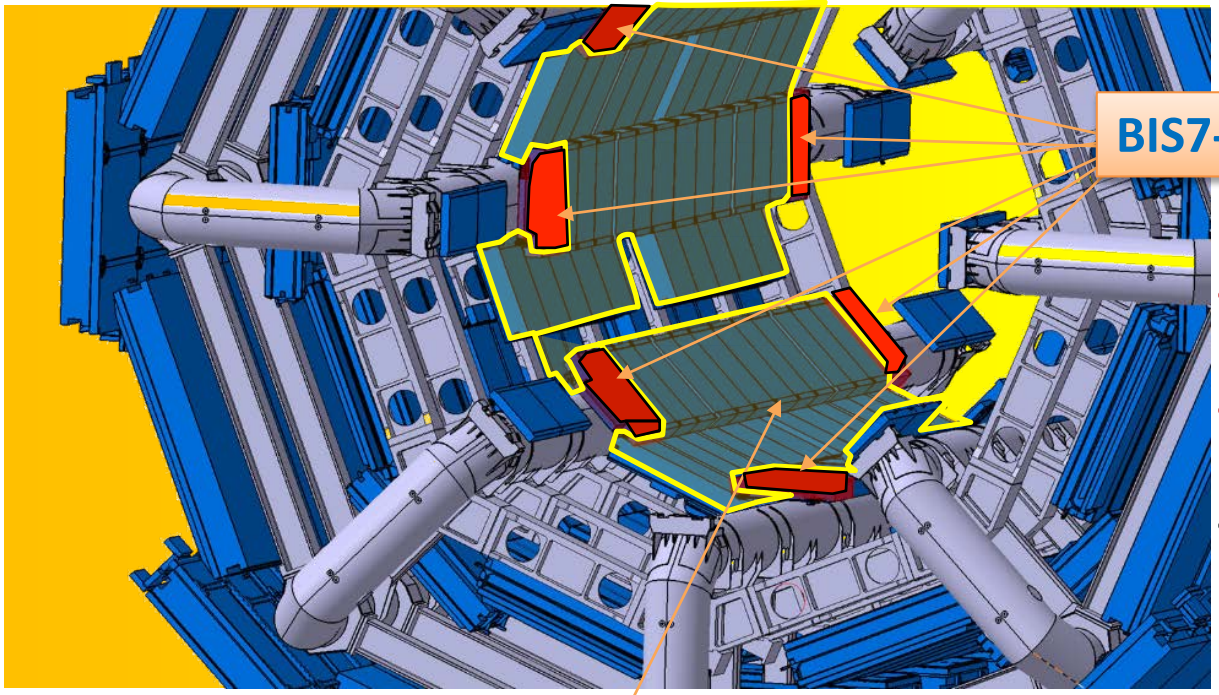
⇨ Install new detectors in the barrel BIS region to cover the other half

⇨ Pilot project for Phase-2 Upgrade: Same requirements and detector technology that will be used to equip ATLAS with a full BI layer





The RPC upgrades: BIS78 (Phase-1), BI (Phase-2)



BIS7-8 in Phase-1/Run-3 2021

RPC BIS78 project:

- 16 BIS7 ≈1820 x 1180 mm^2
  16 BIS8 ≈1820 x 440 mm^2
- 3 independent layers measuring η and ϕ
- Total surface 150 m^2

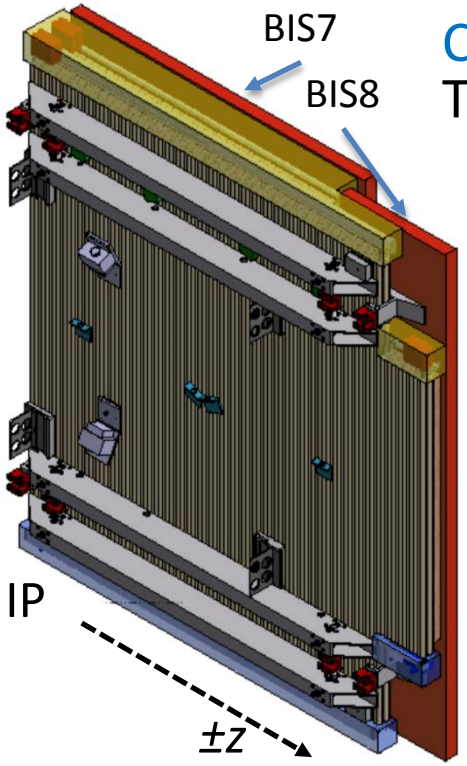
Full BI Layer for Phase-2/Run-4 2026

- 96 BIS ≈1820 x 1096 mm^2 +
  150 BIL ≈2750 x 640 mm^2
- 3 independent layers measuring η and ϕ Total surface 1410 m^2

➔ More details in the presentation by G. Aielli

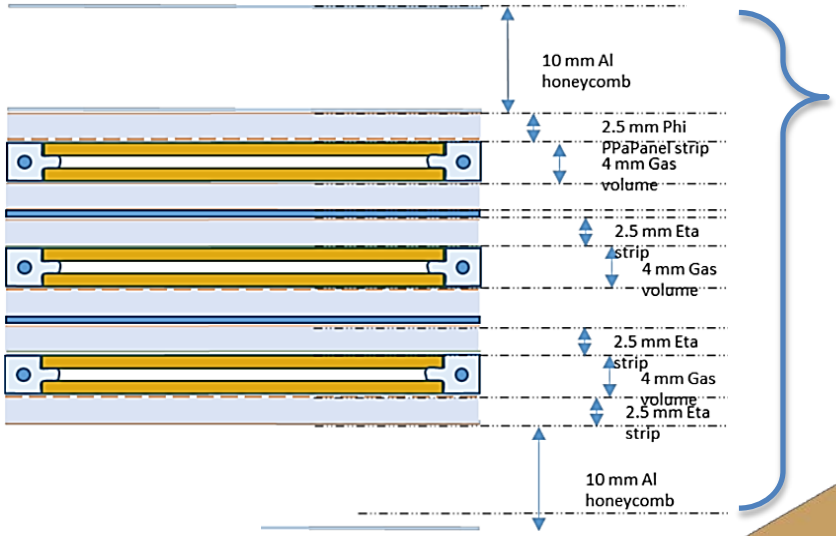
- **In the ATLAS nomenclature RPC-BIS78 are considered a Small Project**
  - **Core Cost < 0.5 MCHF**
  - **No TDR required**
- **Project approved by the ATLAS Collaboration Board in March 2015**
- **BI (and BIS78) design described in the Phase-2 Muon Upgrade TDR**

BIS78 Chamber Layout



Chamber envelopes re-defined and maximized with Technical Coordination for installation in ATLAS in Phase-1

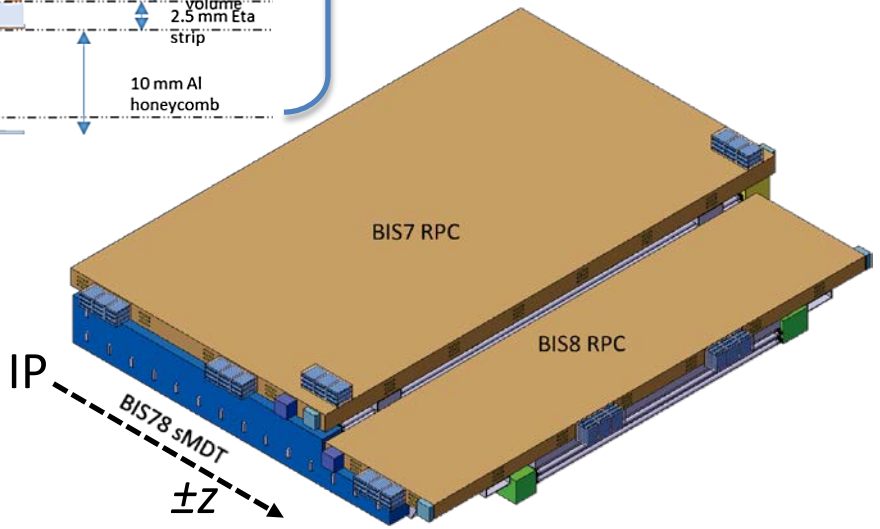
- BIS8 and BIS7 RPC with the same width (most chambers)
- Detailed mechanical layout already developed by MPI



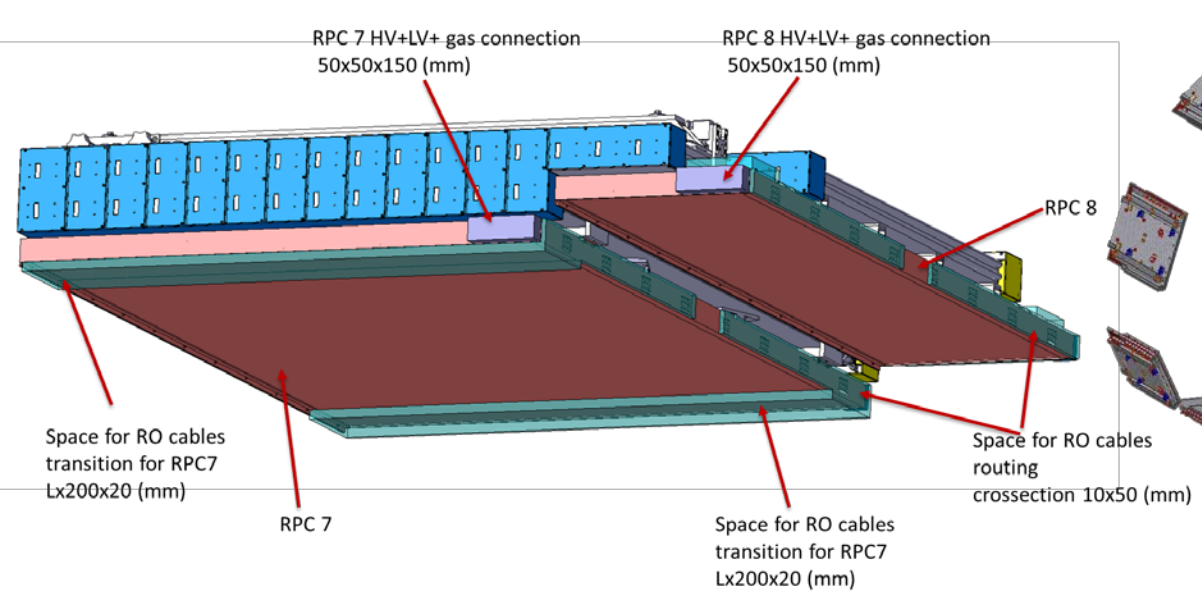
Layout:

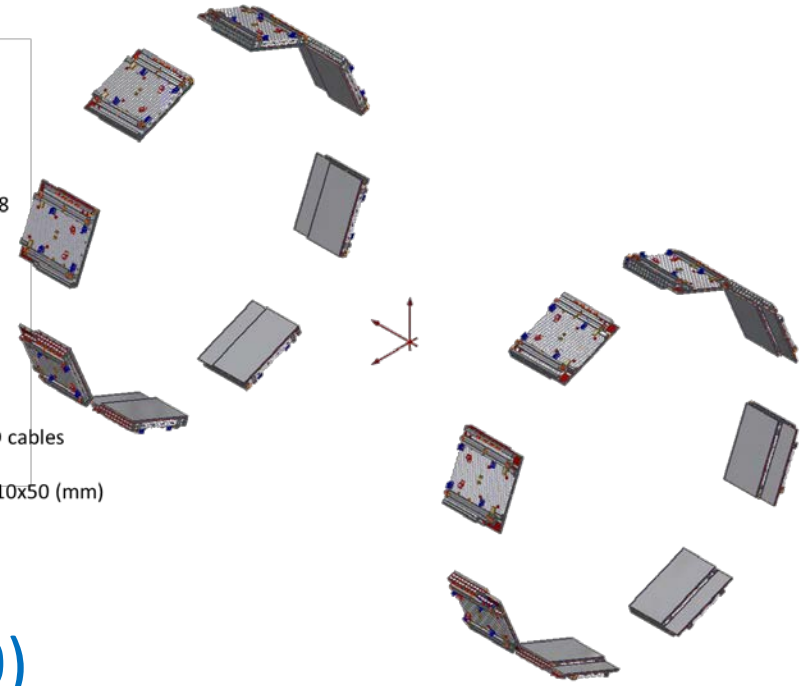
16 new muon stations replacing the 32 existing BIS7-8 MDTs. Each station made of:

- one sMDT BIS7+8 chamber
- two RPC triplets

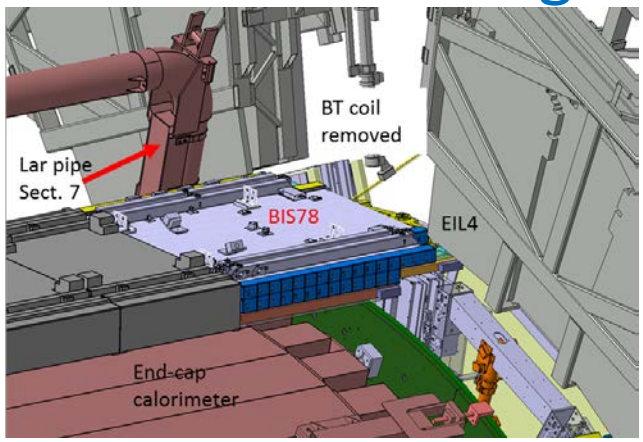


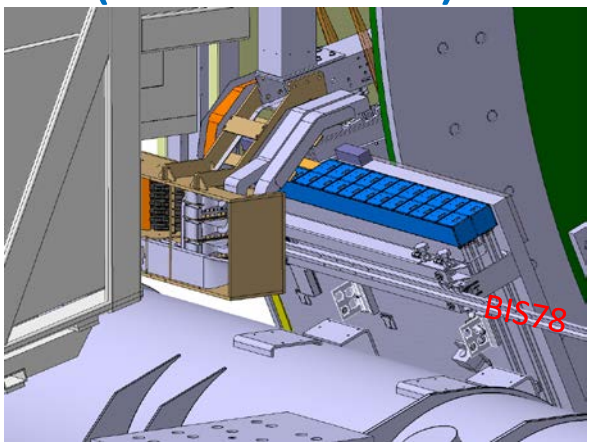
BIS78 in ATLAS

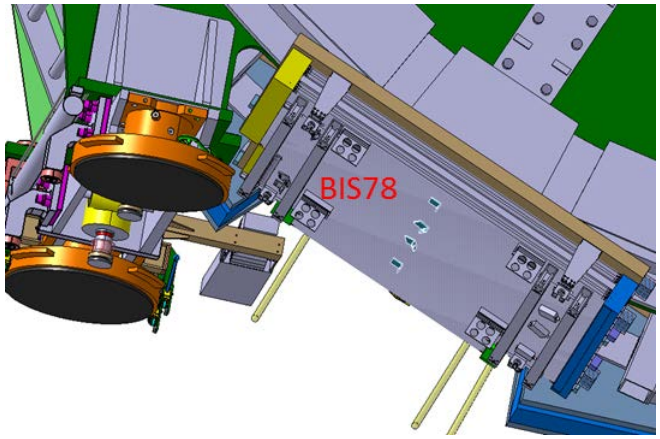




Installation during LS-2 (2019-2020)



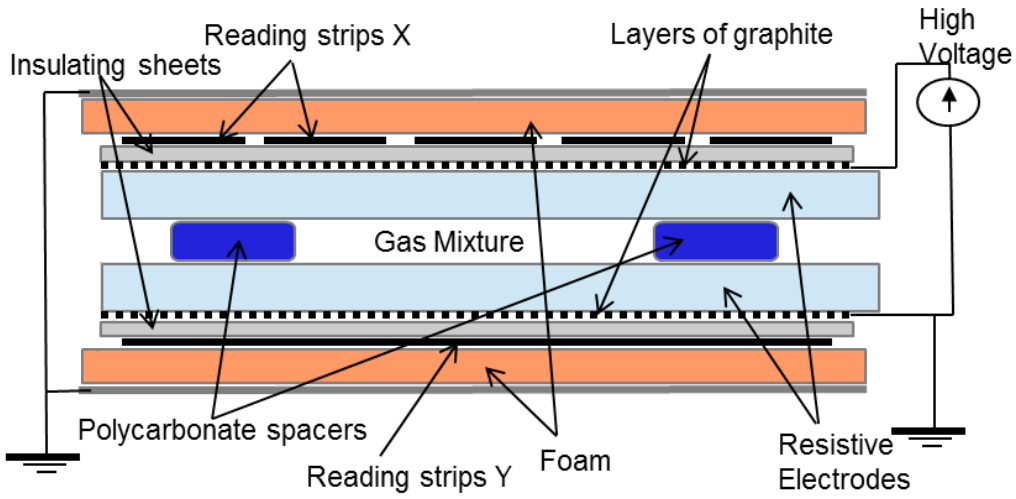




New Generation RPCs for the BIS78 Upgrade

- Thinner gas gap → improved time resolution
- Thinner electrodes → higher induced signal
- Reduced thickness and weight → easier installation
- Almost one half the current operating voltage
- Same avalanche saturation with less developed charge → improved ageing
- New Front-End electronics → Smaller detectable signals

Rate capability up to 10 kHz/cm^2

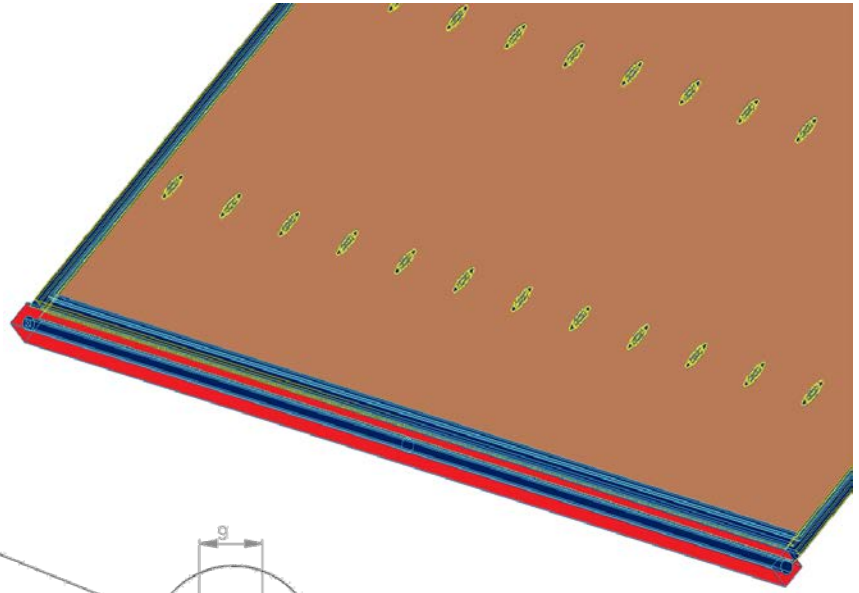


	Standard RPC	BIS78 RPC
Effective threshold	1 mV	0.3 mV
Power Consumption	30 mW	6 mW
Technology	GaAs	BJT Si + SiGe
Gap Width	2 mm	1 mm
Operating Voltage	9600 V	5800 V
Charge x hit	30 pC	5-7 down to 3 pC
Electrode thickness	1.8 mm	1.2 mm
Time resolution	1 ns	0.4 ns
Gaps per chamber	2	3

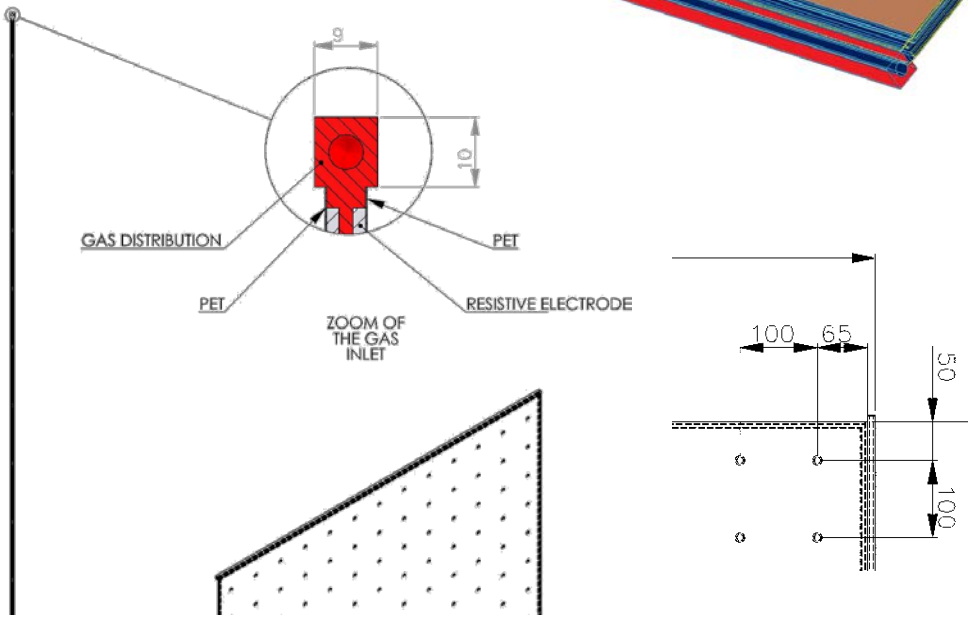
Gap Layout and Gas Connection

Gas connections:

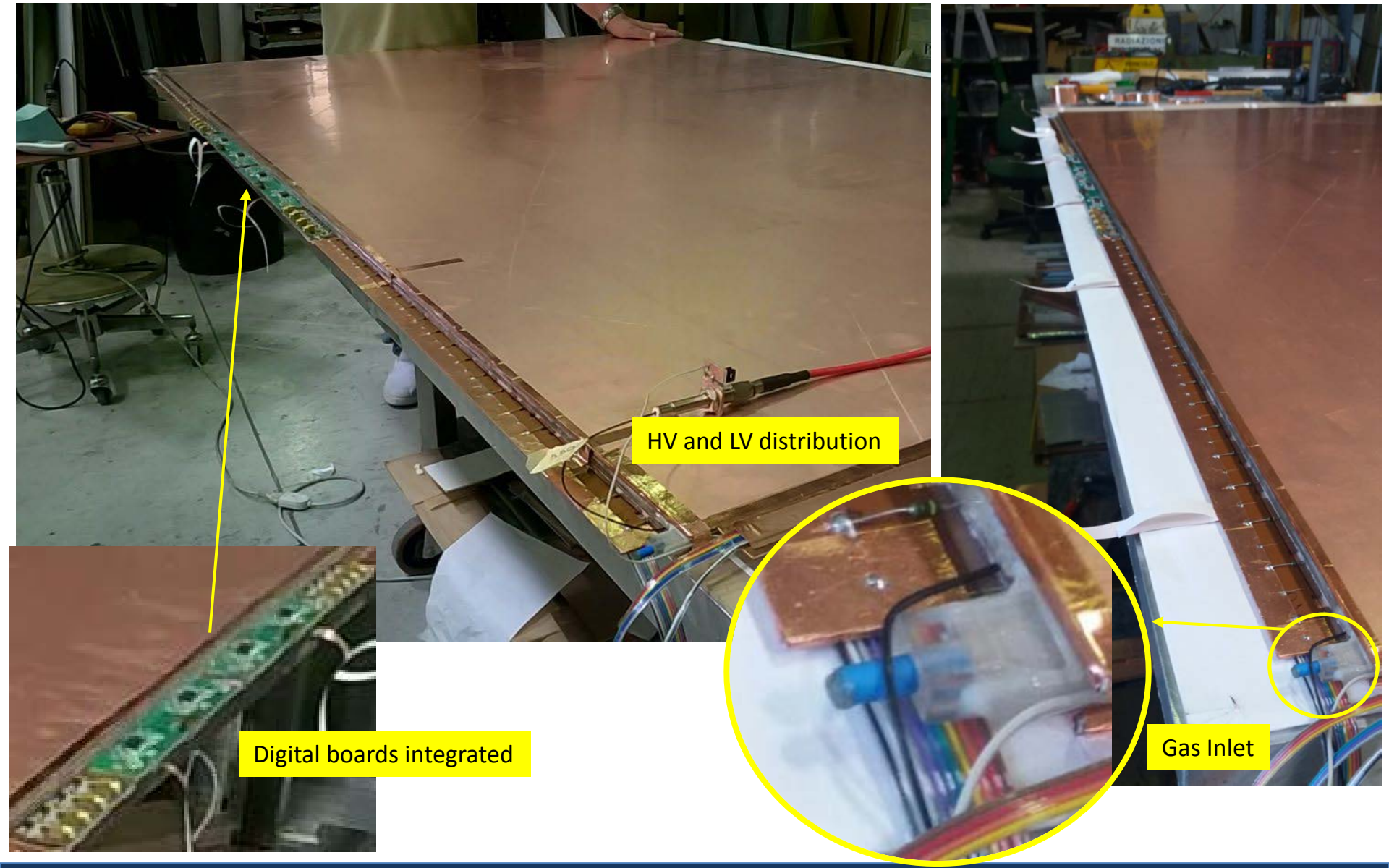
- cylindrical cavities made at two corners of the gas gaps for gas pipe insertion
- inner gas distribution channels along the short sizes of the gas gaps



- Choice used in prototypes and in BME chambers installed in ATLAS during LS1
- This overcomes already at design level possible problems with the fragility of the gas inlets observed in the legacy ATLAS RPCs.



Triplet Pre-Prototype Assembly



Triplet Prototype Assembly and Tests

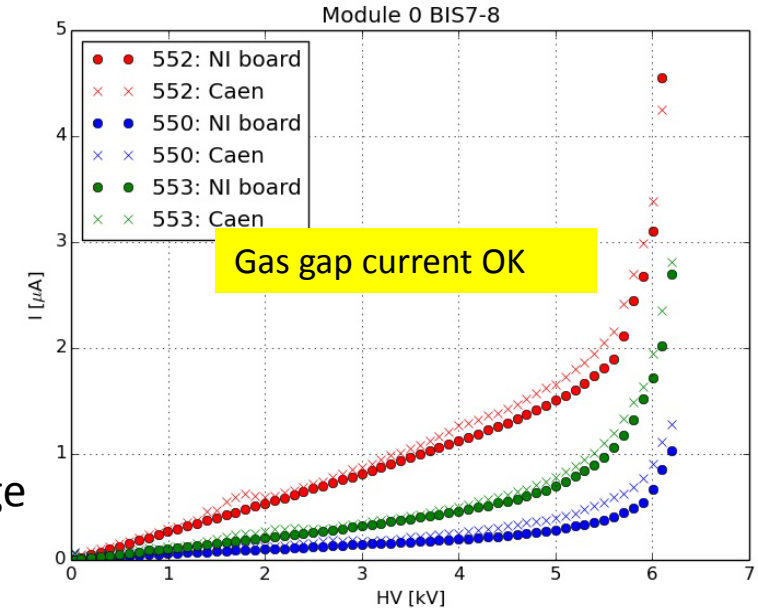
Preliminary services distribution

High-Voltage Gap Supply

Gap Current Monitoring

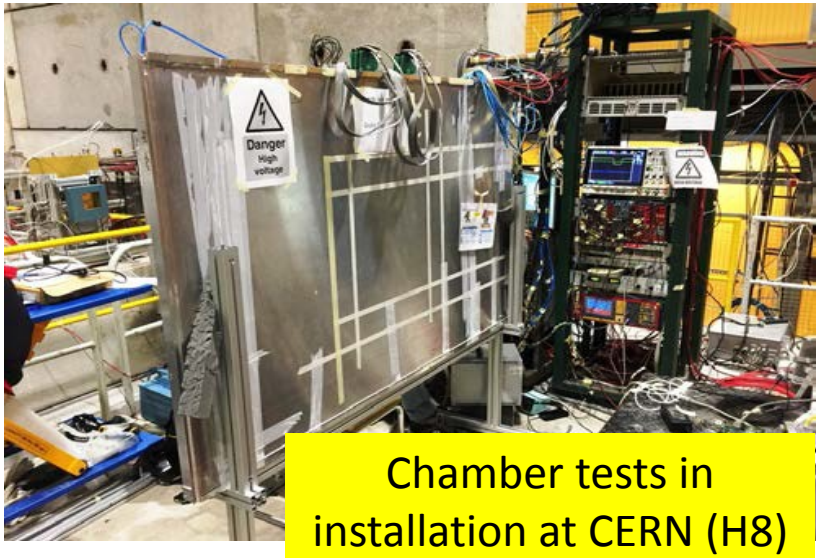
Analog Electronics Voltage Supply

Digital Electronics Voltage Supply and Thresholds



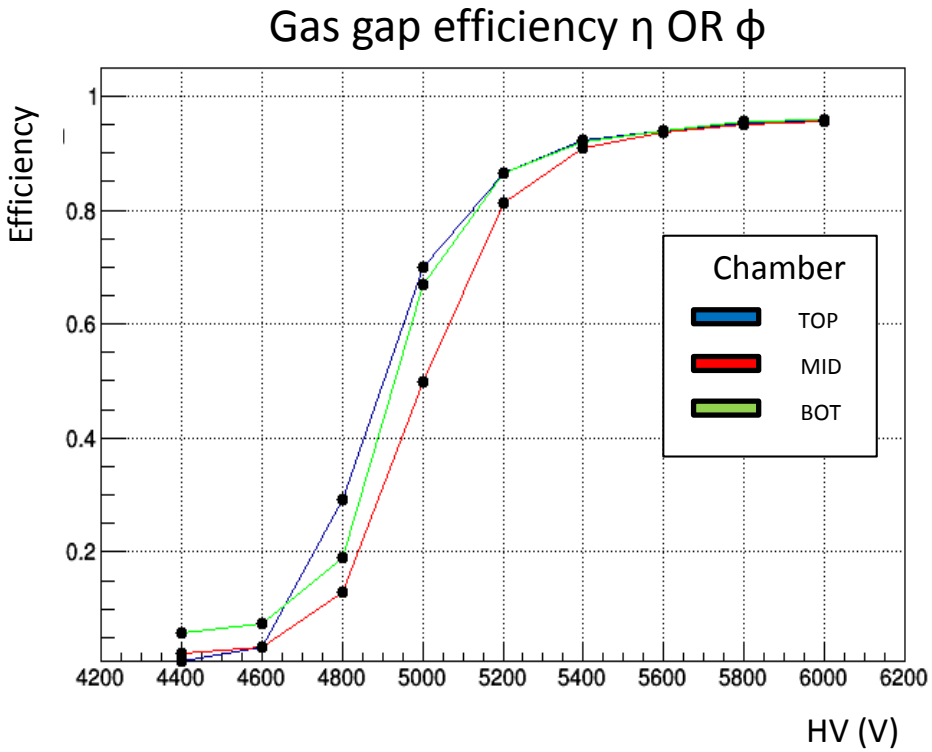
Gas gap current OK

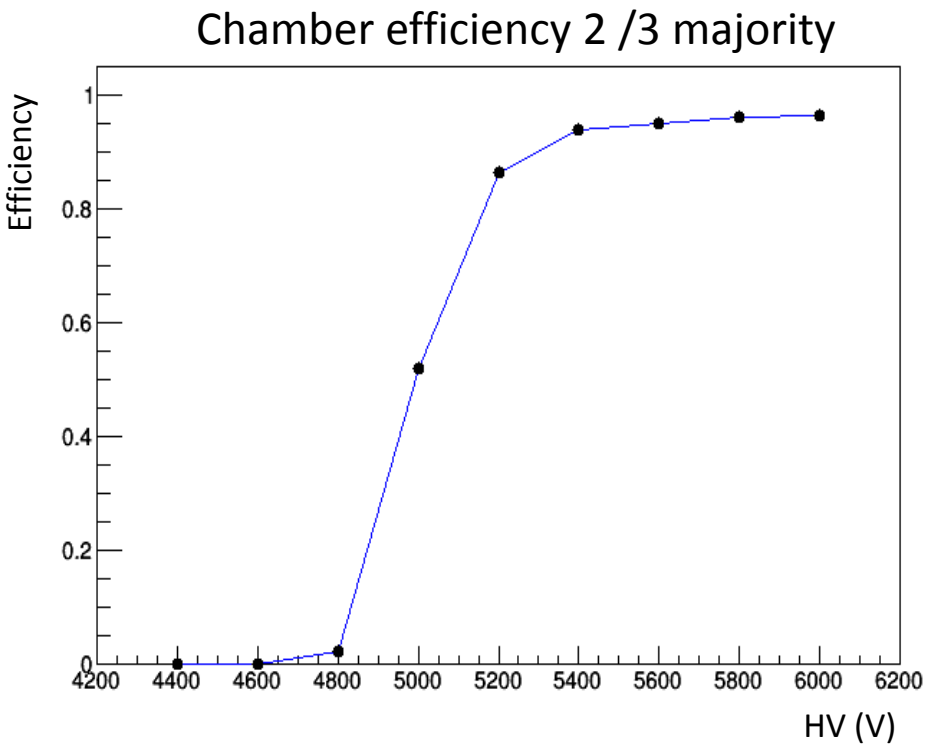
Chamber assembled and tested before shipping to CERN



Chamber tests in installation at CERN (H8)

Triplet Prototype Chamber Efficiency





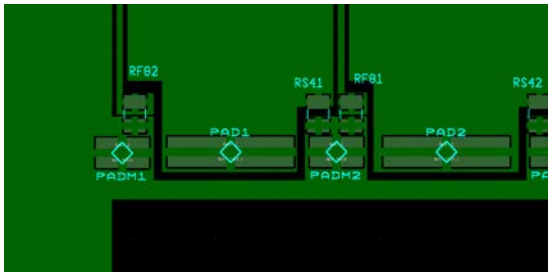
- Chamber Efficiency vs HV
- Left: Layers in OR configuration
- Right: triplet efficiency 2 on 3

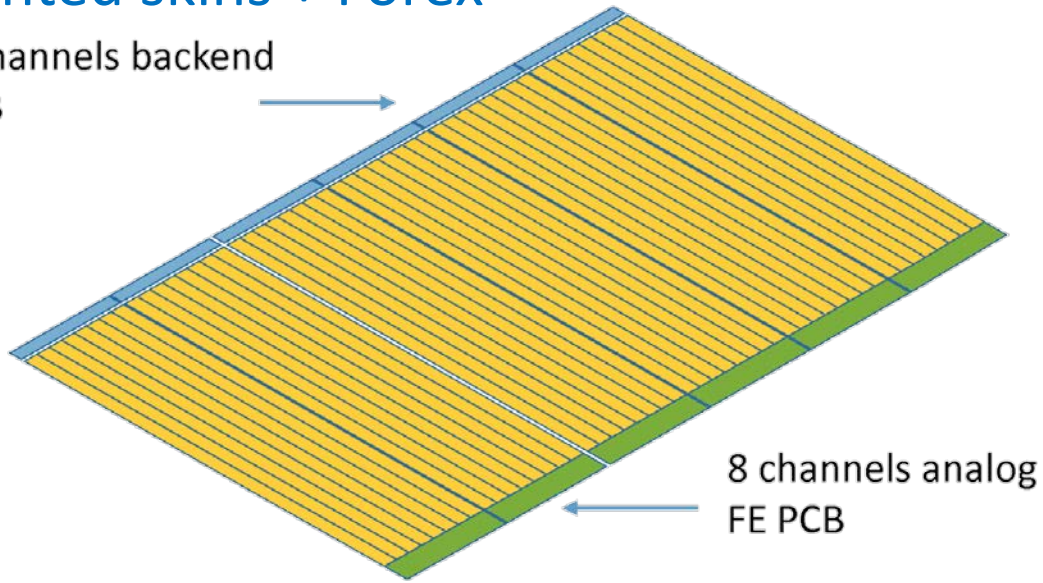
LV parameter

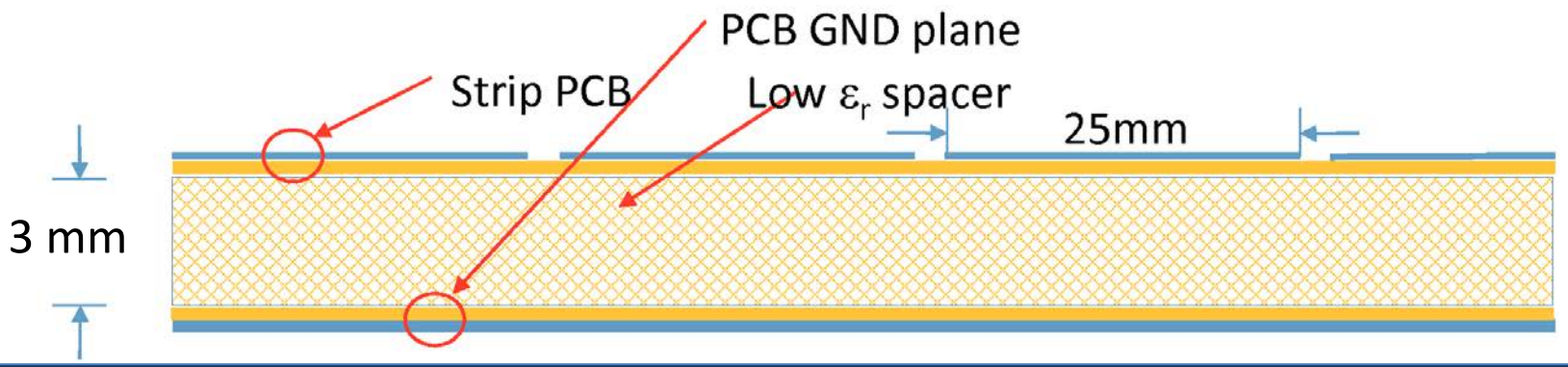
Vth = 1.6 V
Vpu = 0.4 V
Vamp= 1.5 V
Vdis = 2.5 V
Vtras= 3.5 V

The New Strip Panel Layout

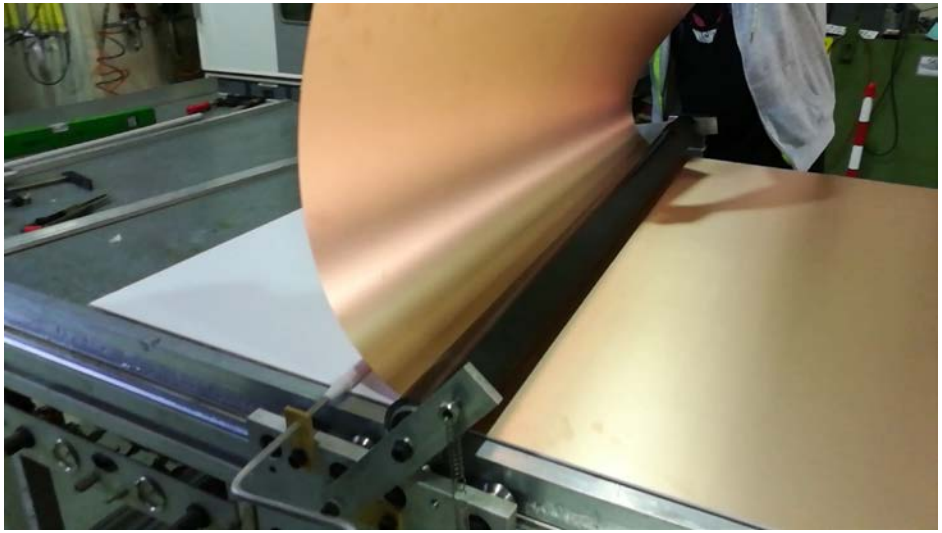
- Earlier prototypes produced similar to the present ATLAS RPCs
- Latest prototype with strip panel replacing the milled PET film by Fiberglass photo printed skins + Forex



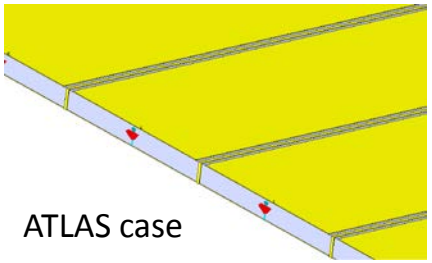


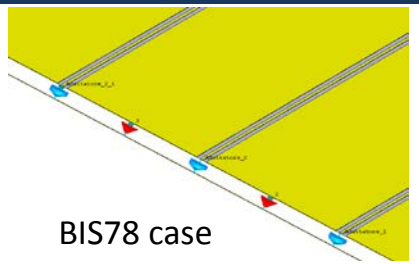


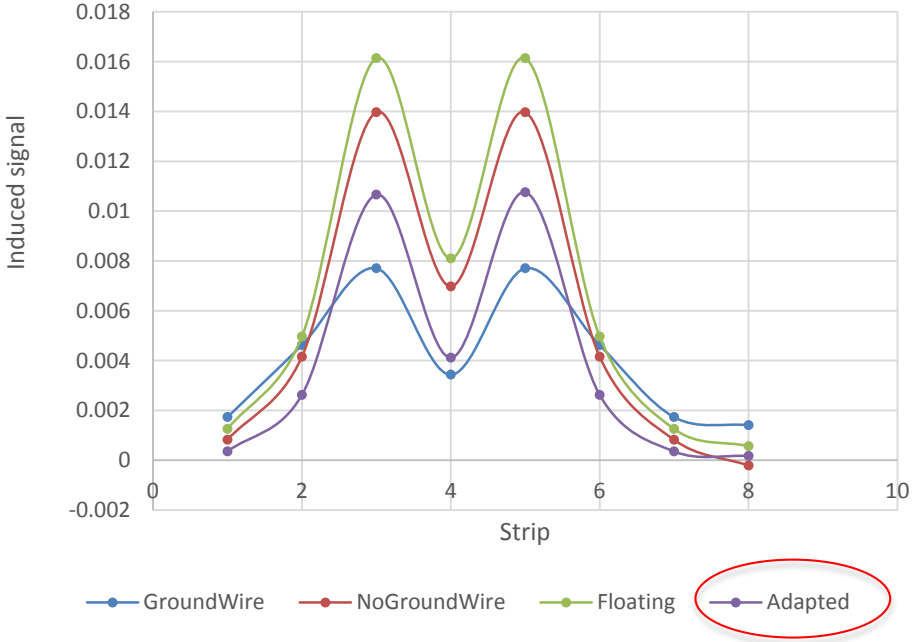
Read Out Panel Simulations



Simpler realization by using of photo printed circuit board





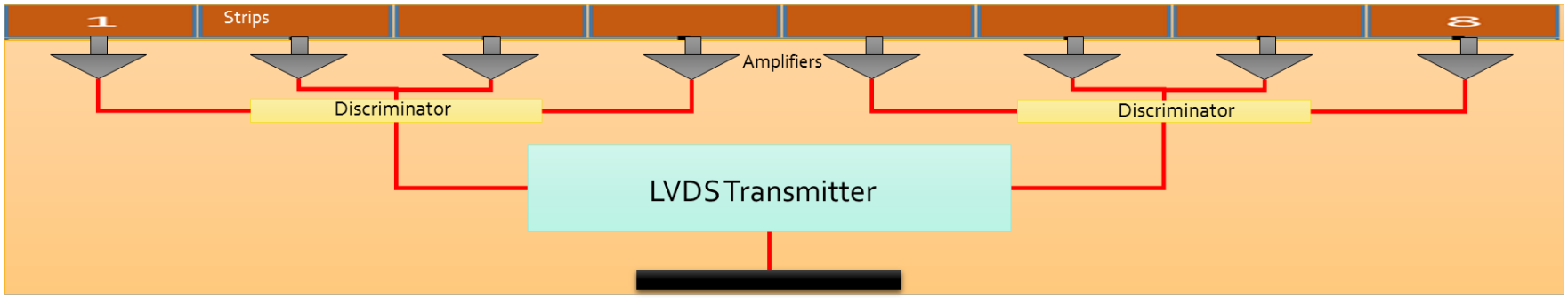


- Cross-talk simulation studies vs strip size, with and without inter-strip ground wire kept floating or with adapted impedance.
- Best result with adapted impedances

➔ Details in poster by Elio Alunno Camelia

The New Front-End Final Design

8-channels Front-End Board composed by the new amplifier, the new discriminator ASIC and the full-custom LVDS transmitter



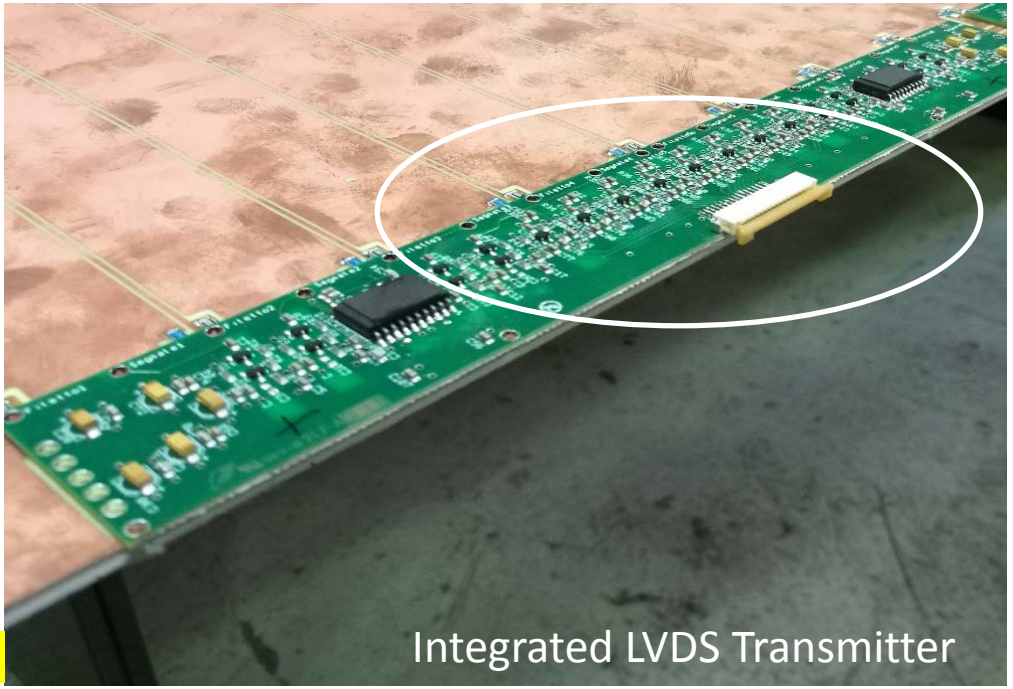
Amplifier Properties:

- Si standard component
- Amplification factor: 2-4 mV/fC
- Power Consumption: 3-5 V 1-2 mA
- Bandwidth: 100 MHz

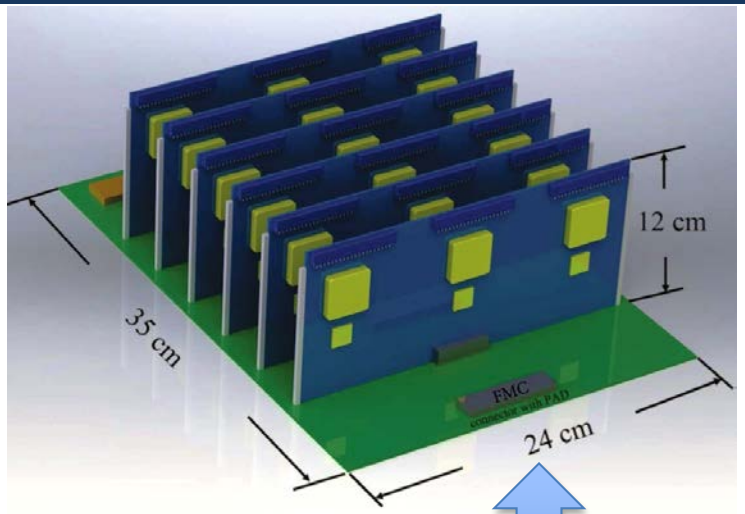
Discriminator Properties:

- SiGe full custom
- Power Consumption: 2-3 V 4-5 mA
- Threshold: 0.5 mV
- Bandwidth: 100 MHz
- Out LVDS

➔ More details on electronics see L. Pizzimento

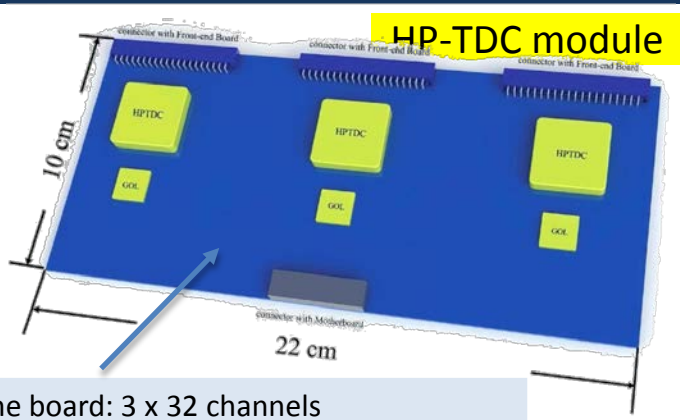

Integrated LVDS Transmitter

Front End Digitization

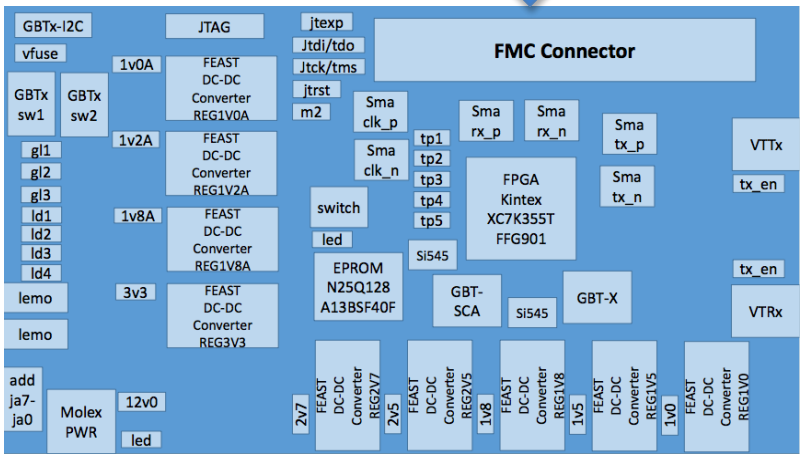


Digitization Motherboard

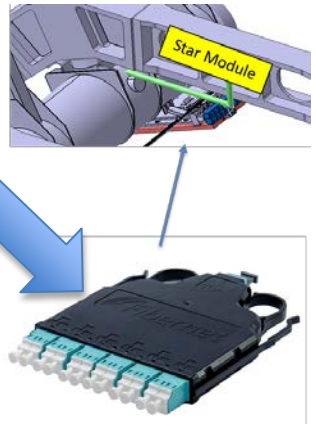
HP-TDC module

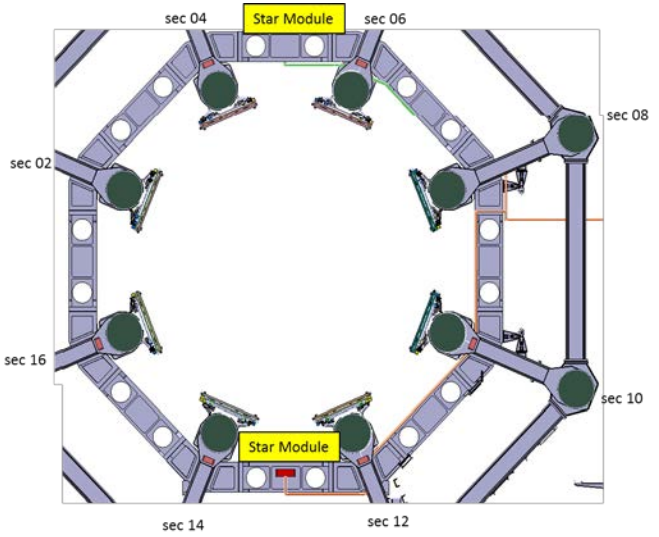


- HP-TDC mezzanine board: 3 x 32 channels
- 200 ps time resolution
- Use in leading and trailing edge: Time over Threshold
- Total latency compatible with Phase 2 requirements

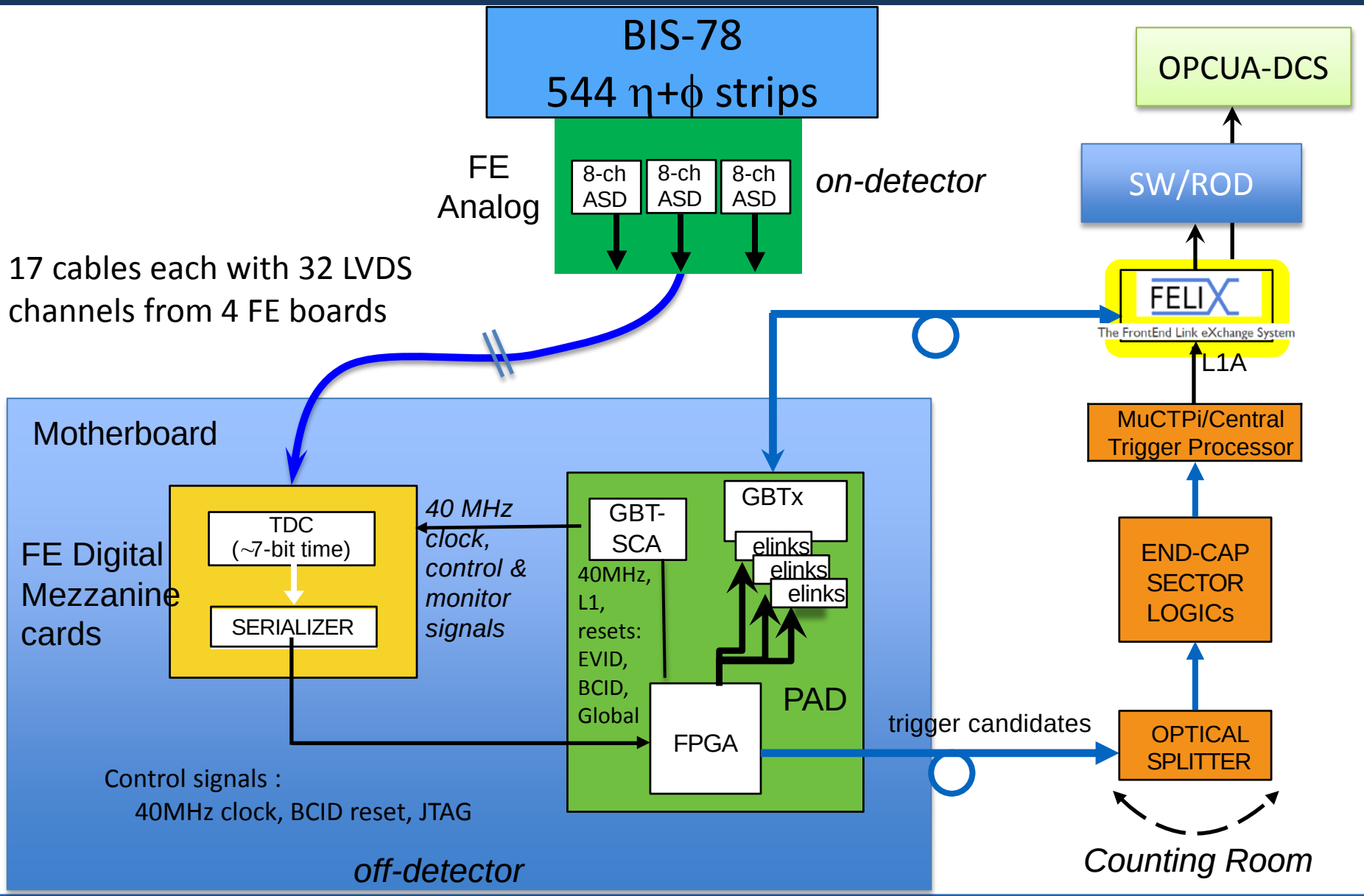


Triger Pad Board



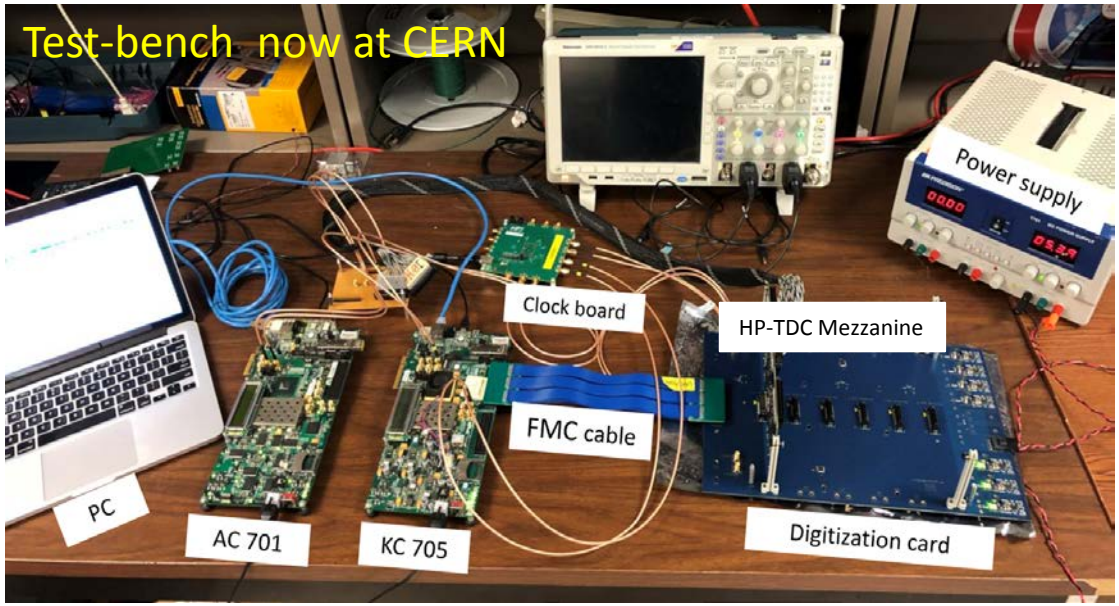


BIS78 Data Flow



Trigger and DAQ Status

- Pre-production of BIS78 digitization electronics completed
- Initial tests indicate expected functionality and performance
- Trigger Pad board expected in March
- Currently preparing for Vertical Slice test-bench and full test chain at CERN:
- RPC Chamber → FE Readout → FEDigi →PAD →FELIX→ Software-ROD
- Power and Monitoring System
  (keep and extend CAEN EASY architecture as for legacy RPC)



Outlook and Conclusions

- The BIS78 upgrade will provide new integrated sMDT+RPC chambers to be installed in the transition region ($1.0<|\eta|<1.3$) as part of the Phase-I Upgrade in LS2 (2021)
- Results on prototypes have been encouraging and have lead to a final prototype presently under test.
- Next Steps:
  - March 2018 → Final prototype at CERN + Chamber Final Design Review
  - May 2018 → Production Readiness Review + Start chamber production
  - Full DAQ vertical slice @ CERN (mid. 2018)
- The BIS78 project also provides an important pilot validation and deployment for the upgrade of the ATLAS muon spectrometer towards the High Luminosity LHC Phase-2 running.

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Thank You!