



Data Acquisition system for real time operation of the CGEM Inner Tracker

MICHELA GRECO, INFN Torino - University of Torino (Italy)

on behalf of CGEM-IT WORKING GROUP



Istituto Nazionale di Fisica Nucleare
SEZIONE DI TORINO



UNIVERSITÀ
DI TORINO

BESIII Collaboration



Istituto Nazionale di Fisica Nucleare
Sezione di Ferrara



Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati



Istituto Nazionale di Fisica Nucleare
Sezione di Torino



BESIII Italian Collaboration

15 countries, 72 institutions
~500 members



Beijing Electron Positron Collider



LINAC

BESIII

BEPCII



中国科学院高能物理研究所
Institute of High Energy Physics Chinese Academy of Sciences

Construction started: 1984

BEPC 1989–2005

$L_{\text{peak}}=1.0 \times 10^{31} / \text{cm}^2\text{s}$

BEPCII 2008–now $L_{\text{peak}}=1.0 \times 10^{33} / \text{cm}^2\text{s}$

$E_{\text{cm}}: 2 - 4.95 \text{ GeV}$

BEPCII Upgrade foreseen in 2024

Beam energy $\gg 2.8 \text{ GeV}$

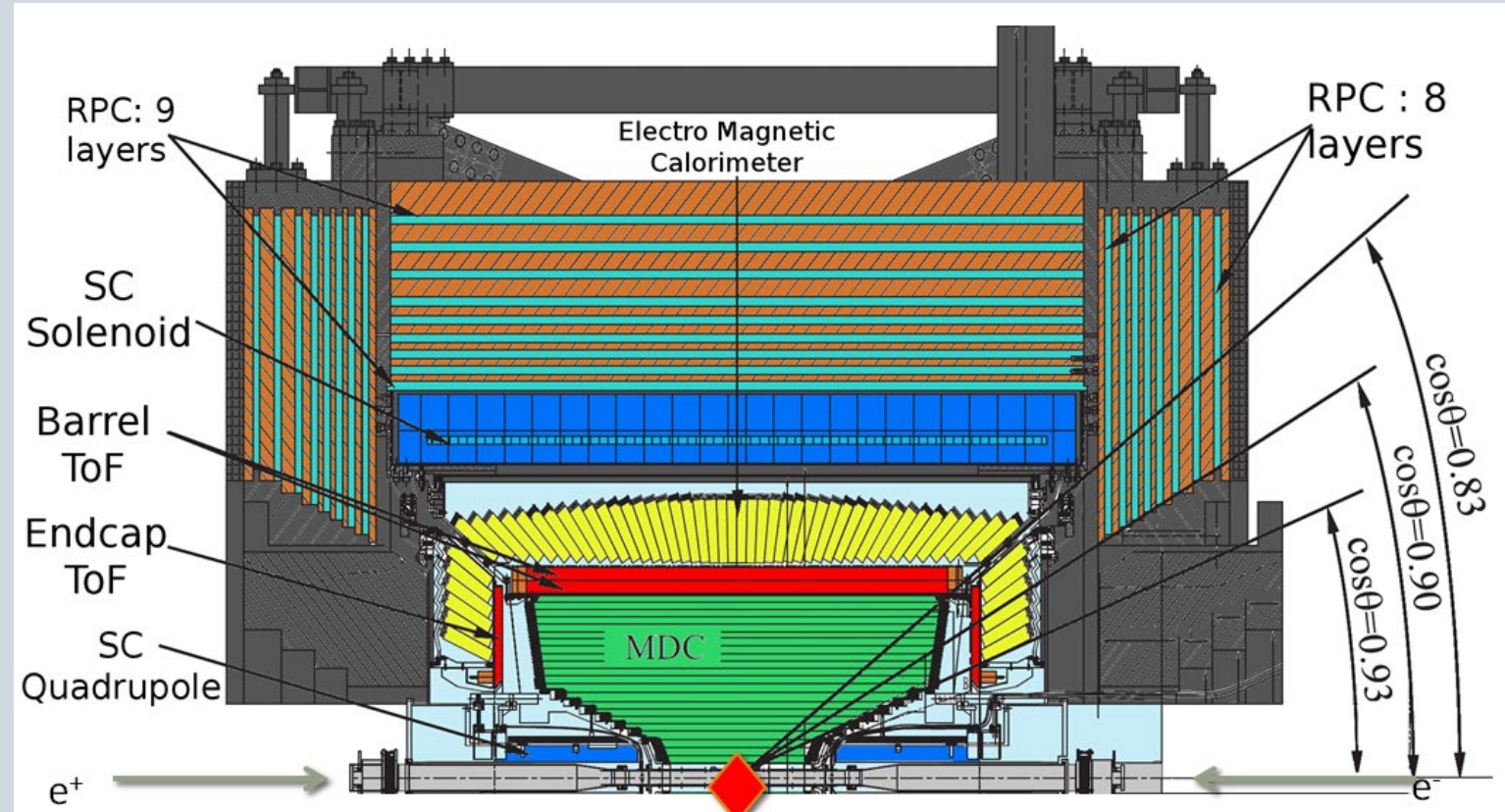
$L \times 3 @ 2.35 \text{ GeV}$



BESIII is designed to study physics in the tau-charm energy region. BESIII has collected the J/ψ world largest data sample (10B).

It has been approved an extension of the data taking till 2030 (at least)

white paper on future physics program
Chinese Physics C 44, 2020

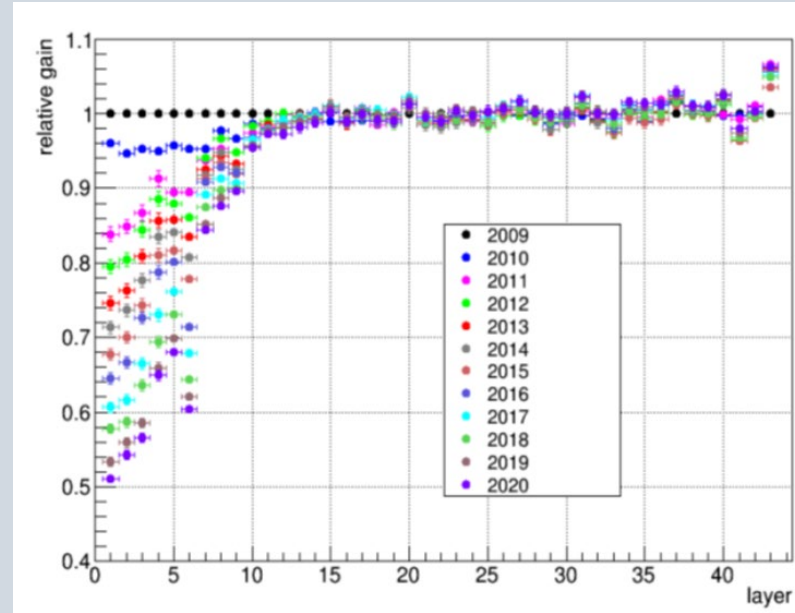
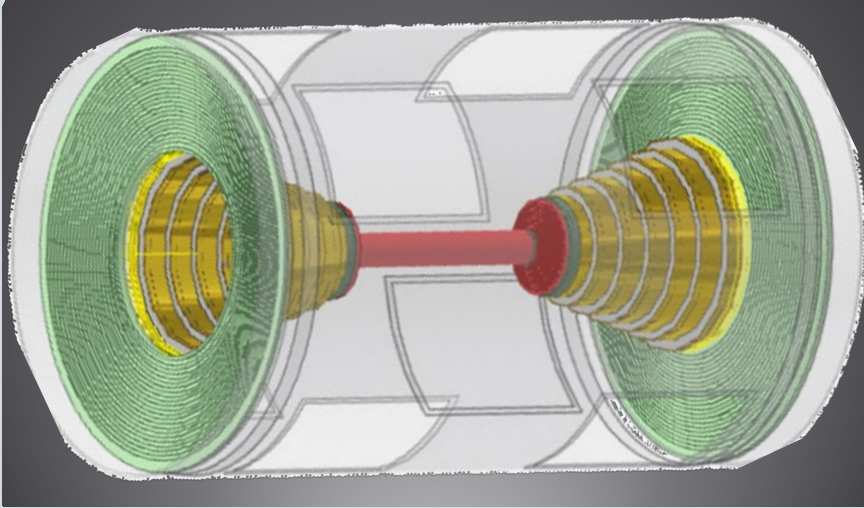


Total weight 750 tonnes, ~40,000 readout channels, Data rate: 5 kHz, 50 Mb/s

MDC, 0.5% at 1 GeV/c
CsI(Tl) calorimeter, 2.5% @ 1 GeV
BTOF, 70 ps / ETOF, 60 ps
 dE/dx 6% e^- Bhabha scattering

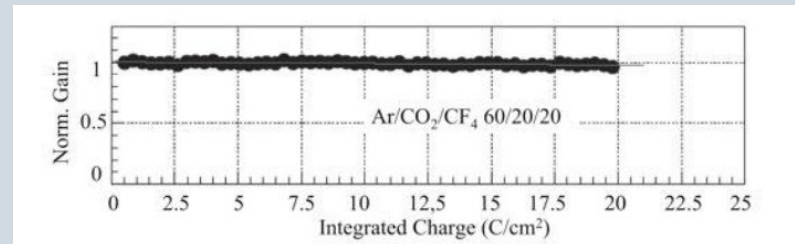
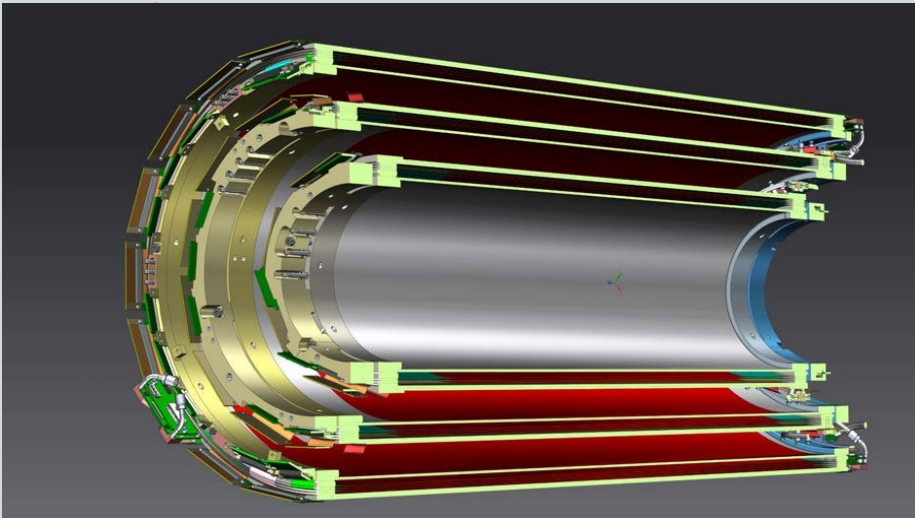
BESIII Inner Tracker

MDC > inner chamber



Aging
Gain loss/year
~ 4% on inner layers

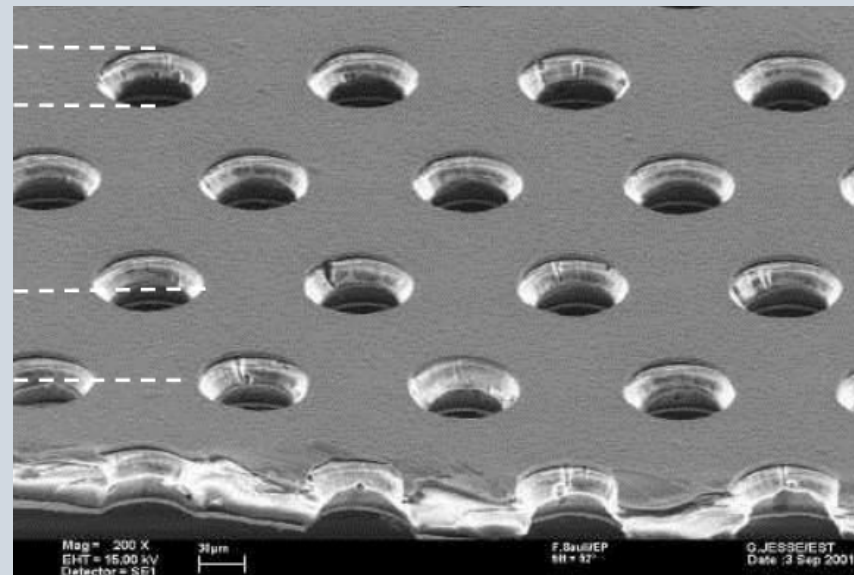
CGEM > GEM technology



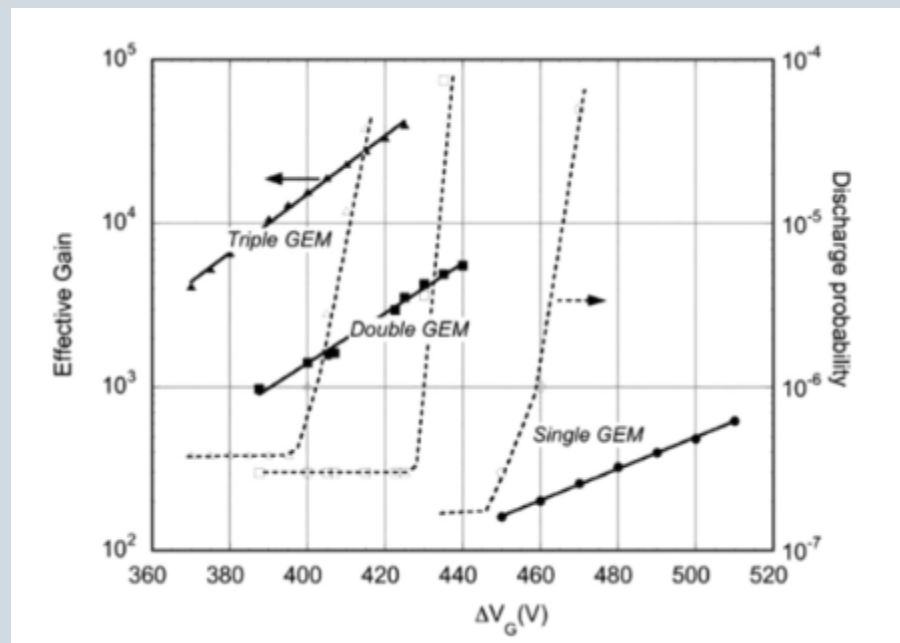
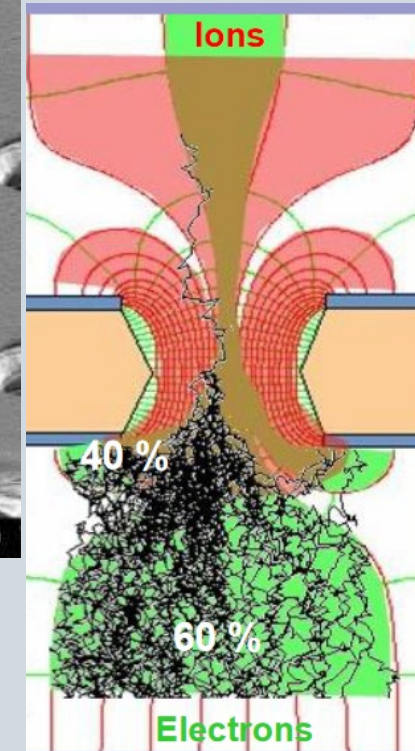
Low spatial charge
High rate capability
Fast response
Light support frame
Very low aging

GEM (Gaseous Electron Multiplier) is a Micro Pattern Gas Detector, invented by Sauli in 1997

- High rate capability
- High radiation hardness
- Scalable and flexible geometry



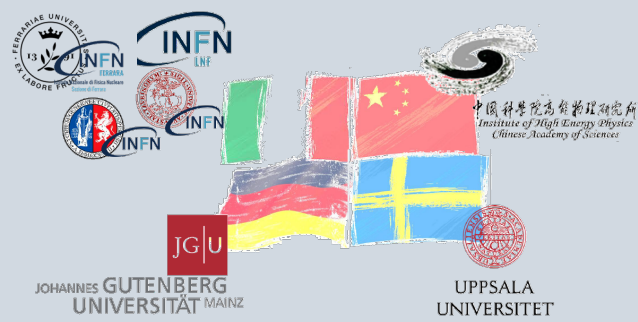
NIMA 386, 1997



More layers of GEM grant high gain with lower applied voltages → lower spark rate

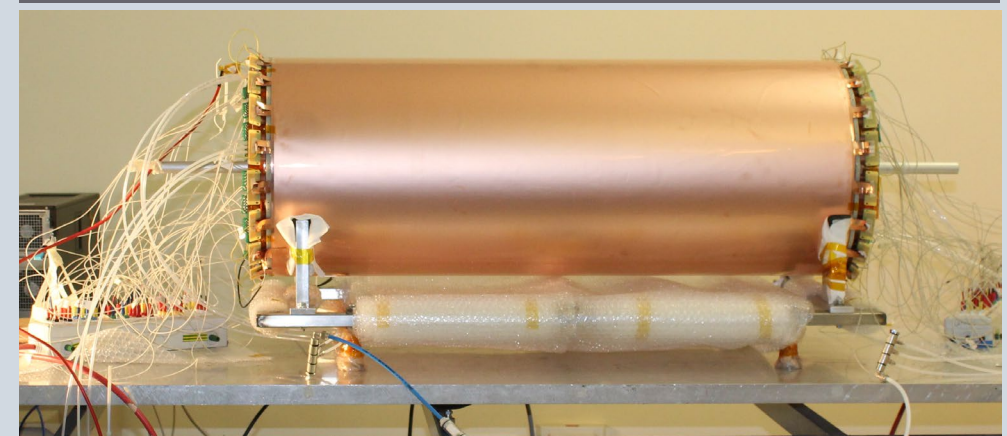
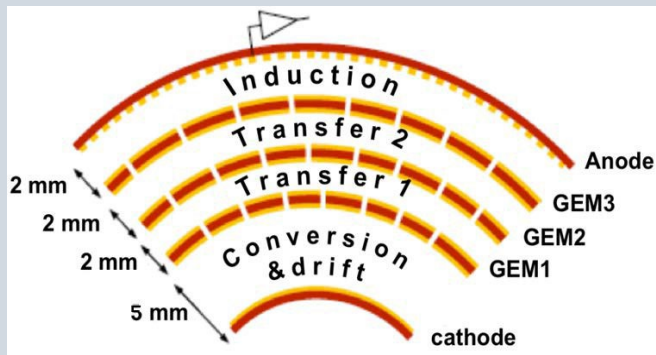
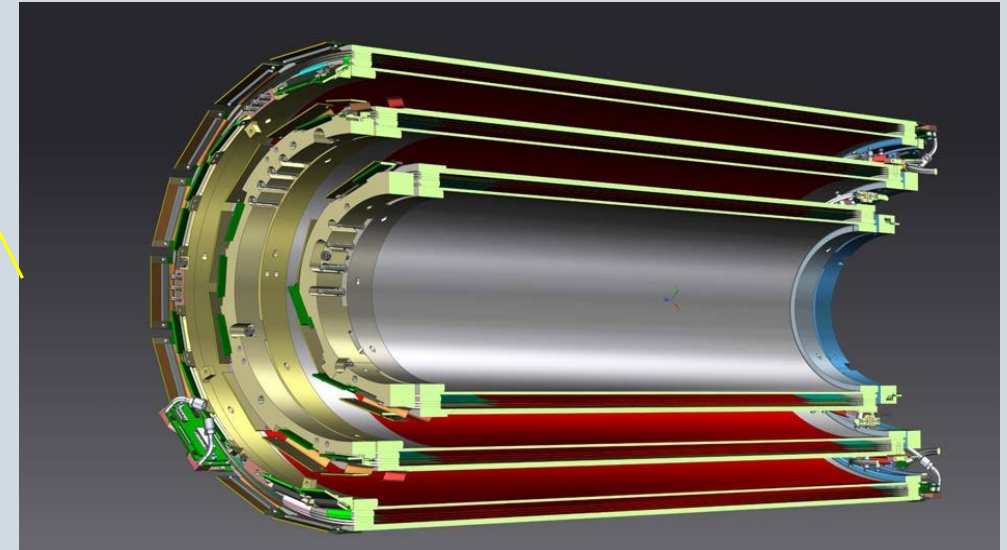
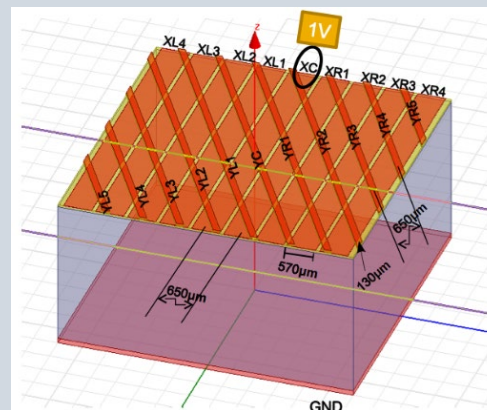
NIM A 2016, 805

Cylindrical Gaseous Electron Multiplier



- $\sigma_{xy} \sim 130 \mu\text{m}$
- $\sigma_z < 1 \text{ mm } (\sim 350 \mu\text{m})$
- $\sigma_{pt}/p_t \sim 0.5\% @ 1 \text{ GeV}/c$
- Operation in 1T magnetic field
- Material budget $\sim 1.5\% X_0$
- High rate capability: $10^4 \text{ Hz}/\text{cm}^2$

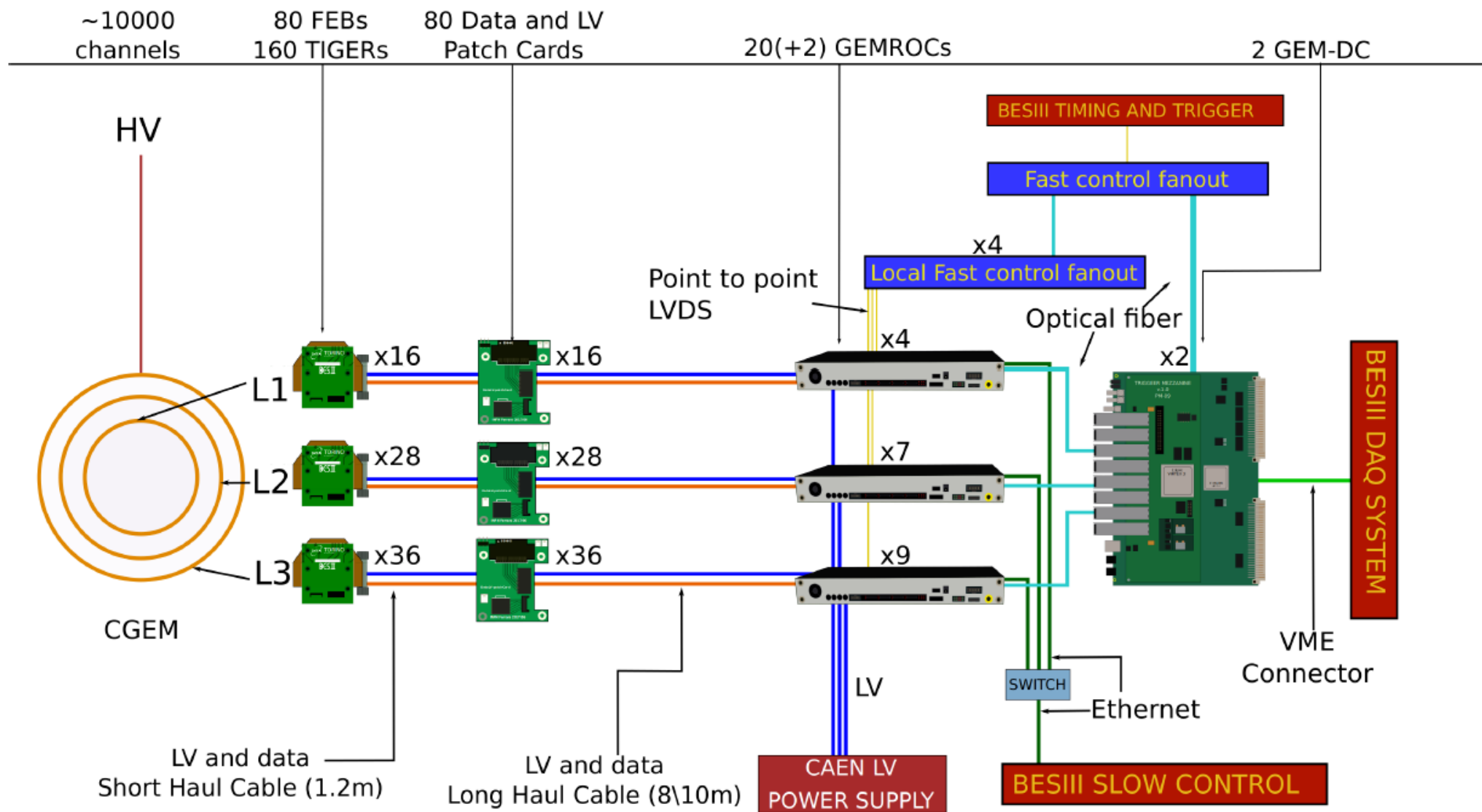
Three layers of cylindrical triple-GEM
 Each layer has two “views” to reconstruct the 3D position of the hits



Ar-iC4H10 (90%-10%)
 1.5/3/3/5 kV/cm

Symmetry 2022, 14(5), 905

Readout chain

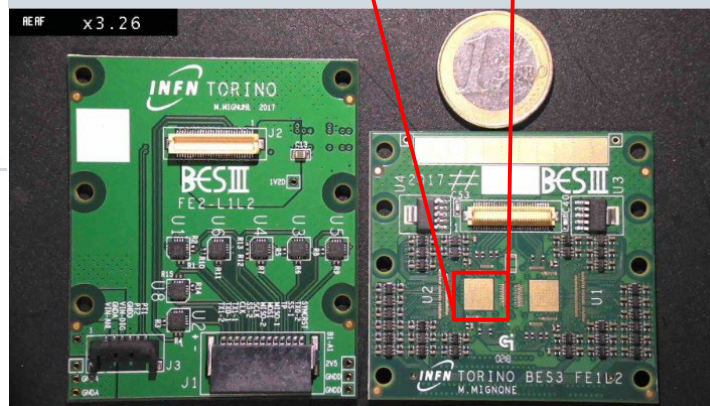
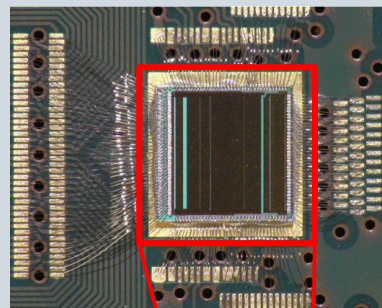
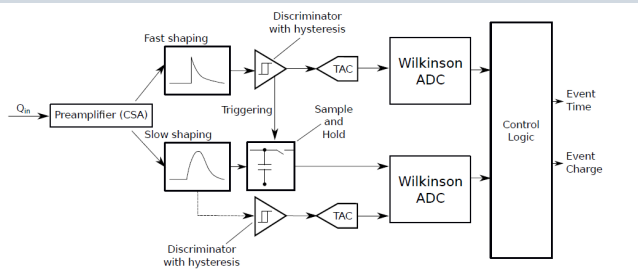


JINST 2021 16 P08065

TIGER (Torino Integrated Gem Electronics Readout)
64-channels ASIC
charge and time readout

Sample & Hold
Time-over-Threshold

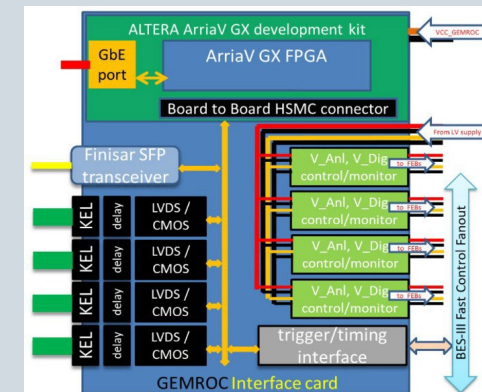
Parameters	Value
Input Charge	2-50 fC
Input Capacitance	Up to 100 pF
Data Rate	60 kHz/ch
Readout Mode	Trigger-less
Non-linearity	<1%
Charge Collection Time	60 ns
Time resolution	<5 ns
Power Consumption	<12 mW/ch
Technology	110 nm process



INFN-Torino

GEM Read Out Card

- Power the FEBs
- Monitor chips voltages and temperature
- Configure the chips
- Receive timing signals
- Control data acquisition via optical links/Ethernet



INFN-Ferrara

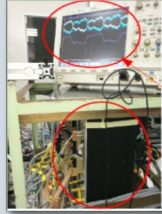
BESIII timing signals

BESIII



FCSF

CGEM



FCF

FCLF



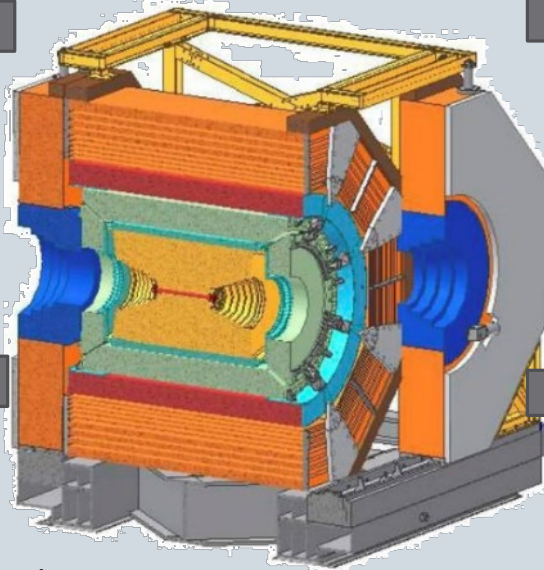
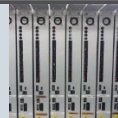
FCLF



FCLF



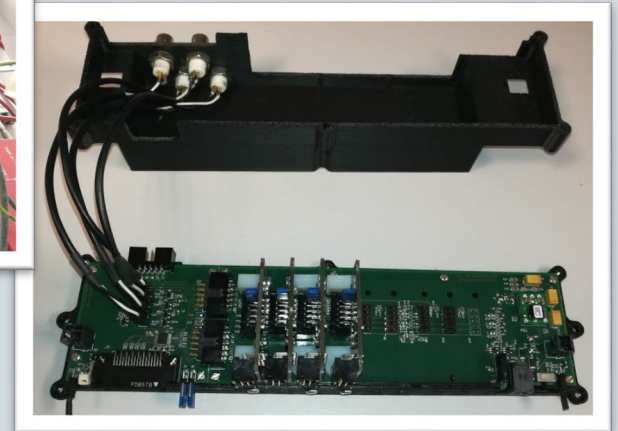
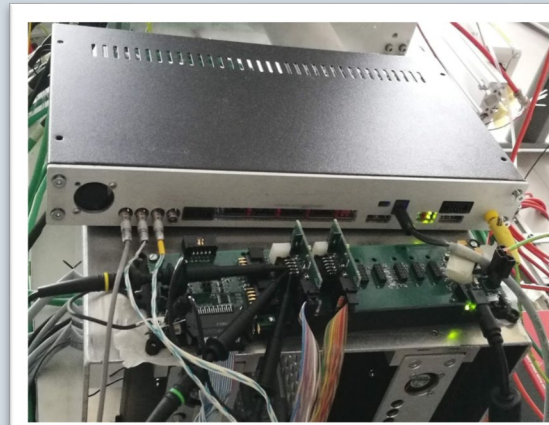
FCLF



4 groups
of GEMROC modules

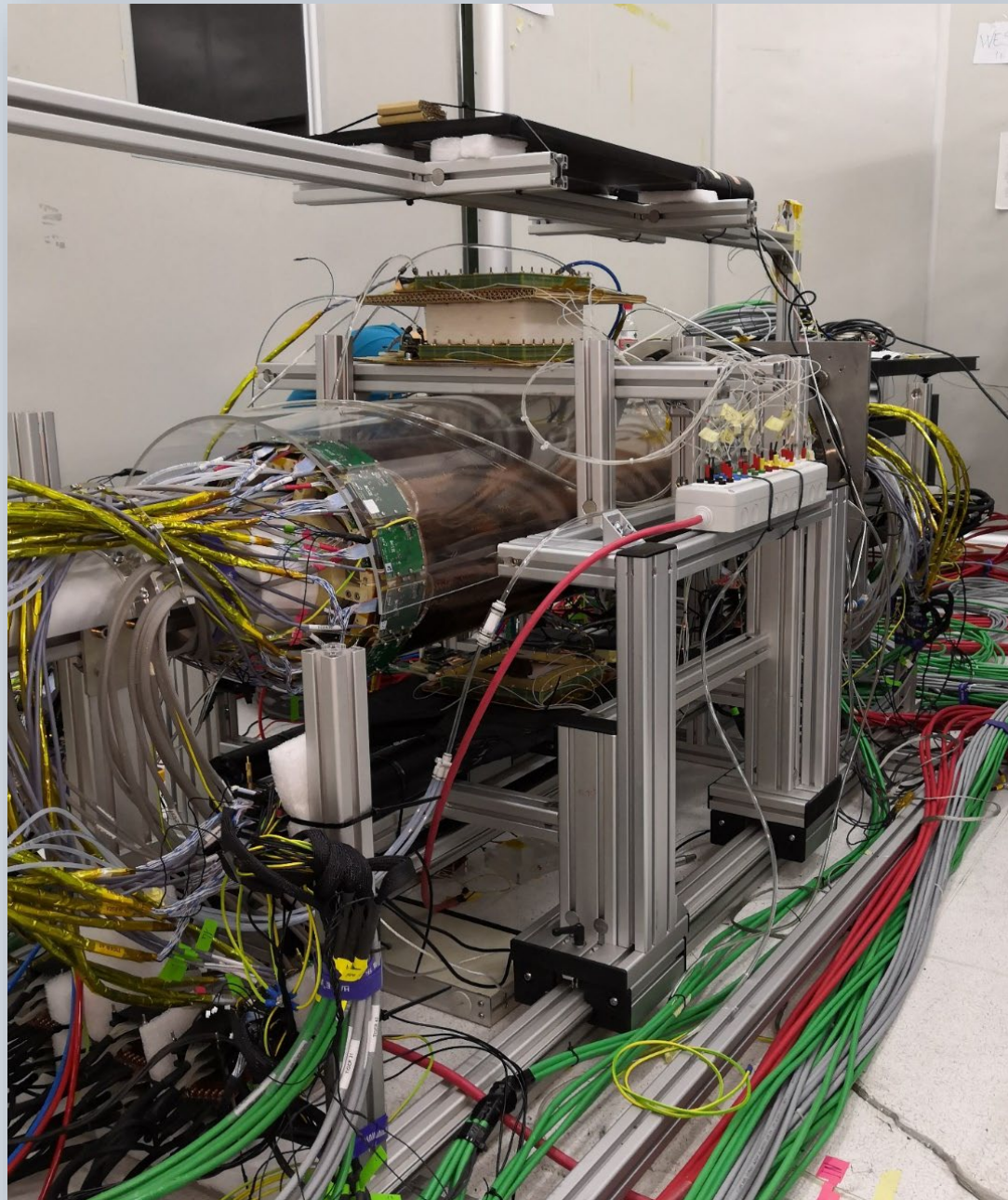
Fast Control system Fanout
a modified GEMROC module which connects to the CLK,
L1, L1_CHK, FULL signals from the BESIII FCSF

Fast Control system Local Fanout
a low cost, not programmable, fanout module which
connects to the CLK, L1, L1_CHK, FULL signals from FCF

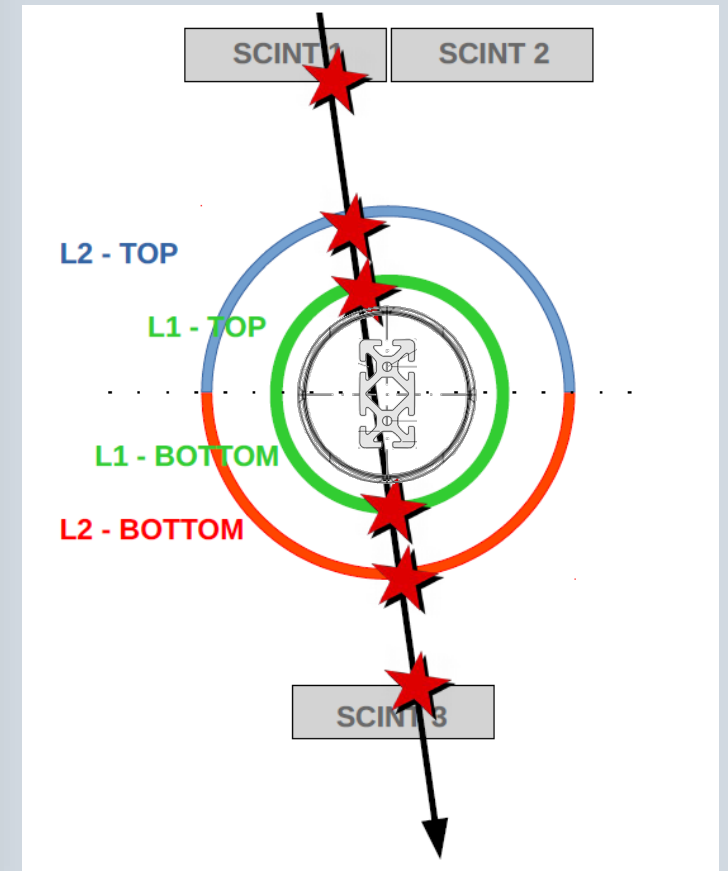


@A.Cotta Ramusino

~5.6k channels
connected
Final LV/HV systems



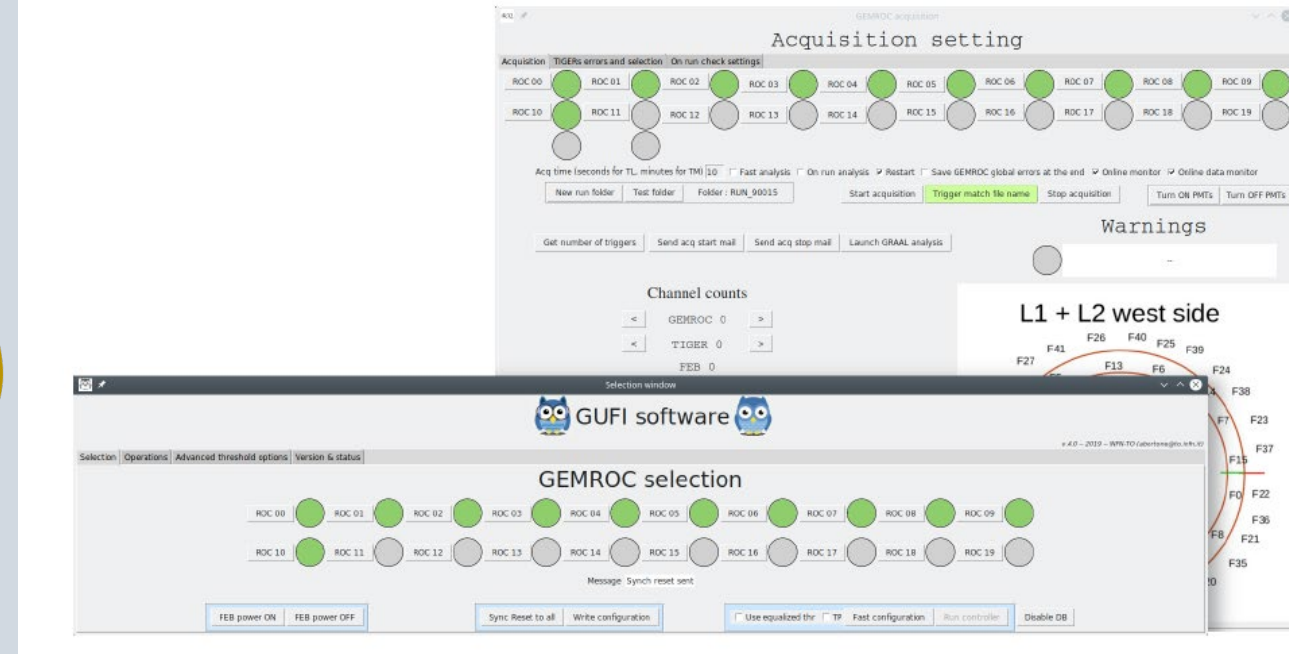
Cosmic telescope in Beijing



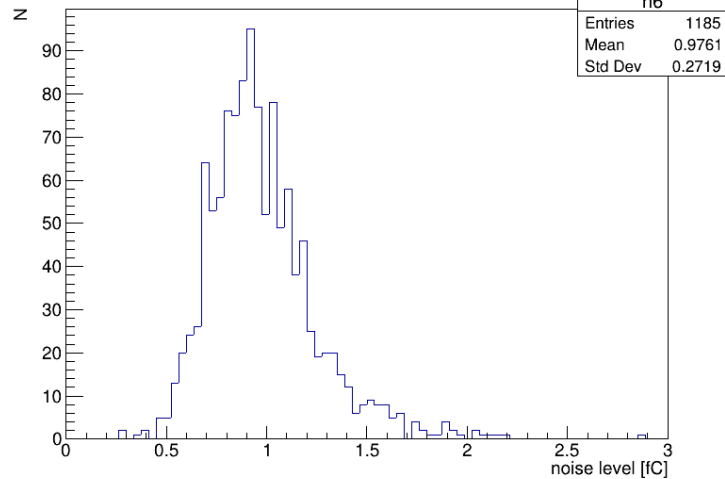
Control System: GUFi

Graphical User Frontend Interface
to characterize, debug and test the system
before the installation

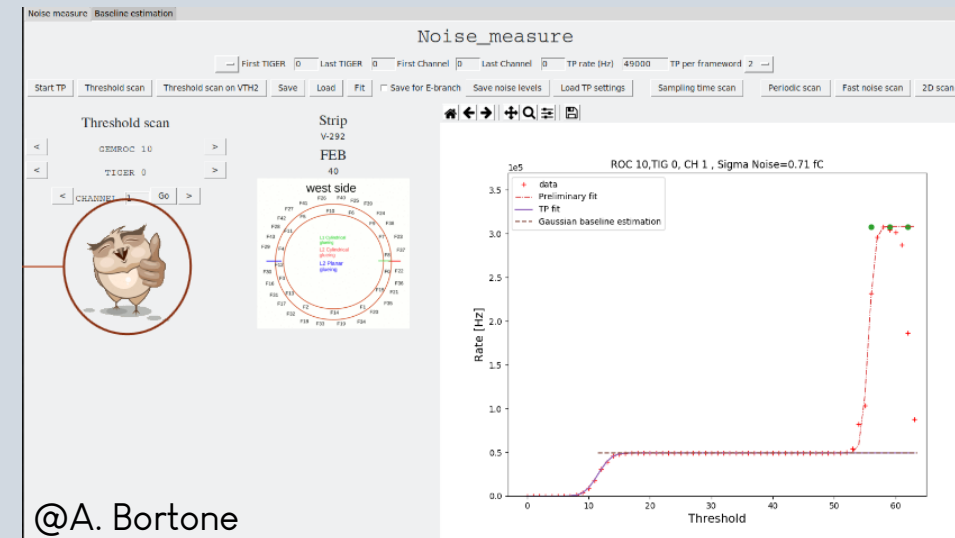
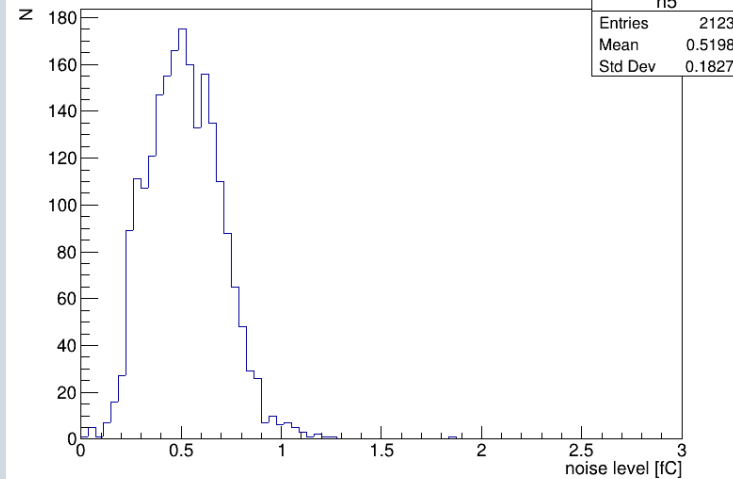
standard and advanced features
tkinter Python library for graphical interfaces



Noise layer 2 (strip X)



Noise Layer 2 (strip V)



@A. Bortone

Control System: HV

to characterize, debug and test the system before the installation



IHEP-CR-HV (DESKTOP-DLI80P9) - VNC Viewer

main_s_wl2_grafana.vi rev. 387

File Edit View Project Operate Tools Window Help

elements in queue: 1 stop STOP I/O_operation: 0.5

Impostazioni di default

IP_address: 192 168 0 1

error out: status code: 0 source: 0

BasePath: %C:\Users\...\GEM-IT_HV-monitoring-status_wfl.log

Impostazioni

I0_ramp	Vset_L1	Vset_L2	L1s	L2s
5	1000	1000	On	On
	250	250	On	On
	600	600	On	On
	250	250	On	On
	600	600	On	On
	250	250	On	On
	750	750	On	On

IOSet-L1_ctrl		VOSet-L1_ctrl	
Ind	0.300		1000.000
G3	0.300		250.000
T2	0.300		600.000
G2	0.300		250.000
T1	0.300		600.000
G1	0.300		250.000
Drift	0.300		750.000

IOSet-L2_ctrl		VOSet-L2_ctrl	
Ind	0.300		1000.000
G3	0.300		250.000
T2	0.300		600.000
G2	0.300		250.000
T1	0.300		600.000
G1	0.300		250.000
Drift	0.300		750.000

IOSet-L3_ctrl		VOSet-L3_ctrl	
Ind	0.300		1000.000
G3	0.300		1000.000
T2	0.300		1000.000
G2	0.300		1000.000
T1	0.300		1000.000
G1	0.300		1000.000
Drift	0.300		1000.000

Discharge_t: 0

L1_I, L1_V, L2_I, L2_V

NOTA BENE: Controllo fine in mo

IHEP-CR-HV (DESKTOP-DLI80P9) - VNC Viewer

main_s_wl2_grafana.vi rev. 387

File Edit View Project Operate Tools Window Help

elements in queue: 1 stop STOP I/O_operation: 0.5

time stamp: 00:00:00.000 PM MM/DD/YYYY

time_window: 60

Ind G3 T2 G2 T1 G1 Drift

L1

PW-L1	L1	Vmon_L1	IOSet-L1	IMon-L1	ZCDet	ZCAAAdj	L1	Disc-L1	Discharge-L1
ON	On	1000.5	0.500	-0.100	OFF	ON	1	0	0
ON	On	250.14	0.500	-0.090	OFF	ON	0	0	0
ON	On	600.3	0.500	-0.088	OFF	ON	0	0	0
ON	On	250.26	0.500	-0.089	OFF	ON	0	0	0
ON	On	600.58	0.500	-0.089	OFF	ON	0	0	0
ON	On	250.24	0.500	-0.055	OFF	ON	0	0	0
ON	On	750.46	0.500	-0.041	OFF	ON	0	0	0

VMon

IMonReal

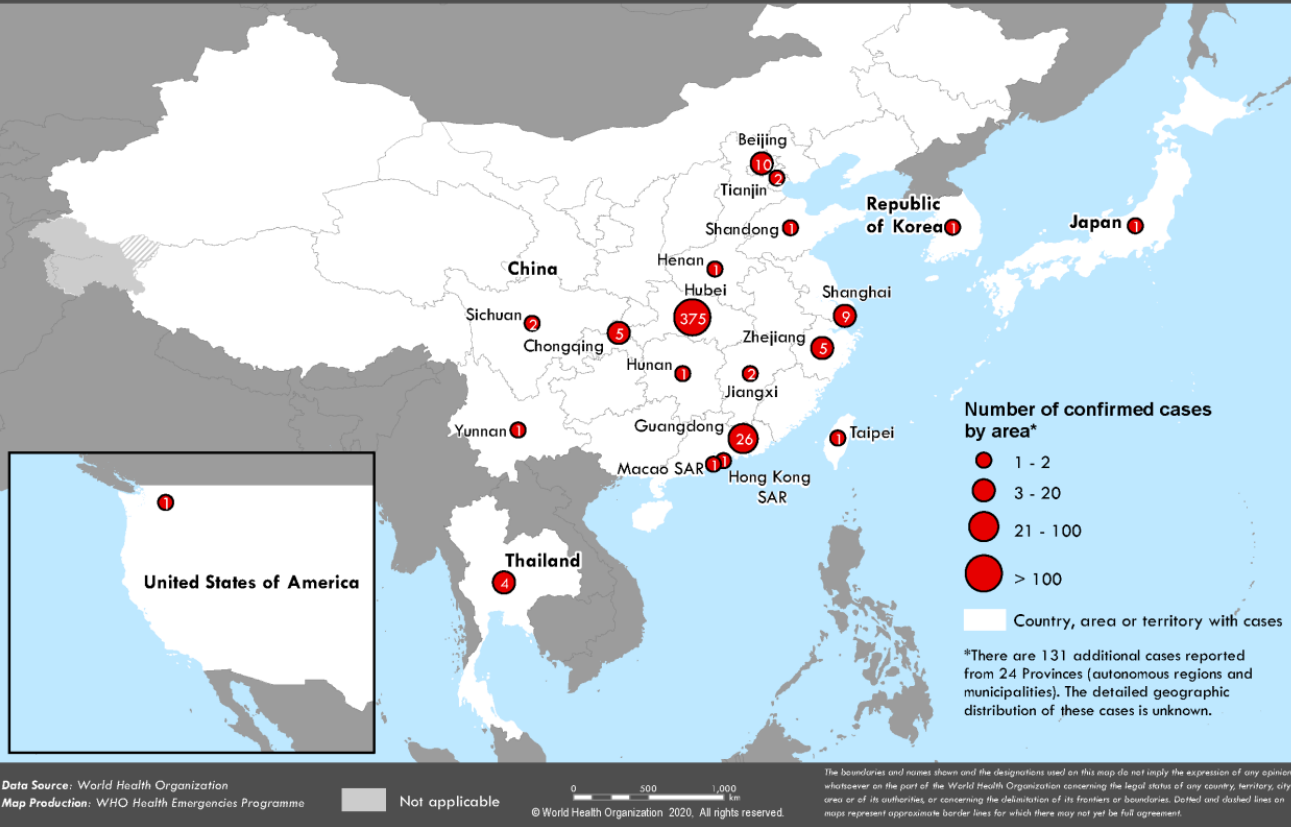
IMonDet

L2

PW-L2	L2	Vmon_L2	IOSet-L2	IMon-L2	ZCDet	ZCAAAdj	L2	Disc-L2	Discharge-L2
ON	On	999.6	0.300	-0.057	OFF	ON	0	0	0
ON	On	250.18	0.300	-0.063	OFF	ON	0	0	0
ON	On	600.1	0.300	-0.063	OFF	ON	0	0	0
ON	On	250.2	0.300	-0.066	OFF	ON	0	0	0
ON	On	600.54	0.300	-0.045	OFF	ON	0	0	0
ON	On	250.26	0.300	-0.048	OFF	ON	0	0	0
ON	On	750.4	0.300	-0.020	OFF	ON	0	0	0

15°C 空气优 27 5:28 PM 10/12/2021

CGEM data taking

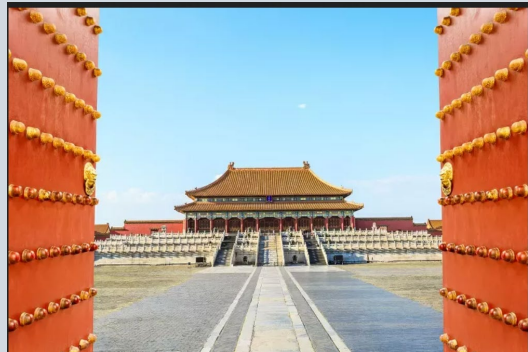


Remote data collection (more than 2 years) by the Italian groups.

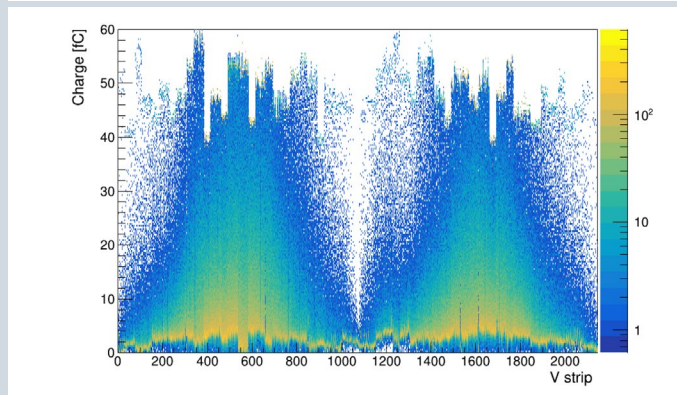
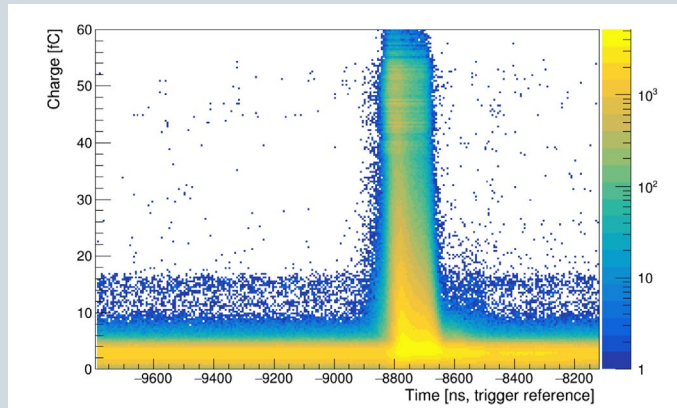
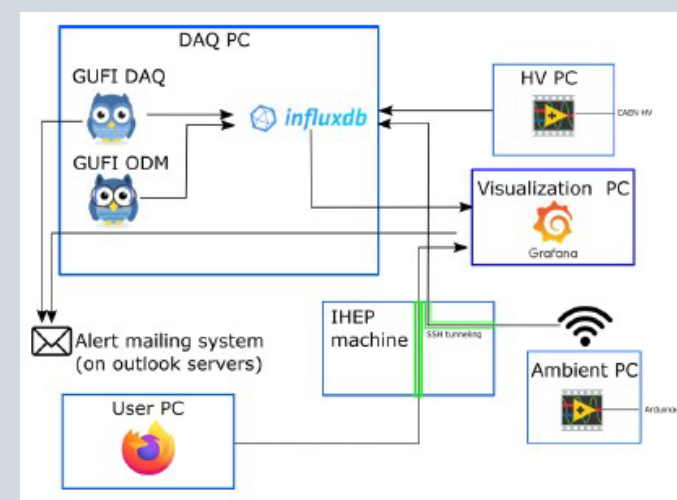
> RT monitoring of operations

On-site operations thanks to the valuable help of colleagues from BESIII MDC team

In parallel, carry out integration activities on a small scale setup



RT monitoring



@A. Bortone

RT monitoring



```
Arduino IDE Window: tresonde_condecimail_mix | Arduino 1.8.19 (Windows Store 1.8.57.0)
File Edit Sketch Tools Help

tresonde_condecimail_mix
//Include All Peripheral Libraries Used By LINX
#include <SPI.h>

#include <EEPROM.h>
#include <Servo.h>
#include <Adafruit_Sensor.h>
#include <Adafruit_BME280.h>
#include <DHT.h>
#include <DHT_U.h>

//Include Device Specific Header From Sketch>>Import Library (In This Case LinxChipkitMax32.h)
//Also Include Desired LINX Listener From Sketch>>Import Library (In This Case LinxSerialListener.h)
#include <LinxArduinoUno.h>
#include <LinxSerialListener.h>

int myCustomCommand_dht22 ();
int myCustomCommand_bme280 ();

//Create A Pointer To The LINX Device Object We Instantiate In Setup()
LinxArduinoUno* LinxDevice;
//Initialize LINX Device And Listener

void setup()
{
  //Instantiate The LINX Device
  pinMode(7,OUTPUT);
  //digitalWrite(7,LOW);
  //delay(2000);
  digitalWrite(7,HIGH);

  //Instantiate The LINX Device
  pinMode(8,OUTPUT);
  digitalWrite(8,LOW);
}

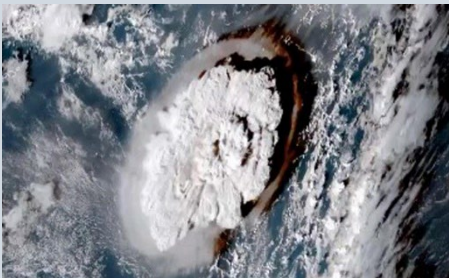
Done uploading.

Sketch uses 27334 bytes (84%) of program storage space. Maximum is 32256 bytes.
Global variables use 1166 bytes (56%) of dynamic memory, leaving 882 bytes for local variables. Maximum is 2048 byte

22
```



RT monitoring

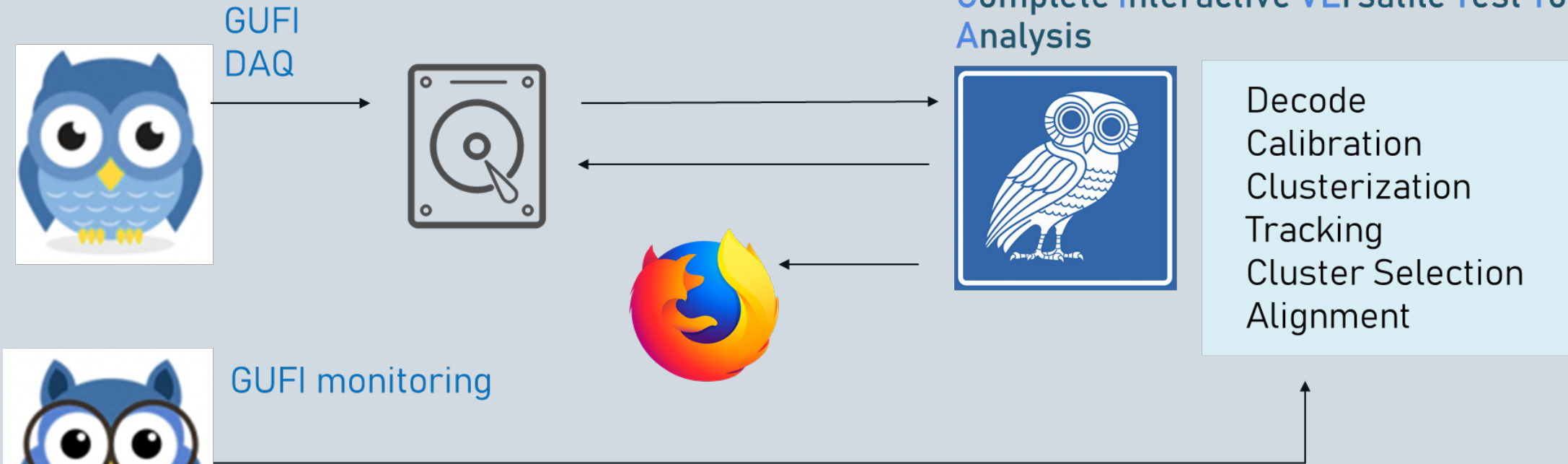


Hunga Tonga–Hunga Ha'apai eruption



Fast-Analysis tool: CIVETTA

CIVETTA
Complete Interactive **V**ersatile Test Tool
Analysis

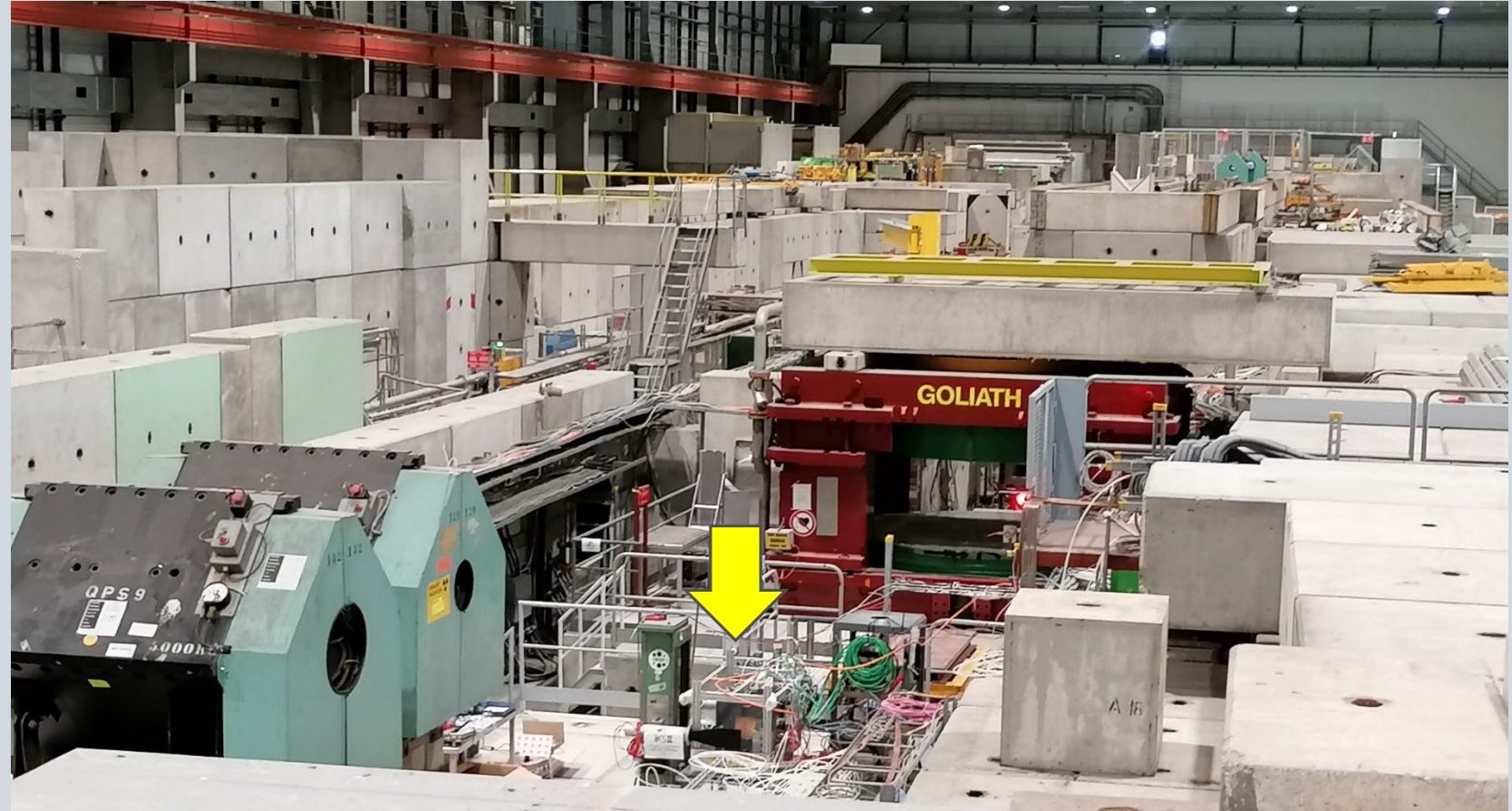
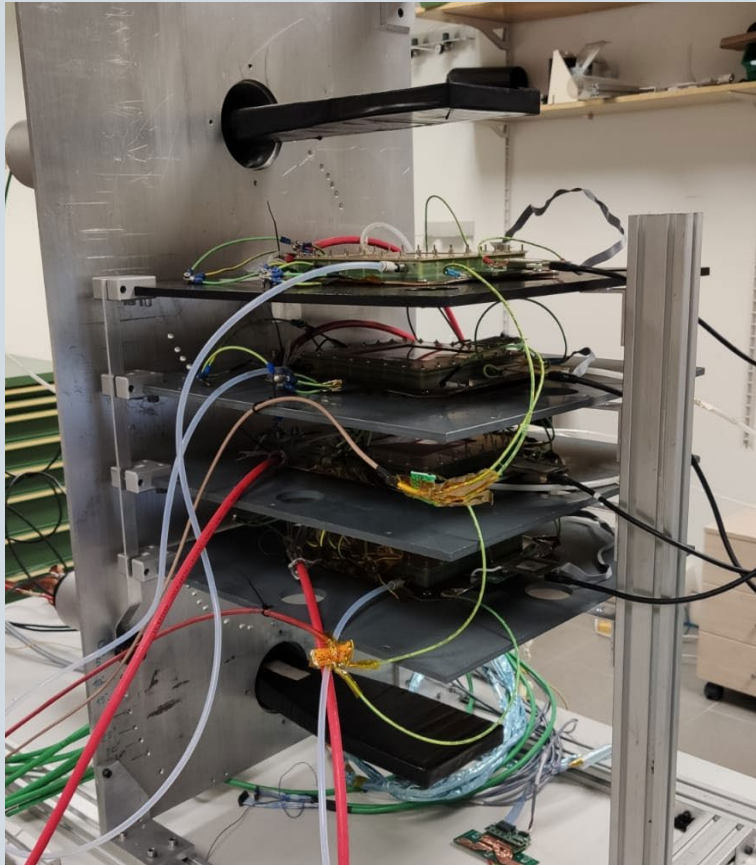


@A. Bortone

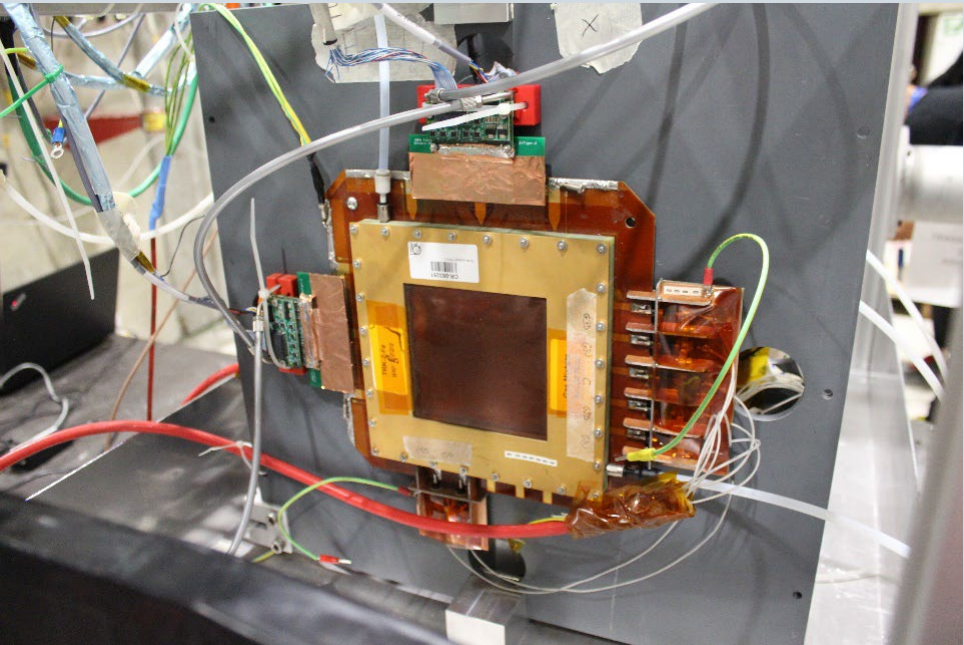


- complete metrics > performance of the detector
- software is fully parallelized at the sub-run level to take advantage of all CPU on the machine and maximize performance

Integration tests



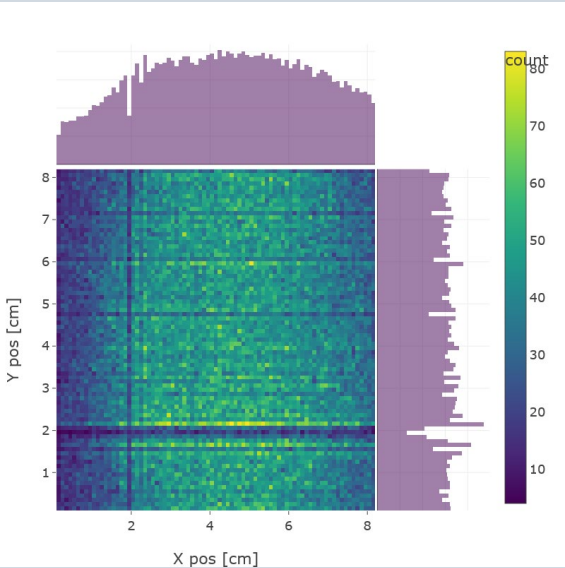
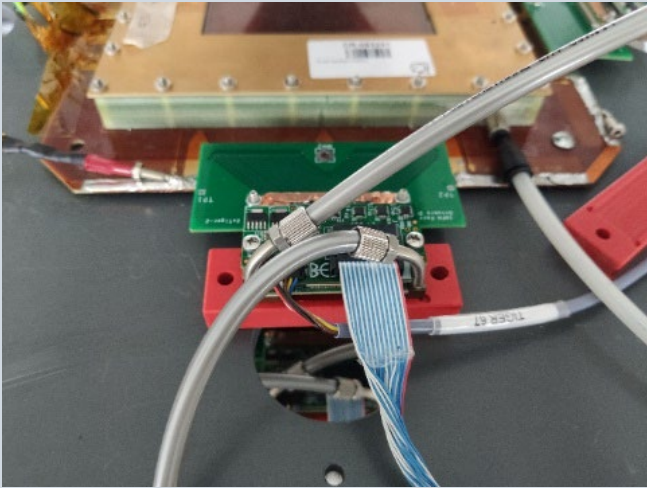
Integration tests



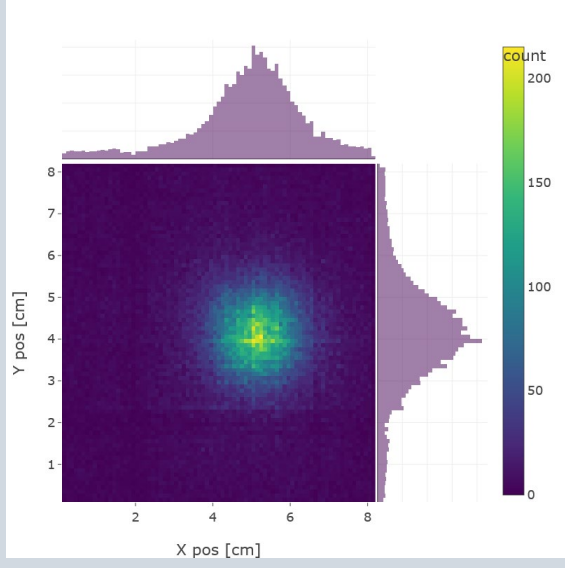
12/21 July 2021
RD51 test beam
@ H4 line CERN North Area, Preveessin

4.5 s spills
180 k muons
4M pions

250 M triggers



Muons @80 GeV/c

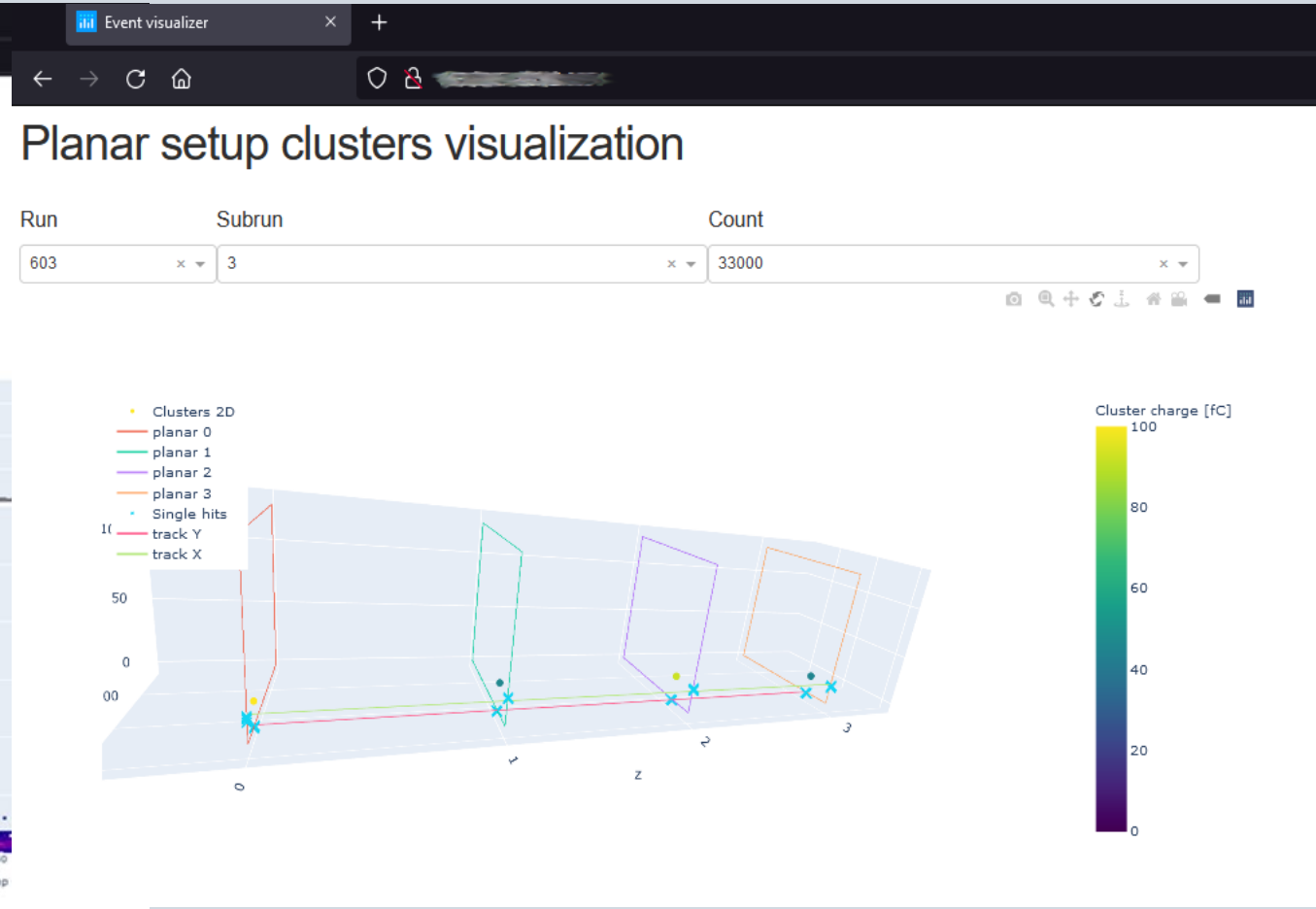
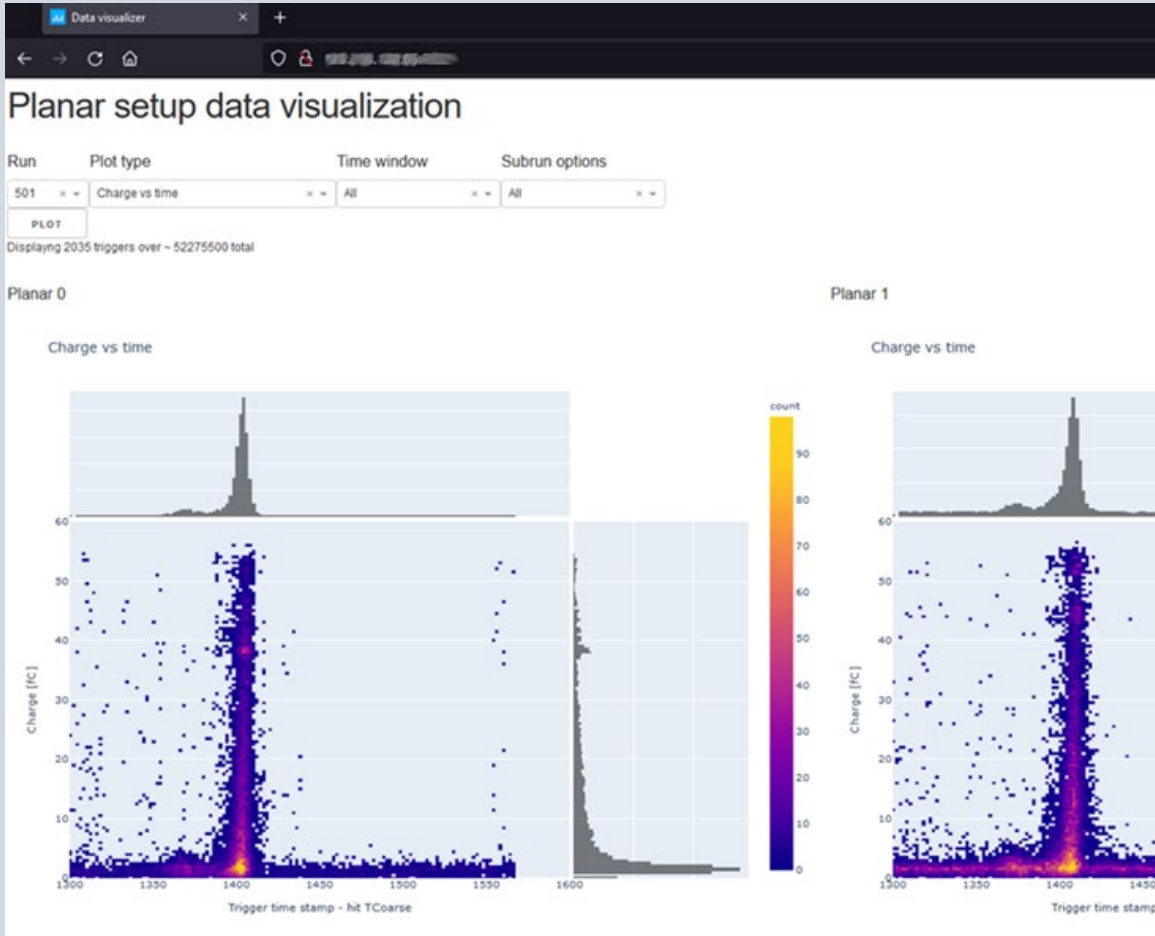


Pions @150 GeV/c

CIVETTA

Online metrics and events visualization via web browser using Plotly-Dash
Immediately after run end on a subsample to check goodness

DAQ sw at TB:
STRESS –TEST!



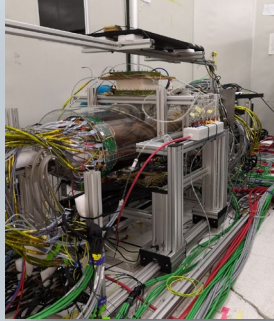
Offline Data analysis [PM2021](#)
[ICHEP2022](#)

Summary

As the pandemic spread, we did not expect to manage operations remotely for such a long period of time.

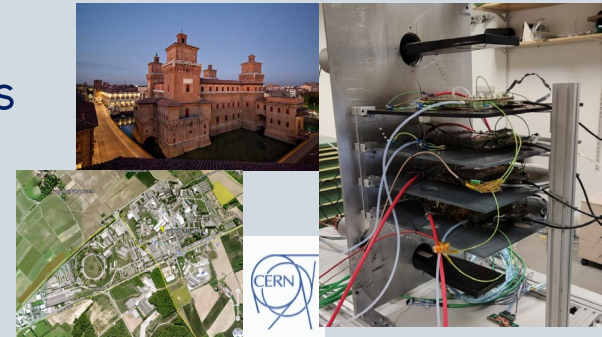


The DAQ system, which was intended for a "short" startup, was set for a longer operation.



A RT monitoring system was developed to safely operate the CGEM detector.

A fast analysis tool was implemented to support integration tests at the small facility, operating in Ferrara and under the test beam@CERN.



The test beam was a real pressure test for the GUFU/CIVETTA system: everything was fine!



謝謝
thank you