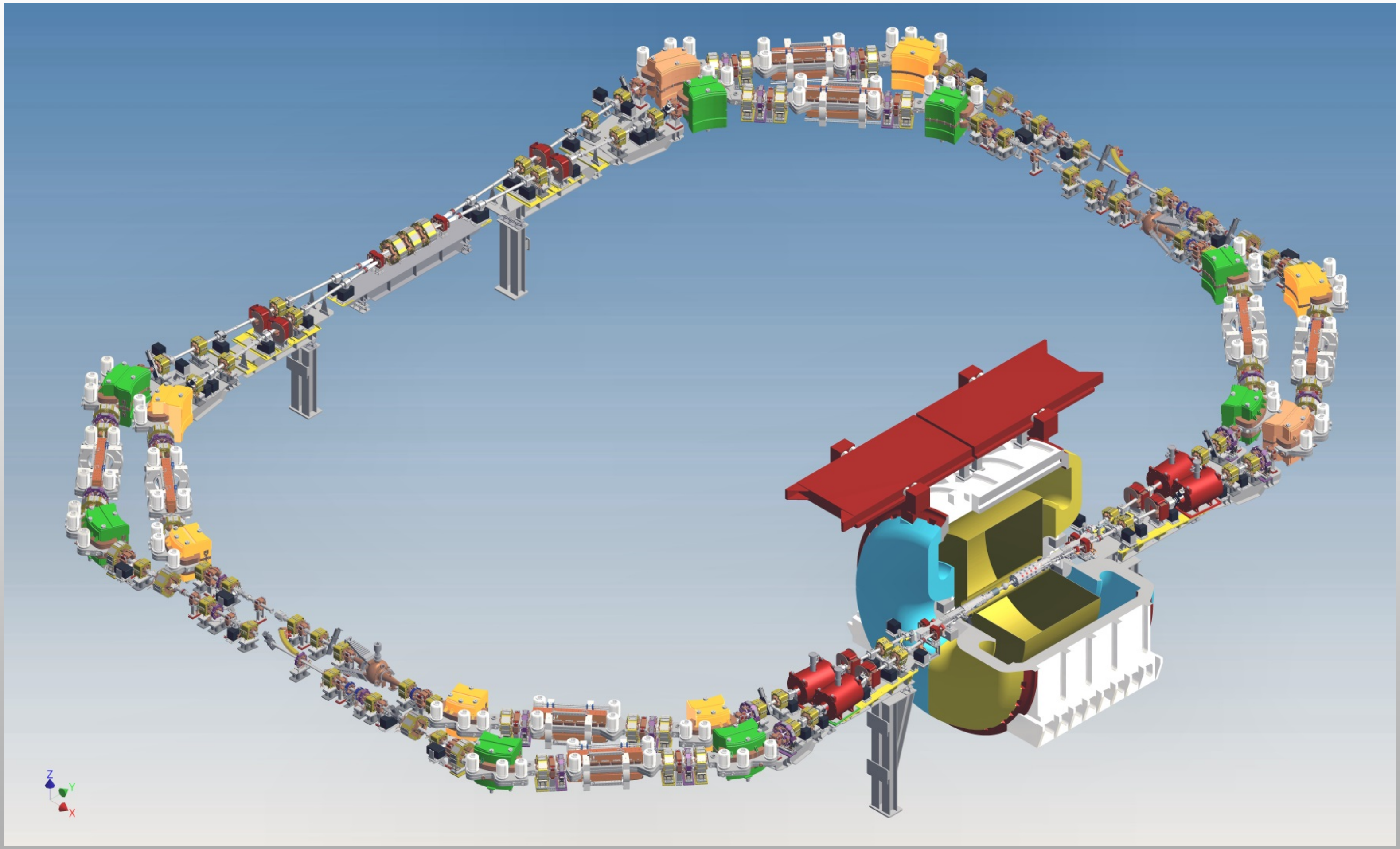
# LNF Accelerators
# Evolutions and Upgrades

Andrea Ghigo
on behalf of Accelerator Division

Miniworkshop su Acceleratori

Legnaro, February 17, 2015

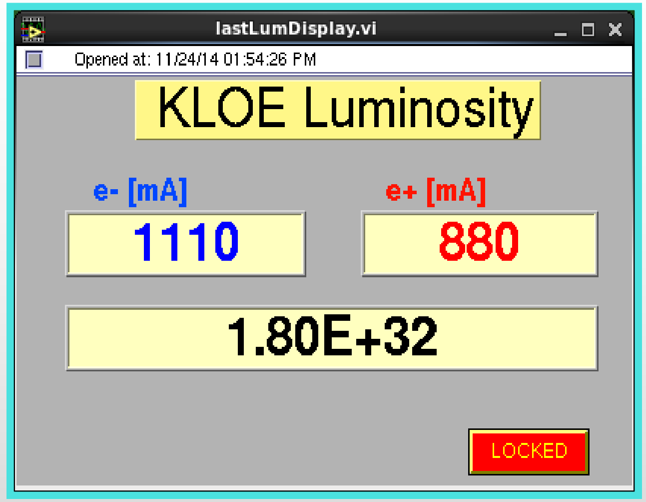
# DAΦNE and KLOE activities



Aiming at delivering 1 $fb^{-1}$ after 8 months operation after LNF Scientific Committee November 13, 2014

# Peak Luminosity

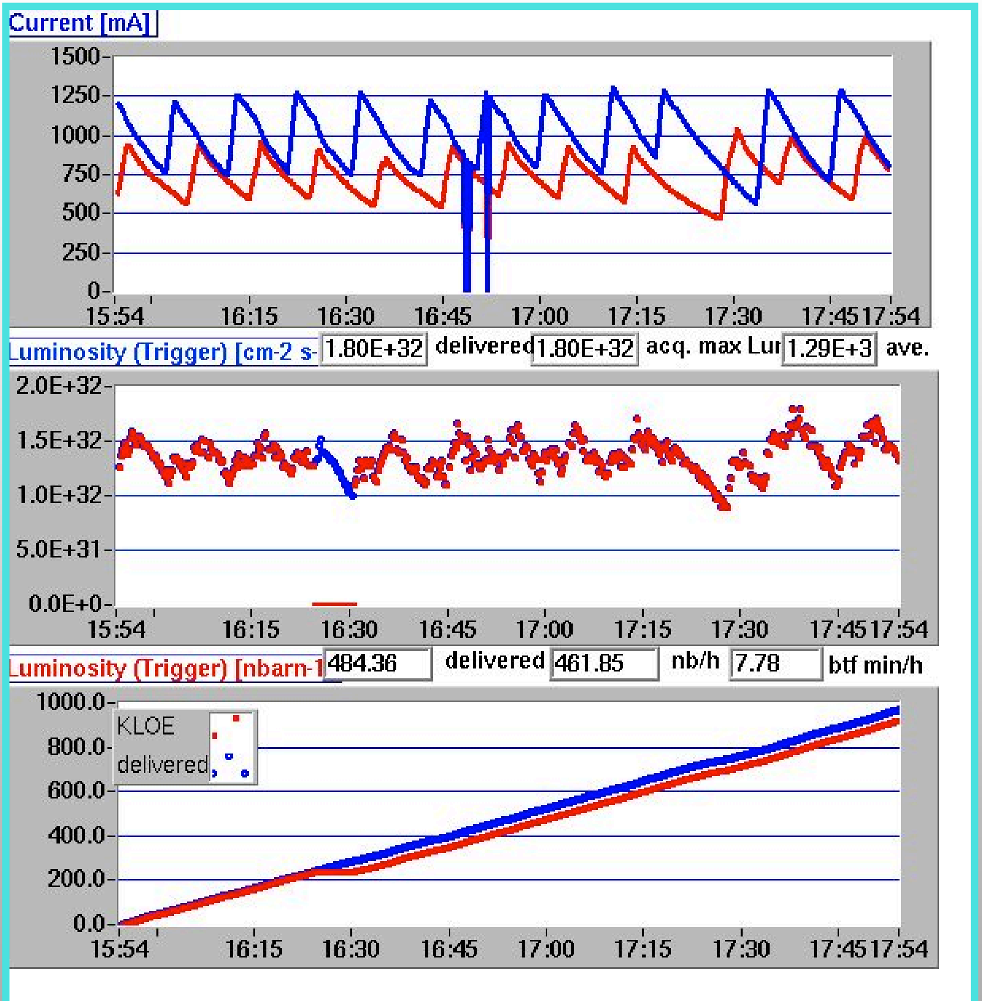
24 Nov 2014




*95 bunches*

| | DAΦNE CW upgrade SIDDHARTA (2009) | DAΦNE KLOE (2005) | DAΦNE (CW) KLOE (2012) | DAΦNE (CW) KLOE-2 (2014) |
|---|---|---|---|---|
| $L_{peak}$ [$cm^{-2}s^{-1}$] | $4.53 \cdot 10^{32}$ | $1.50 \cdot 10^{32}$ | $1.52 \cdot 10^{32}$ | $1.80 \cdot 10^{32}$ |
| $I^-$ [A] | 1.52 | 1.4 | 0.93 | 1.11 |
| $I^+$ [A] | 1.0 | 1.2 | 0.72 | 0.88 |
| $N_{bunches}$ | 105 | 111 | 100 | 95 |

# Hourly integrated Luminosity  November 2014



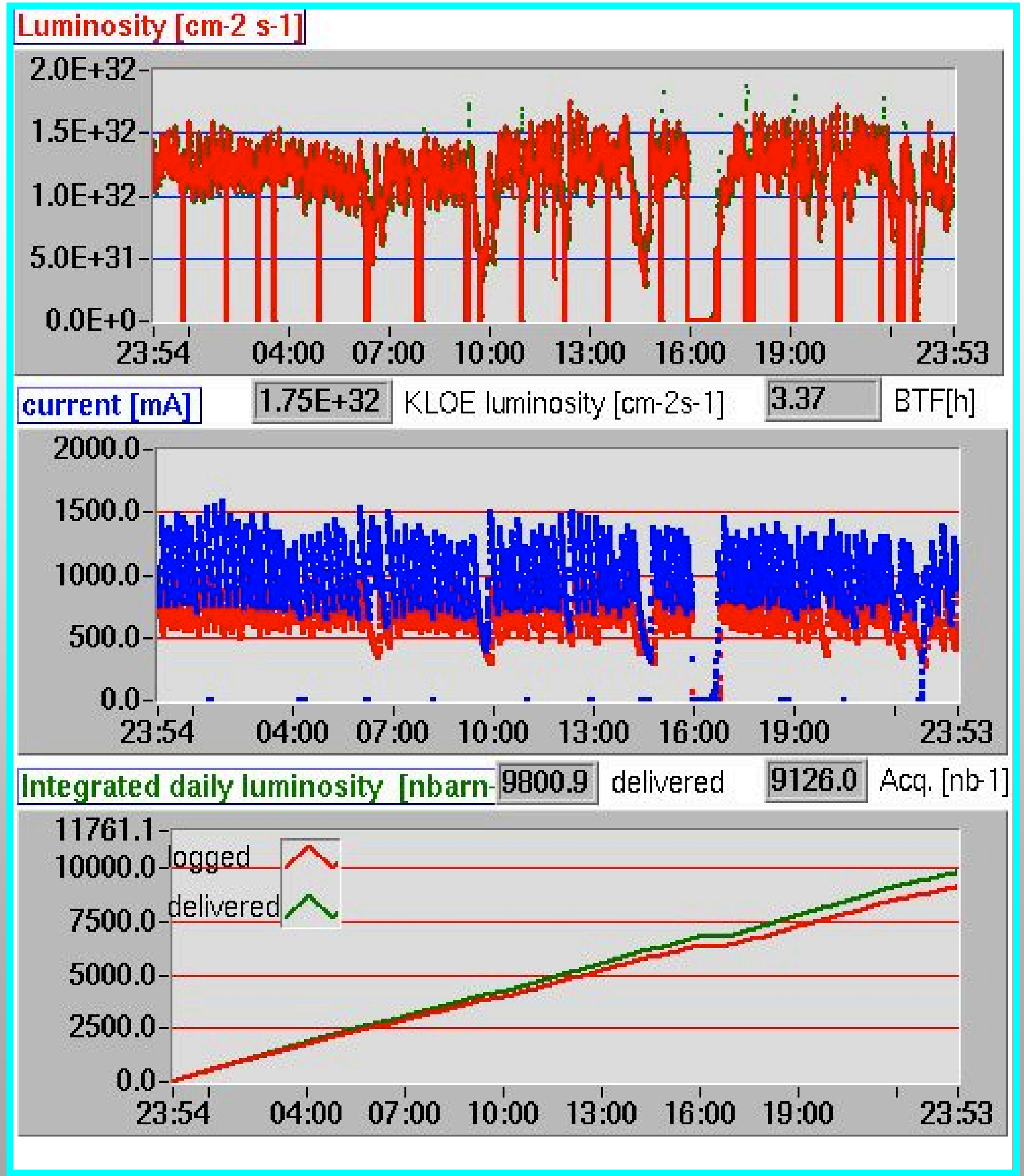

$L_{\int 1\ hour} = 0.485\ pb^{-1}$

*moderate injection regime*

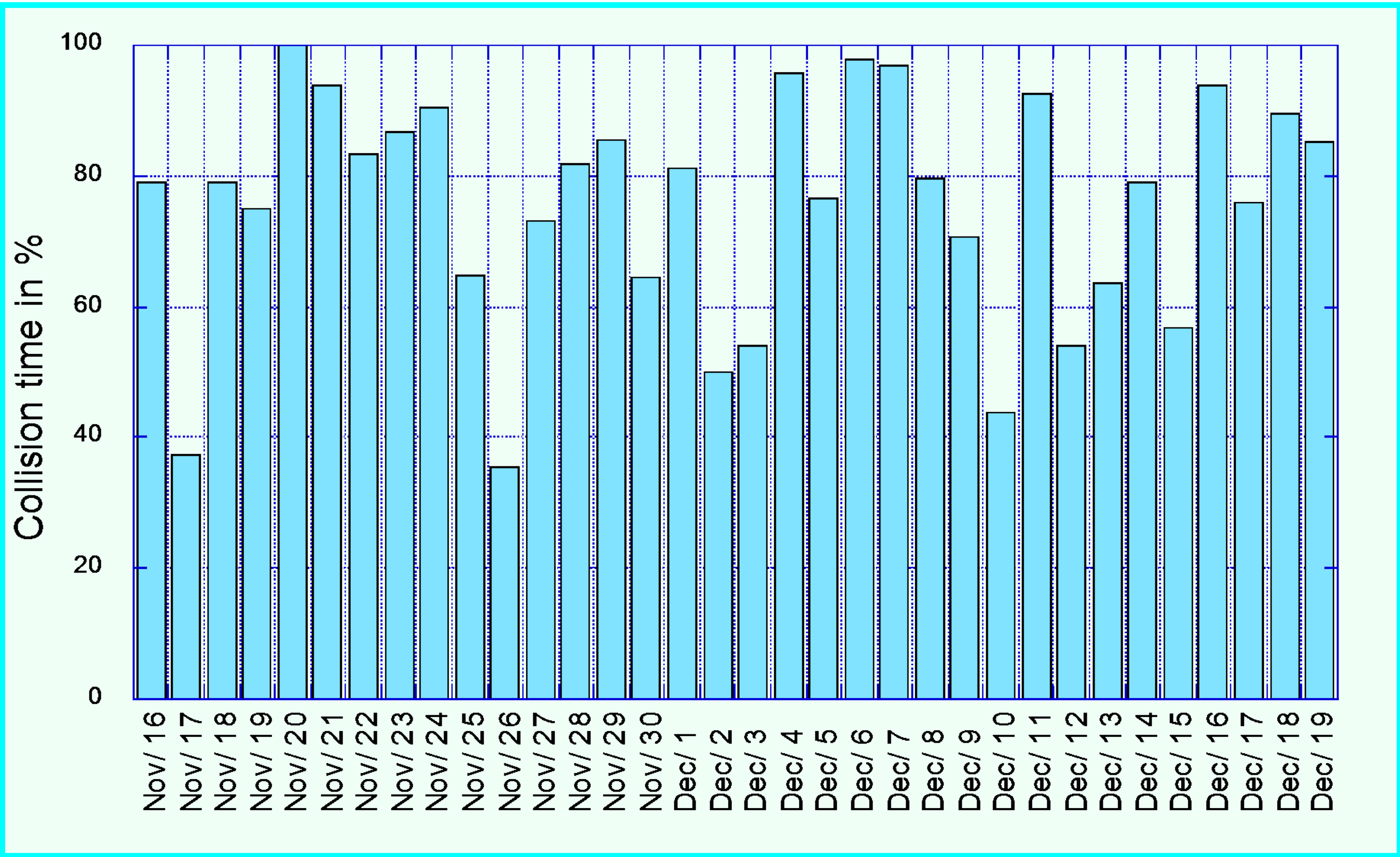
$L_{\int day} > 11\ pb^{-1}$ *possible*

**Background** was compatible with the detector data-taking

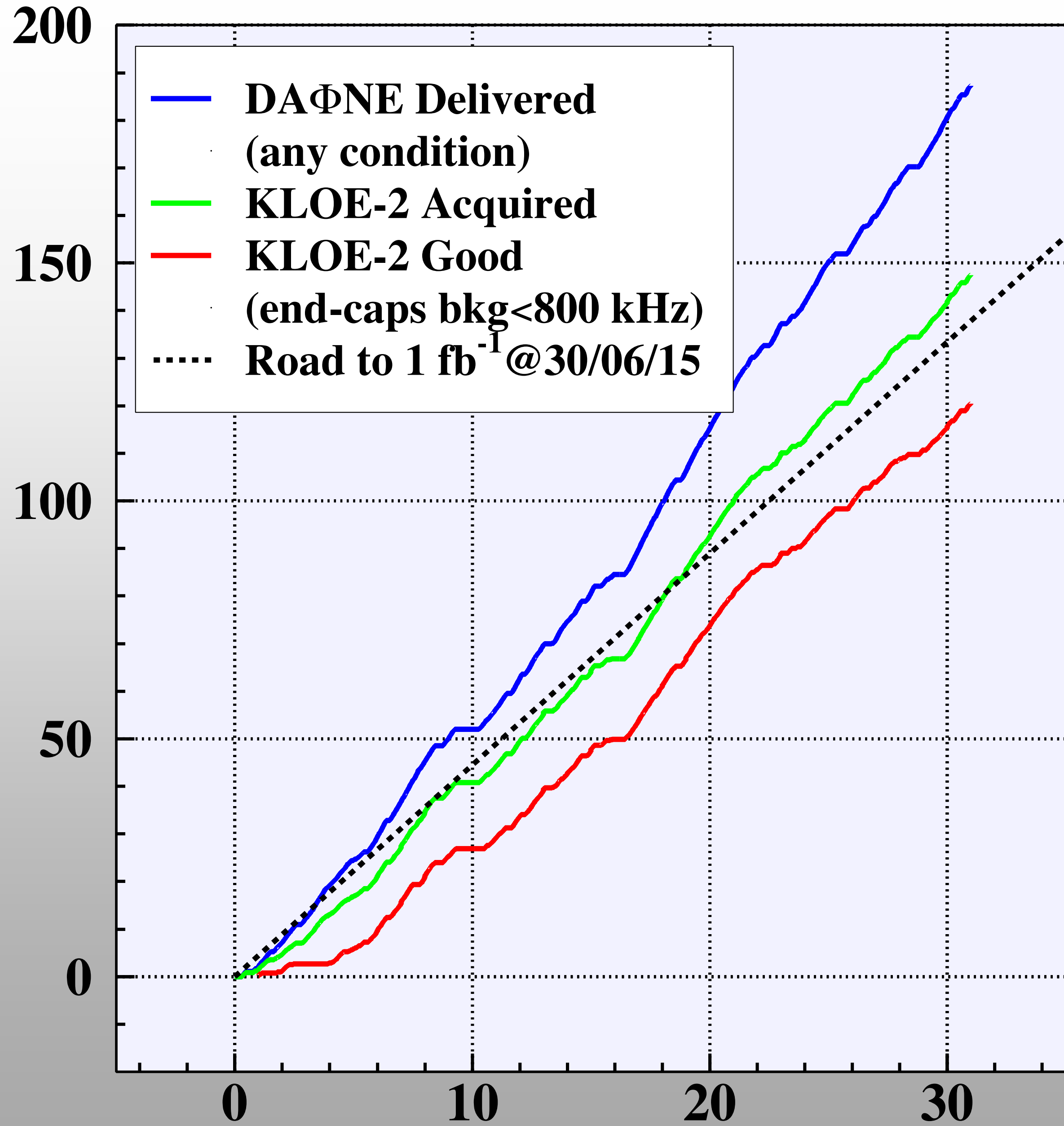
# Daily integrated Luminosity November 2014



# Collider uptime




Collision time is defined as the percentage DAFNE has been delivering a *reasonable luminosity* to the KLOE-2 detector Low Collision time has been due to scheduled activities mainly about the detector

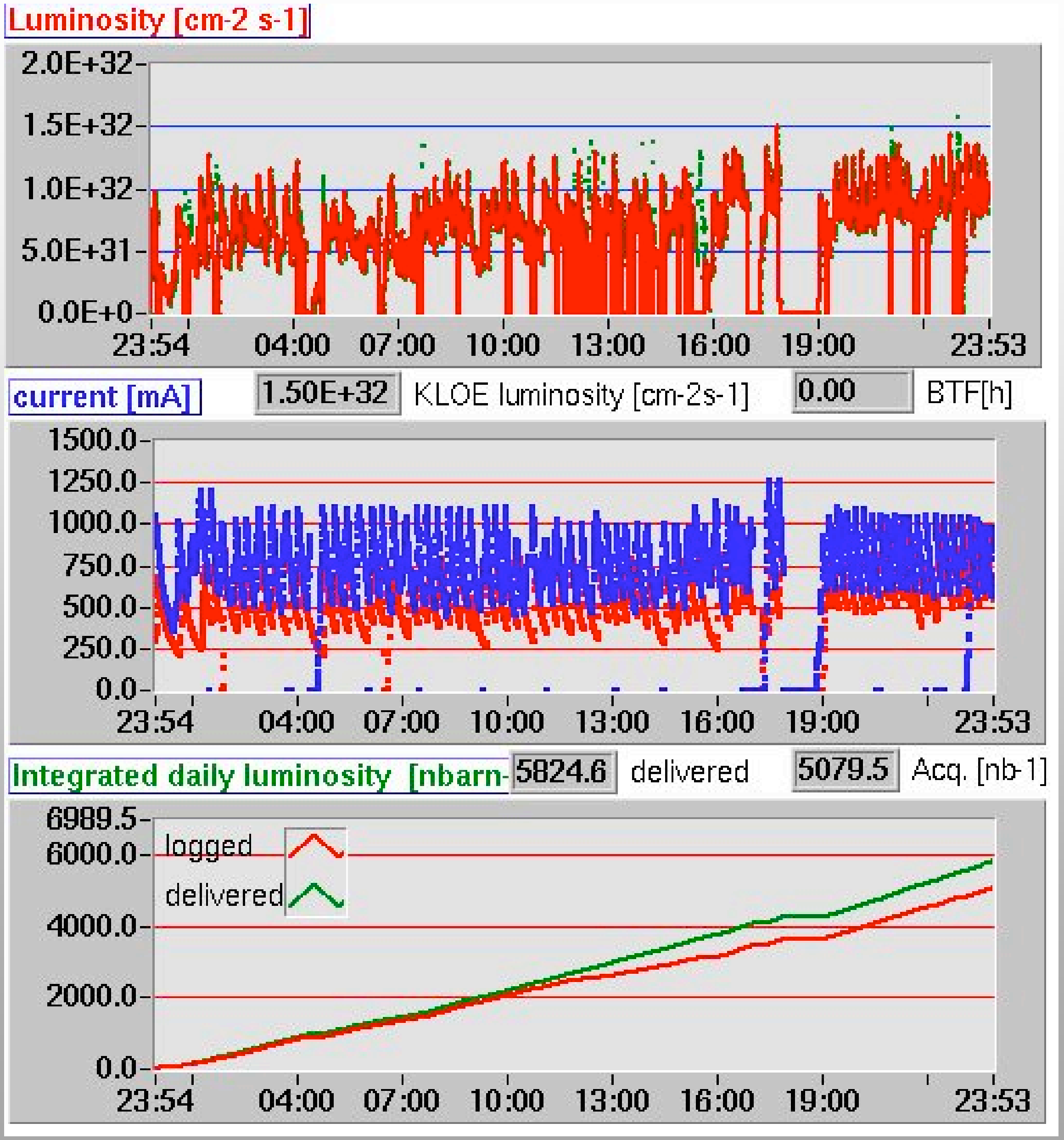

DAΦNE Delivered
(any condition)
KLOE-2 Acquired
KLOE-2 Good
(end-caps bkg<800 kHz)
Road to 1 fb-1@30/06/15
200
150
100
50
0
0
10
20
30

# Electron main ring klystron replacement February 2015

# 2015 restart: inner tracker in acquisition

Sunday Feb 15th:

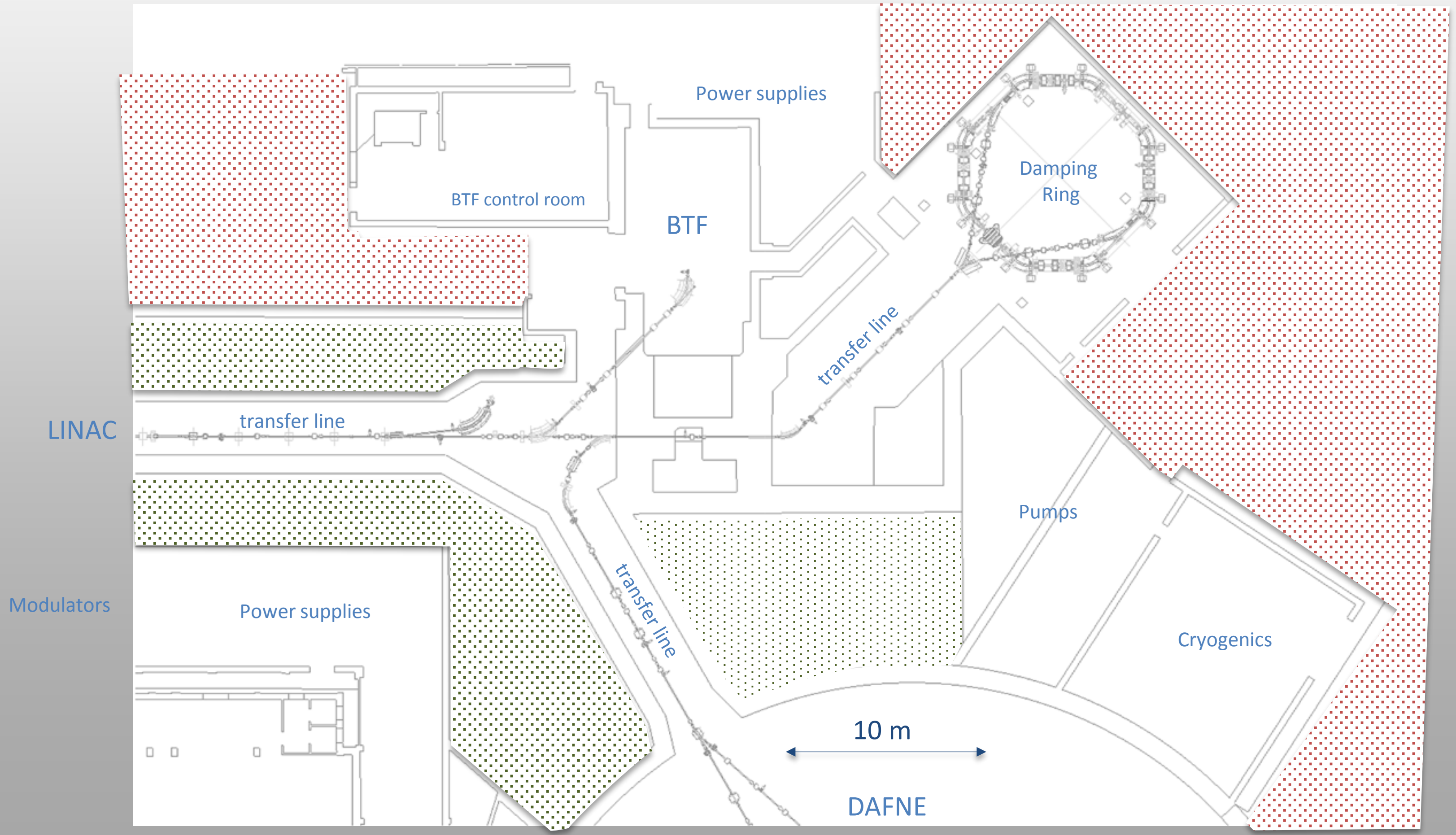
- peak luminosity of 1.5*10^32
- 5 pb-1 /day on disk,
- Reasonable background,
- Inner tracker on



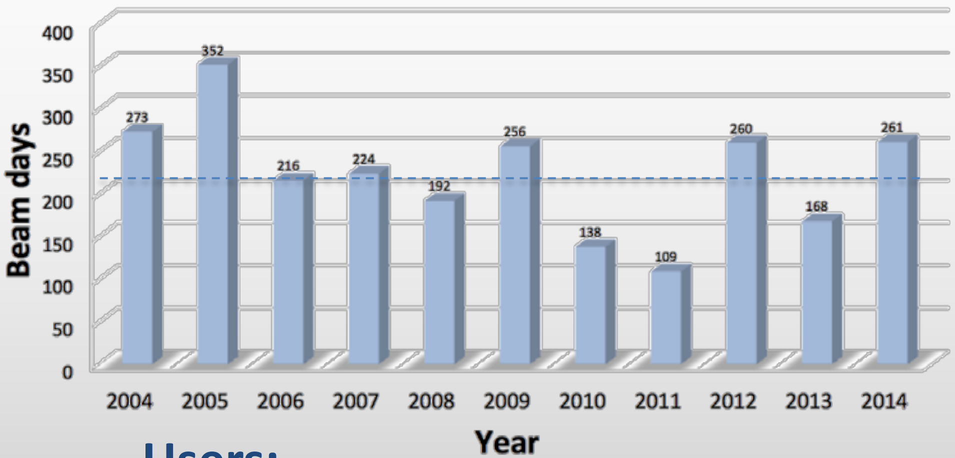
# Beam Test Facility (BTF) @ DAFNE

The **BTF** is a transfer line optimized for **two** main purposes:

- the production of **single-particle** distribution of electrons/positrons
- the extraction of the **full beam** from the DAFNE linac



# BTF users




- **11 years** of consolidated and steady running
- Average beam time: **220 days/year**
- Average shift : 8 days
- **70%** of the beam time in parasitic mode during DAFNE collider operations
- **30%** of foreign users

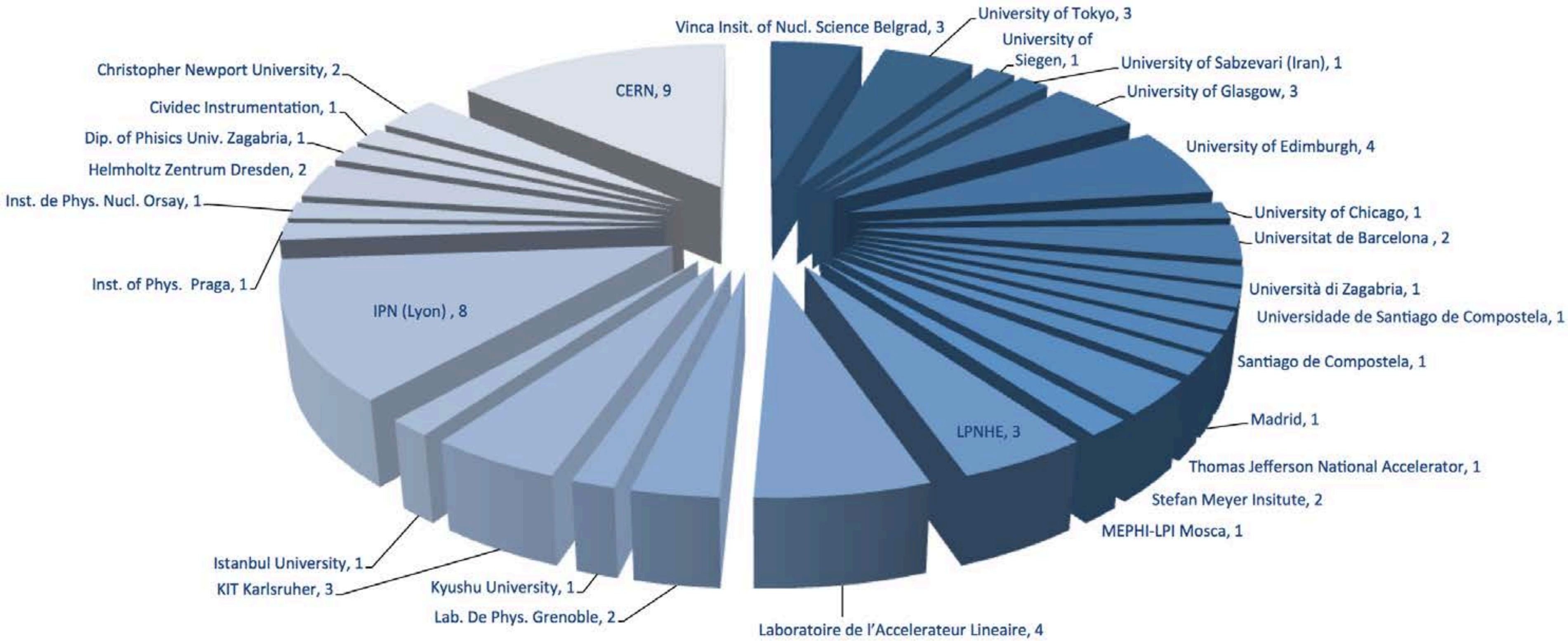
**Users:**

- Mainly detector testing from the **HEP** and **astro-particle** community

**but also:**

- High intensity tests and experiments:
  - RAP
  - AIRFLY, AMY
  - Channeling experiments
  - C-SPEED
  - Beam diagnostics (pepper-pot, diamonds)
  - Neutron and charged particles production

# Foreign institutions users




BTF users, coming from foreign institutions (multiple shifts counted once), during the last 3 years

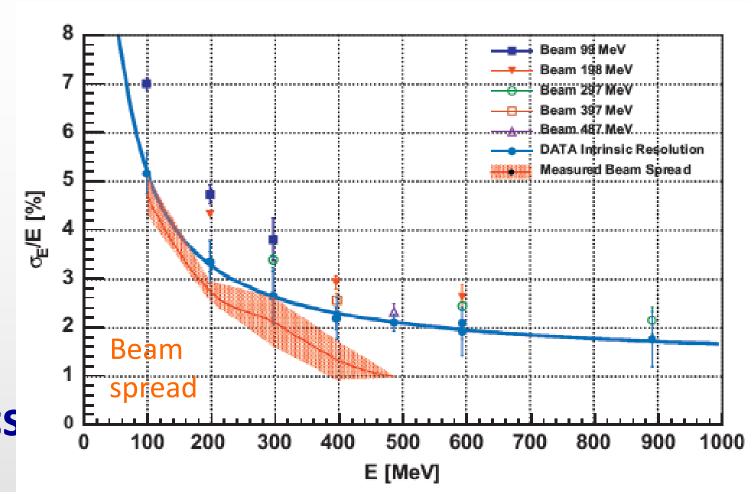
# BTF beam

- Energy spread **Δp/p ~1%**
- Beam spot: **1 – 2 mm RMS**
- Divergence: **1 – 1.5 mrad**

Effect of **multiple scattering** in air and line **optics**

- Beam position: **0.25 mm RMS**
- Pulse duration: **1.5 – 40 ns**
  - (10 ns during DAFNE operations)

Measurement of the beam *E* spread

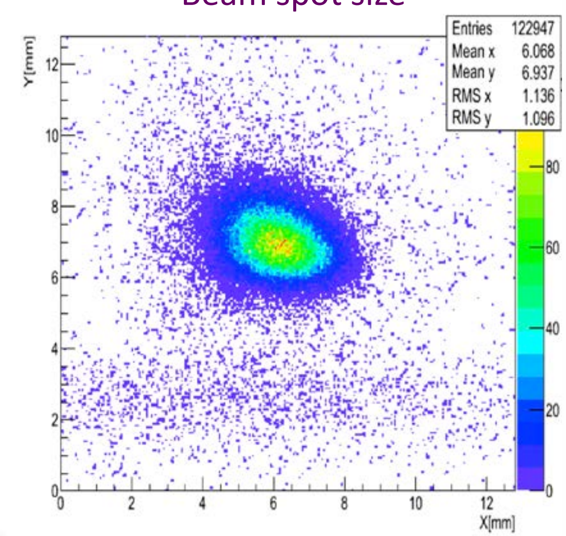



NIM A 718 (2013) 107–109

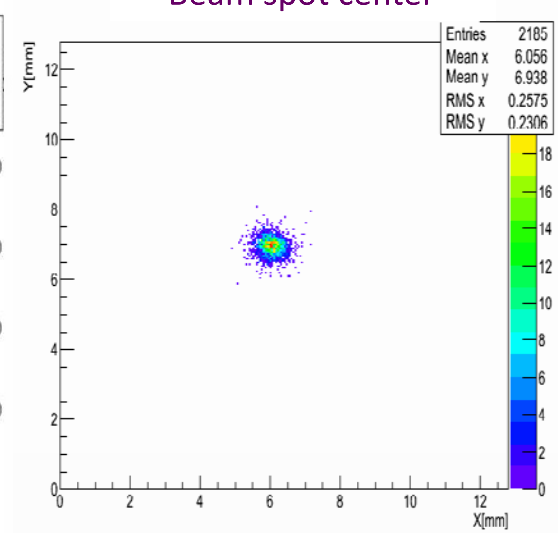
High intensity

- Present authorization **for BTF hall**:
  - <n> = **3.125 $10^{10}$ electrons/s** at 800 MeV
  - 5 nC/s = 10 mA × 10 ns × 50 Hz
  - Translates to ≈**$10^{18}$ electrons/year**
- Shielding requirements:
  - 1 m of concrete
  - 15 cm of lead

Beam spot size

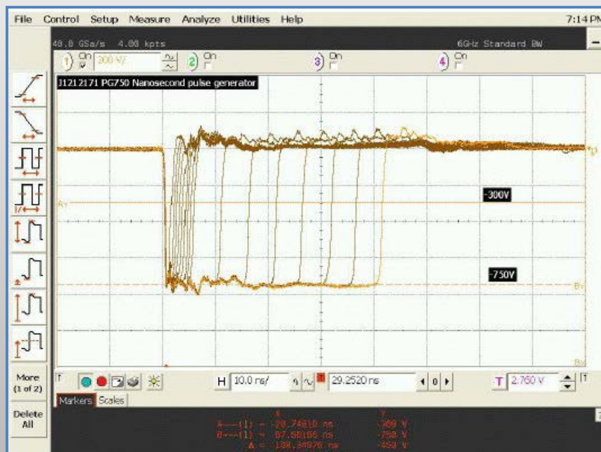


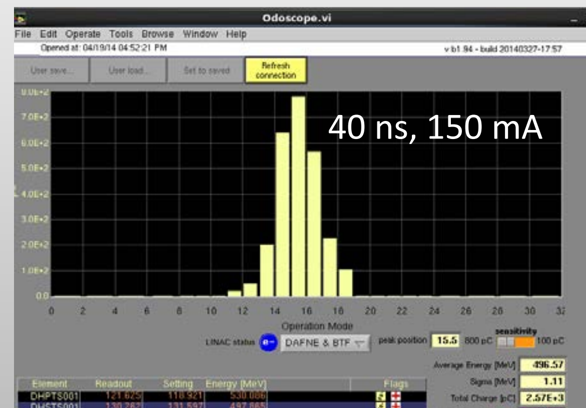

Beam spot center

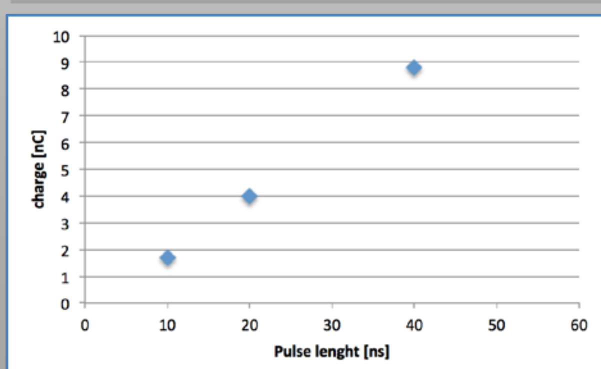


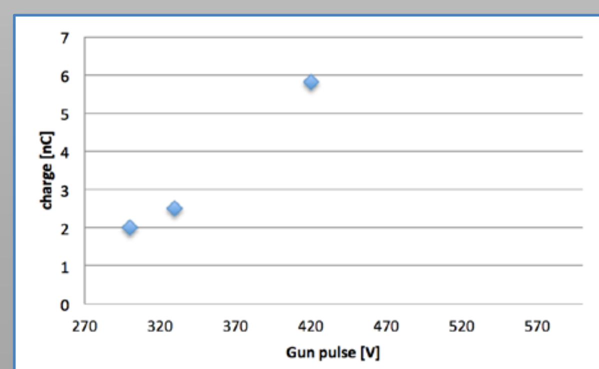
**Improvements of the beam parameters** driven by the requirements of possible future experiments:

- Make the linac pulses variable in length:
  - Upgrade of the gun pulsing system, now capable of delivering pulses between **1.5** and **40 ns**, in steps of 0.5 ns, and pulse height between **300** and **750 V** in steps of 30 V
  - Studying the energy spread vs. pulse length, towards a **≈150 ns** pulse
- Verify all possible handles in order to increase the **total pulse charge**
- Optimize **focalization** at the exit of the gun, and the **transport** along the linac, in order to reach the maximum possible energy (both with electrons and positrons)
- Improve the **diagnostics** (BPM's all along the linac all connected and read-out)

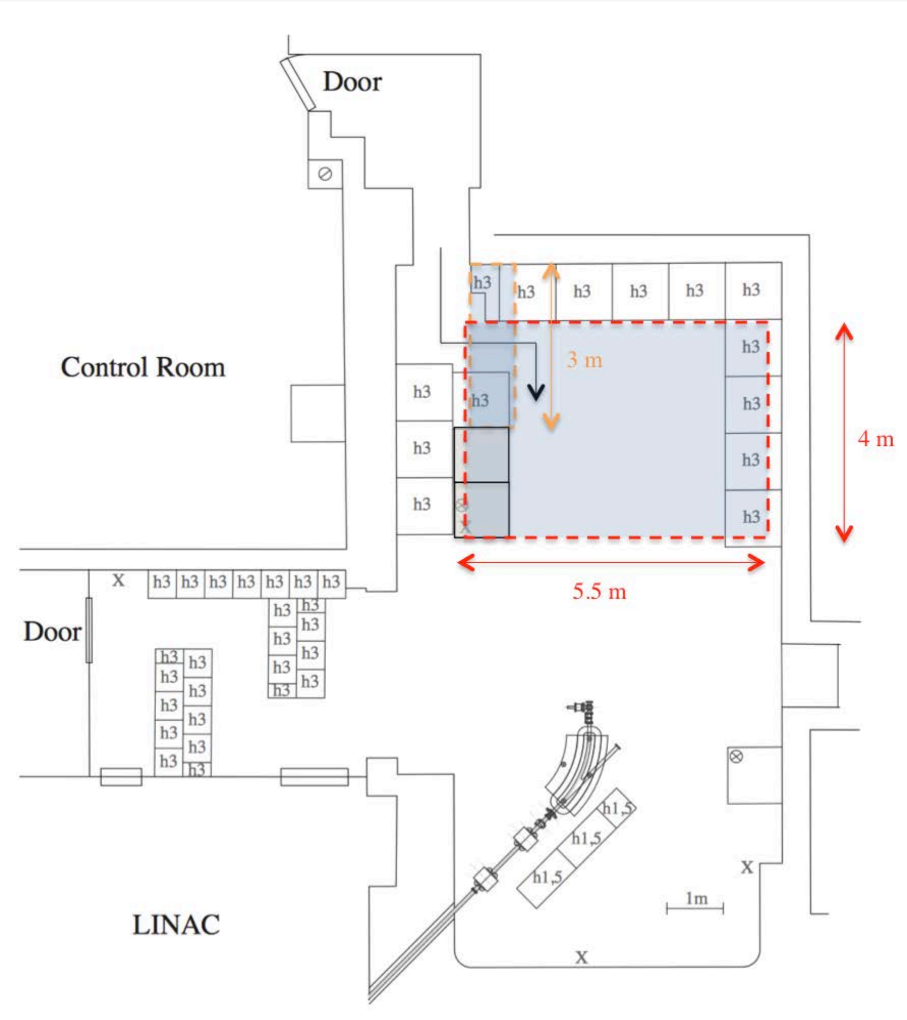


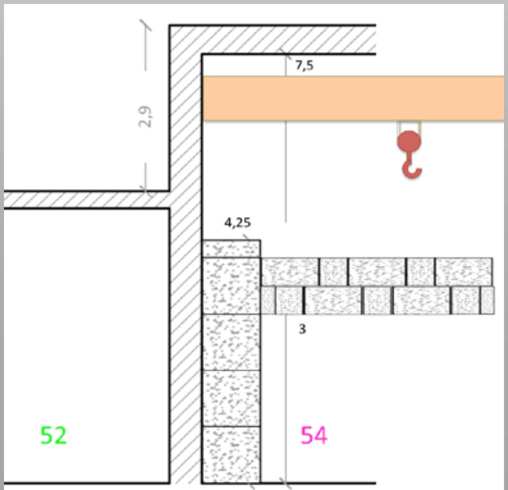



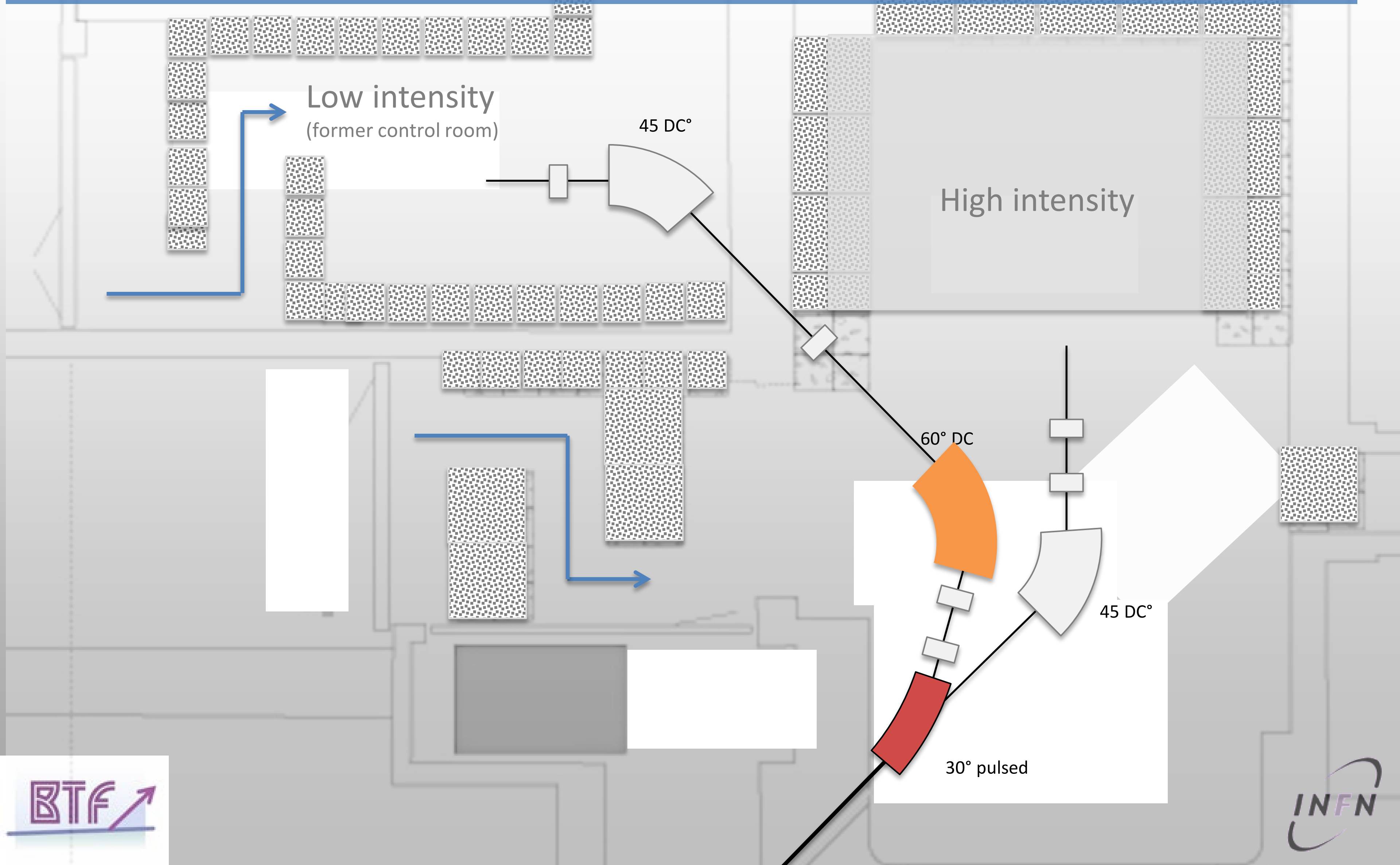
# Summer 2015: add concrete ceiling



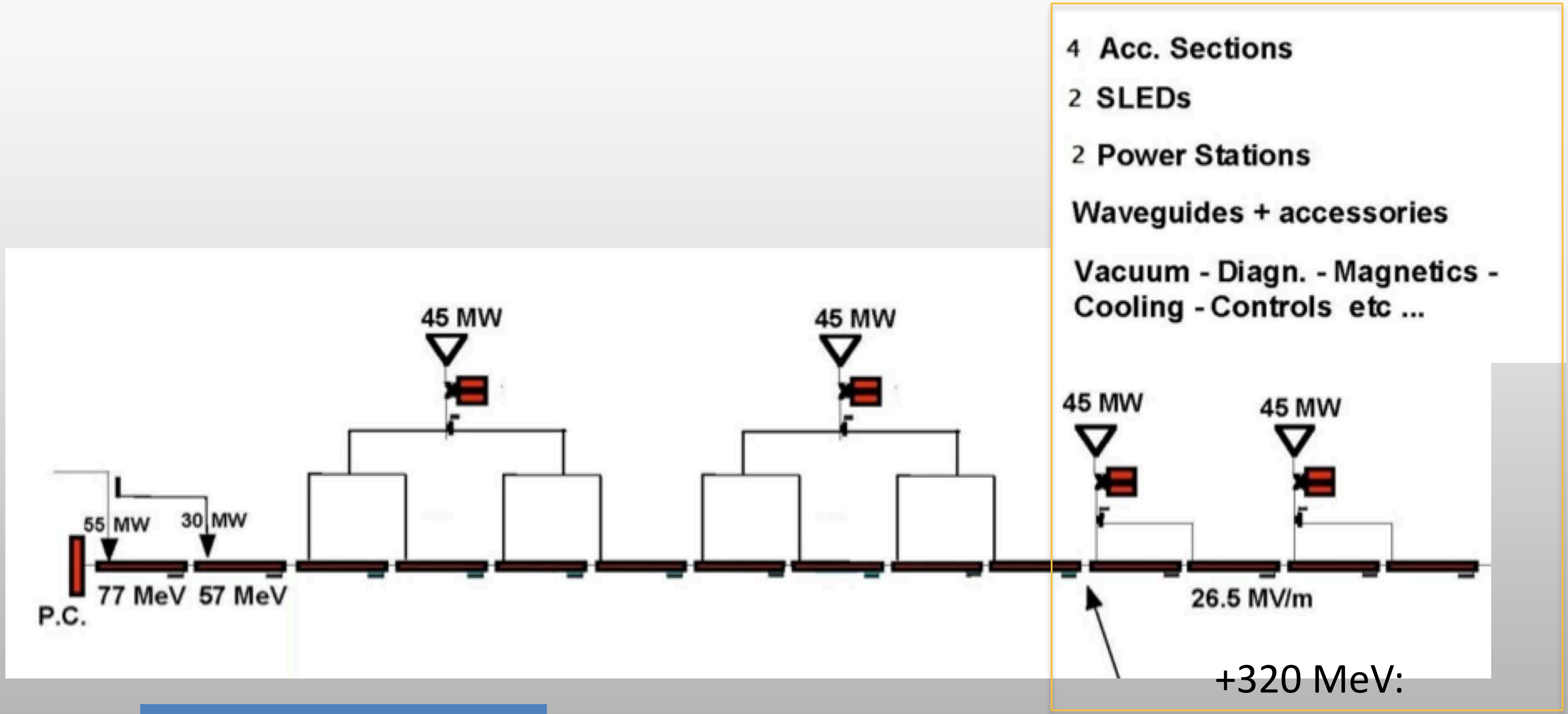



**Doubling of BTF lines**

- Control room already been moved upstairs to free additional area
- Modified lines calculation under way
- Shielding to be properly calculated

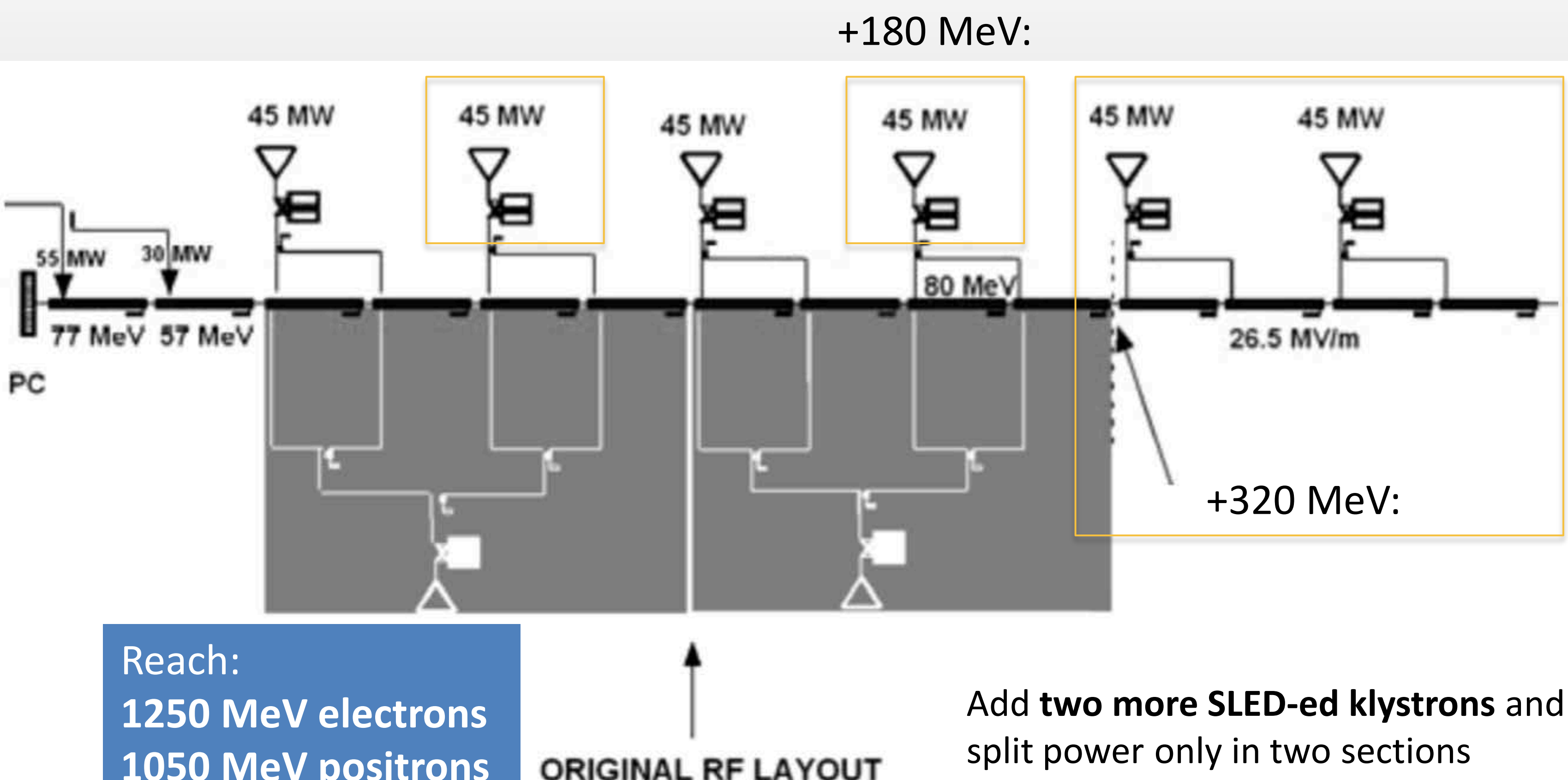


# Linac energy upgrade: add 4 sections and 2 RF stations




Reach:
**1070 MeV electrons**
**870 MeV positrons**

# Linac energy upgrade: add 4 sections and 4 RF stations



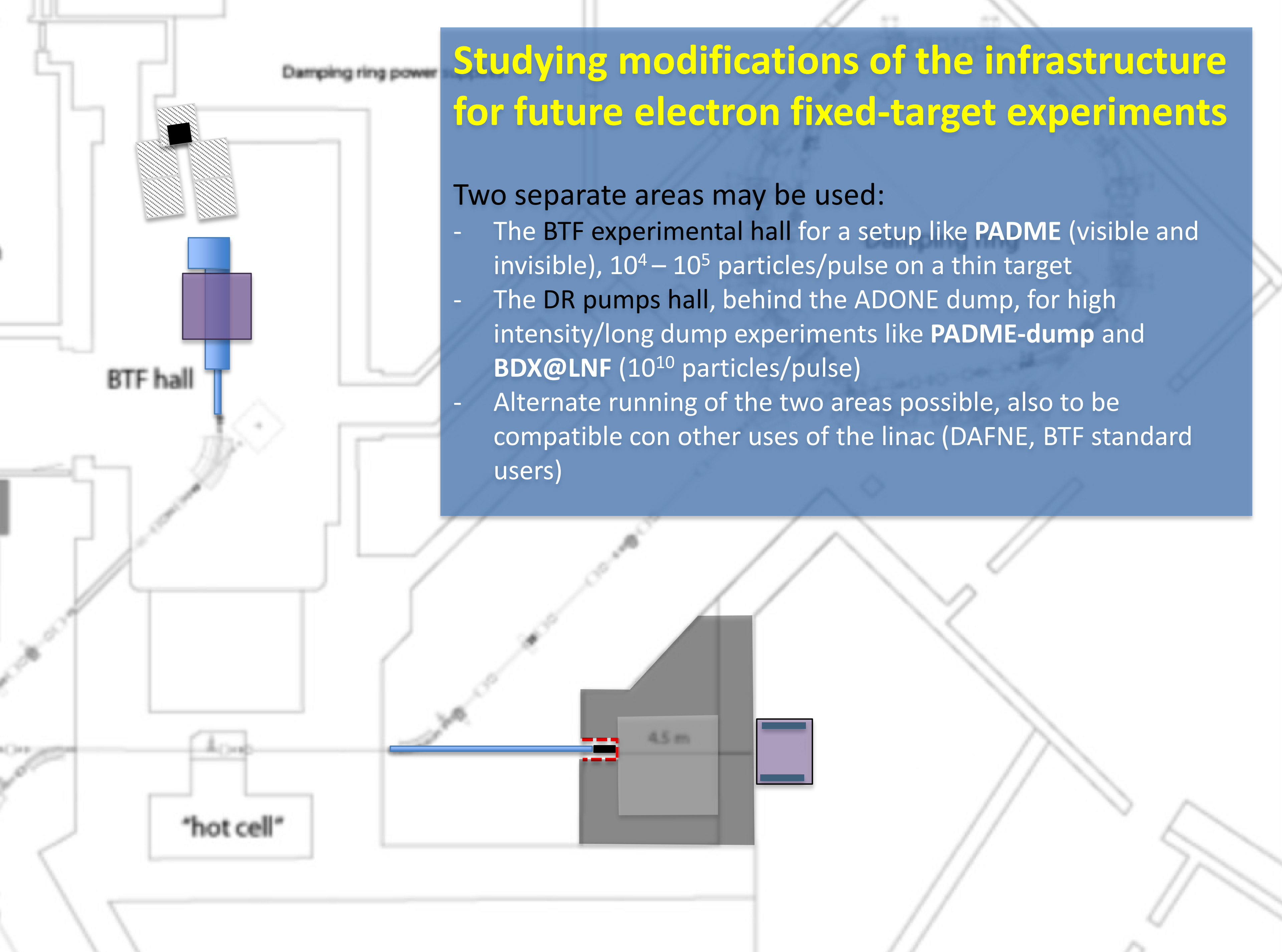

Reach:
**1250 MeV electrons**
**1050 MeV positrons**

Add **two more SLED-ed klystrons** and split power only in two sections instead of four

# Studying modifications of the infrastructure for future electron fixed-target experiments

Two separate areas may be used:

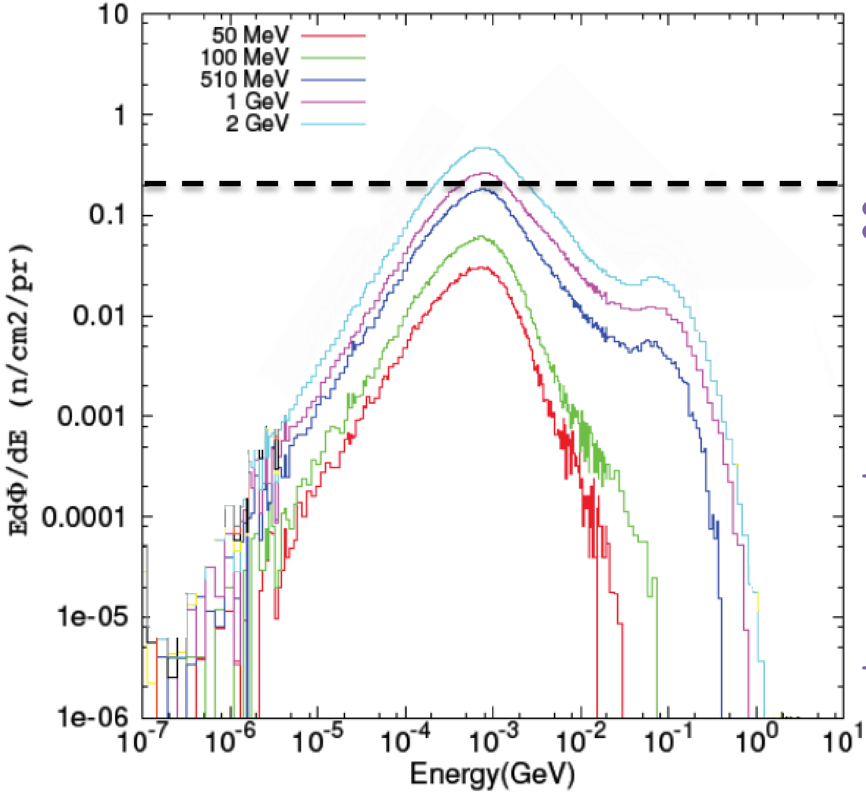
- The BTF experimental hall for a setup like **PADME** (visible and invisible), $10^4 - 10^5$ particles/pulse on a thin target
- The DR pumps hall, behind the ADONE dump, for high intensity/long dump experiments like **PADME-dump** and **BDX@LNF** ($10^{10}$ particles/pulse)
- Alternate running of the two areas possible, also to be compatible con other uses of the linac (DAFNE, BTF standard users)



# Existing dump

- Cavity in the wall covered by lead bricks
- 50 cm additional concrete blocks with $25 \times 25\ cm^2$ hole for beam entrance

# Neutron @ BTF




Electrons on W target

- At 725 MeV and full linac power: $10^{13}$ e/s
  - to be compared e.g. with nELBE, N=$6\cdot10^{15}$ e/s
- **Swanson estimate**
  - **$9.3\cdot10^{10}$ $Z^{(0.73\pm0.05)}$ n/s $kW^{-1}$**
  - **$2.15\cdot10^{12}$ n/s $kW^{-1}$** for tungsten
- **n@BTF optimized target**: **$2.75\cdot10^{12}$ n/s $kW^{-1}$**
- Increasing pulse height and length, we can increase 50× (from 40 W to ~1 kW)

# External programs

- ELI-NP 20 MeV gamma beam by Thomson Scattering – Magurele
- STAR 10 KeV X ray beam by TS- Cosenza
- HL-LHC High luminosity LHC studies - CERN
- FCC Future Circular Collider studies -CERN
- ESRF EU Synchrotron radiation facility upgrade - Grenoble

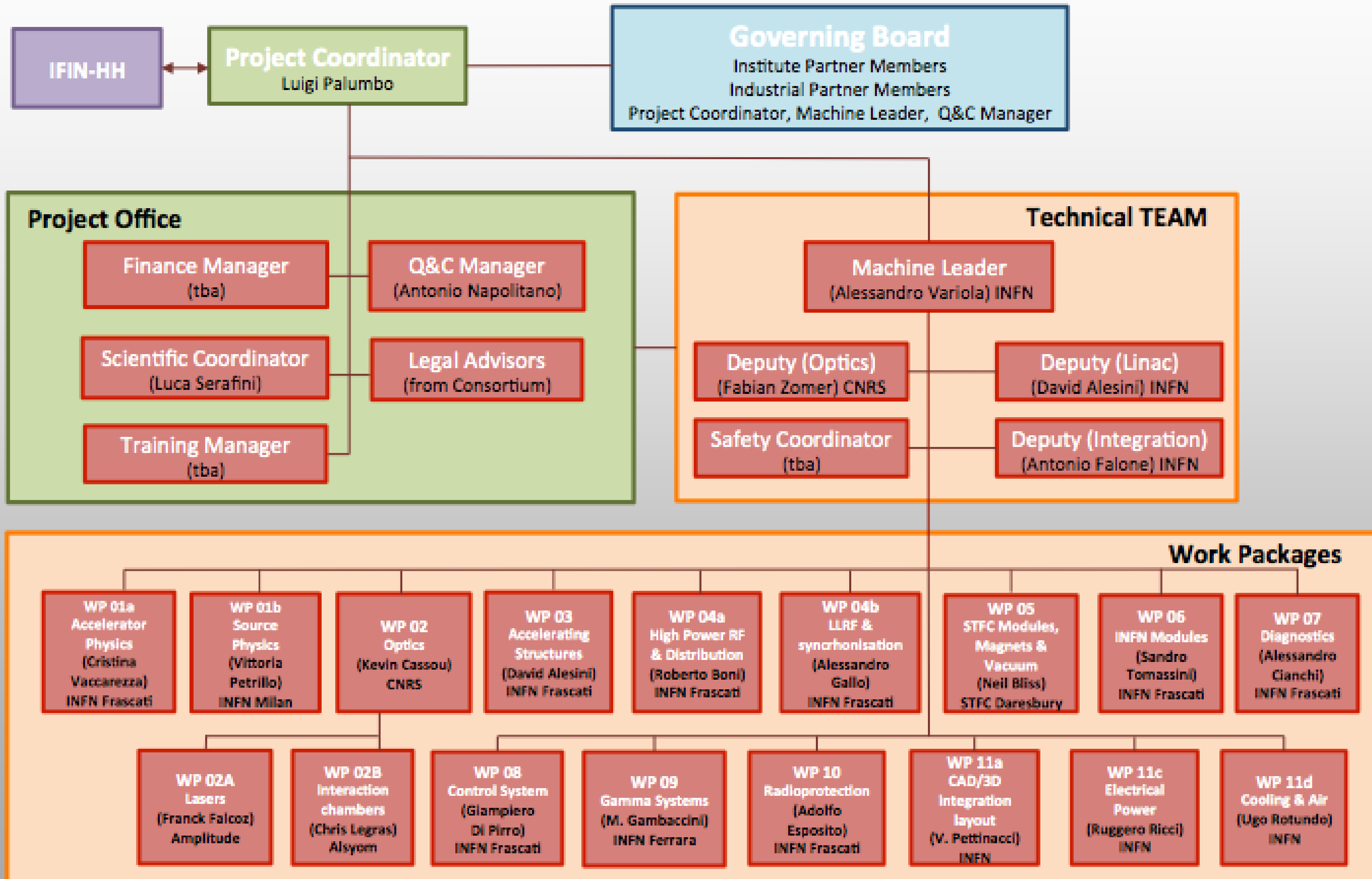
# ELI-NP

20 MeV Gamma photons source based on Thomson scattering

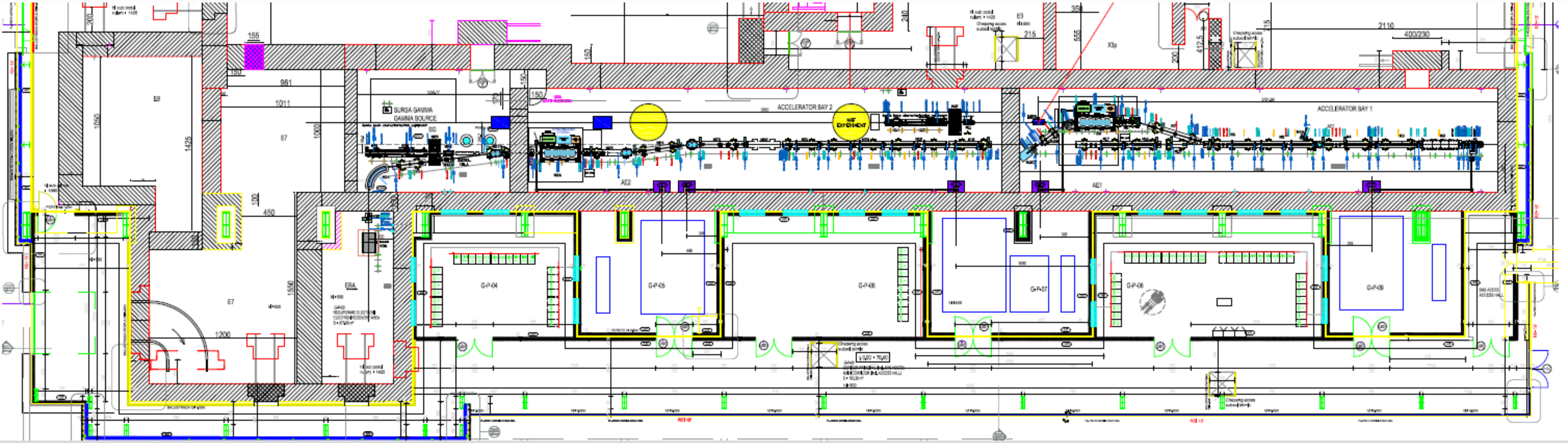
EuroGammas consortium participants:
INFN: LNF,Fe,Mi,CT,Fi and Roma1
CNRS: LAL Orsay
Università "la Sapienza"
Alsyom
ACP-Amplitude
COMEB
Scandinova

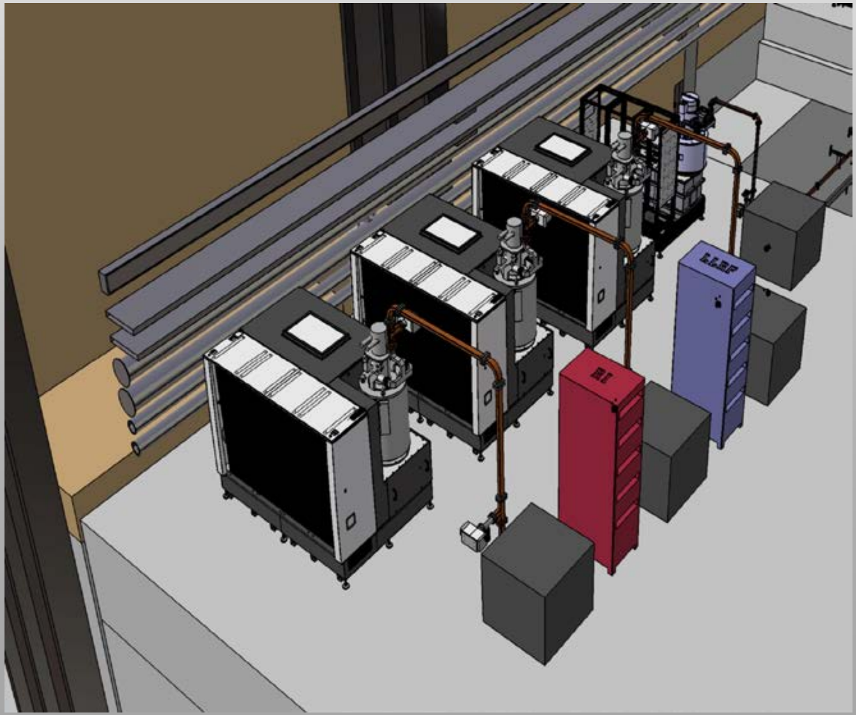
# EuroGammaS Organisational Breakdown Structure (OBS)

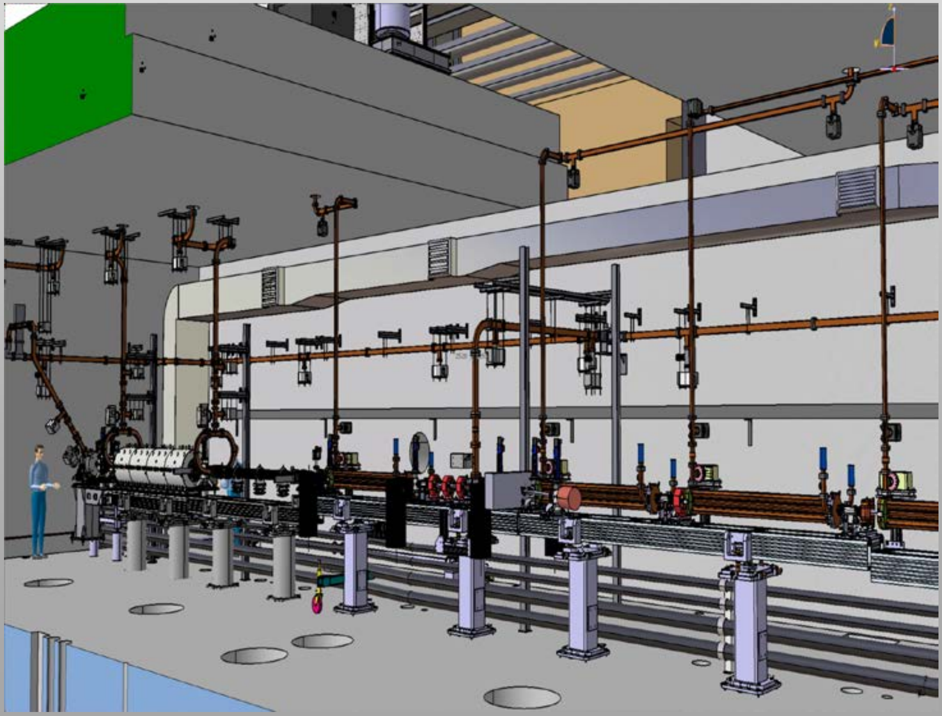
Hierarchical management structure, communication routes and reporting links



# Gamma source layout: 720 MeV Linac





# TW C-Band accelerating structures: design

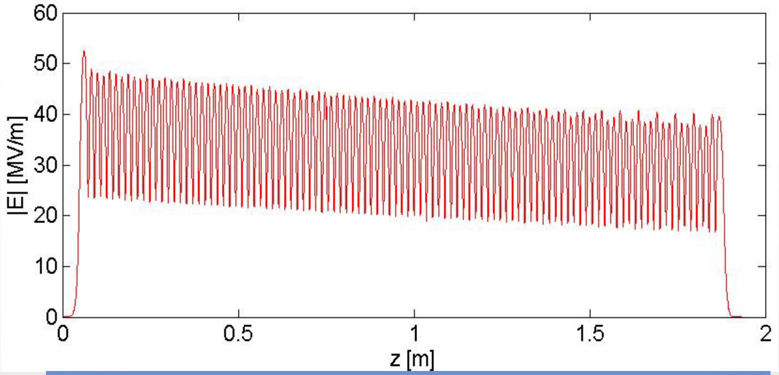
**Several new things have been fixed with respect to the TDR document:**

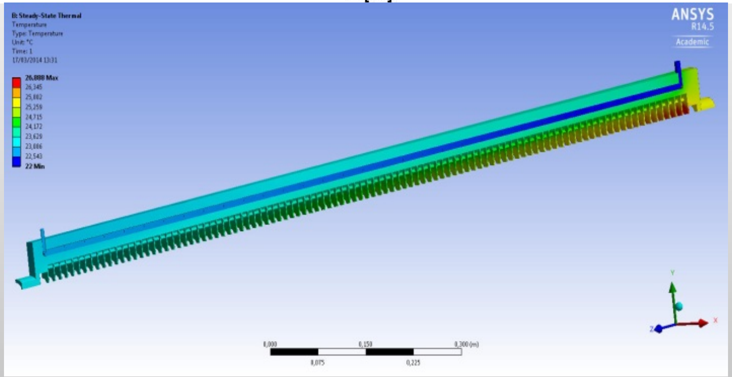
1) **Irises and radius of each cell for a Quasi CG field have been fixed;**

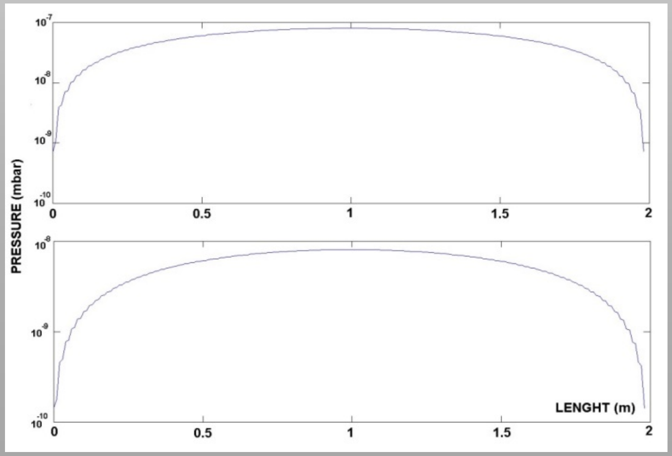
2) **Thermal analysis completed;**

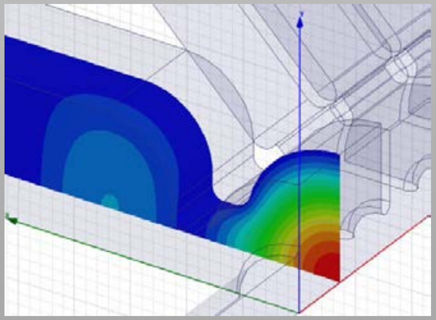
3) **New coupler design (race track) with compensation of the quadrupole field component;**

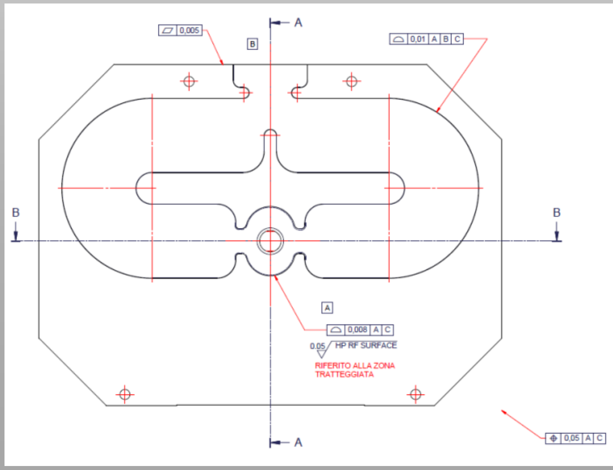
4) **Vacuum calculations (LNF/STFC)**



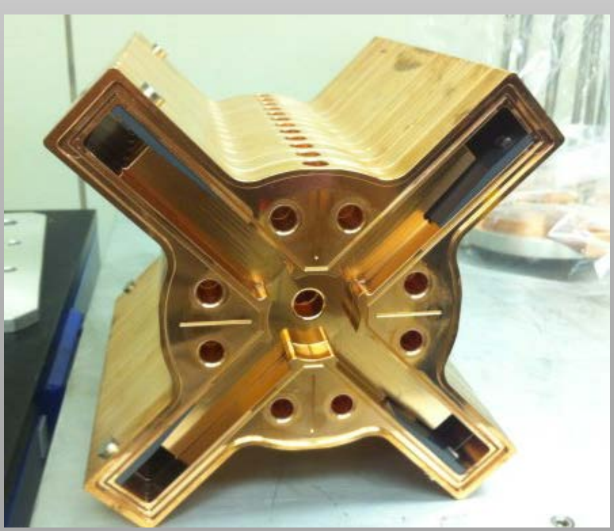


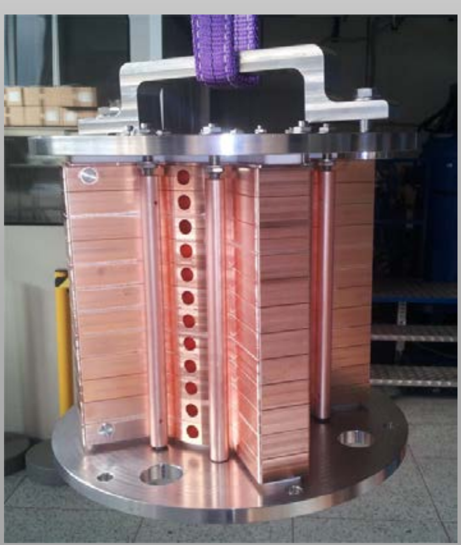
# C-BAND HOM DAMPED ACCELERATING STRUCTURES

[D. Alesini et al., thpri042, proc. of IPAC 14, 2014 and wepfi013, proc. of IPAC 13, 2013]

The linac energy booster of the European ELI-NP proposal foresees the use of 12, 1.8 m long, travelling wave C-Band structures, with a field phase advance per cell of $2\pi/3$ and a repetition rate of 100 Hz. Because of the **multi-bunch operation, the structures have been designed with a dipole HOM damping system** to avoid beam break-up (BBU). They are quasi-constant gradient structures with symmetric input couplers and a very effective damping of the HOM's in each cell. An **innovative electromagnetic and mechanical design** has been done to simplify the fabrication and to reduce their cost.

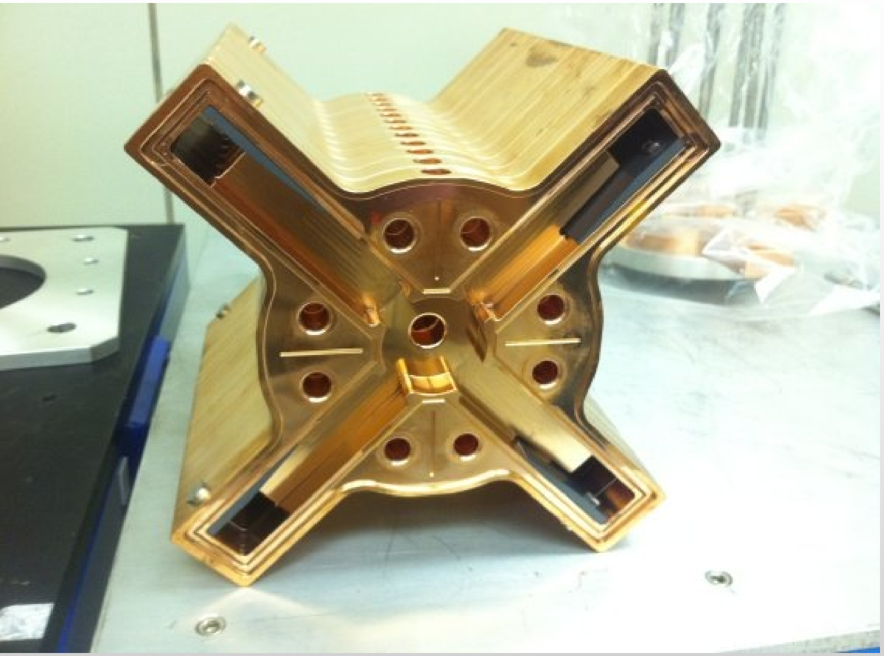
The structures are fabricated in modules (10 modules) that are brazed, then the Sic Absorbers are inserted and the full structure is finally brazed.

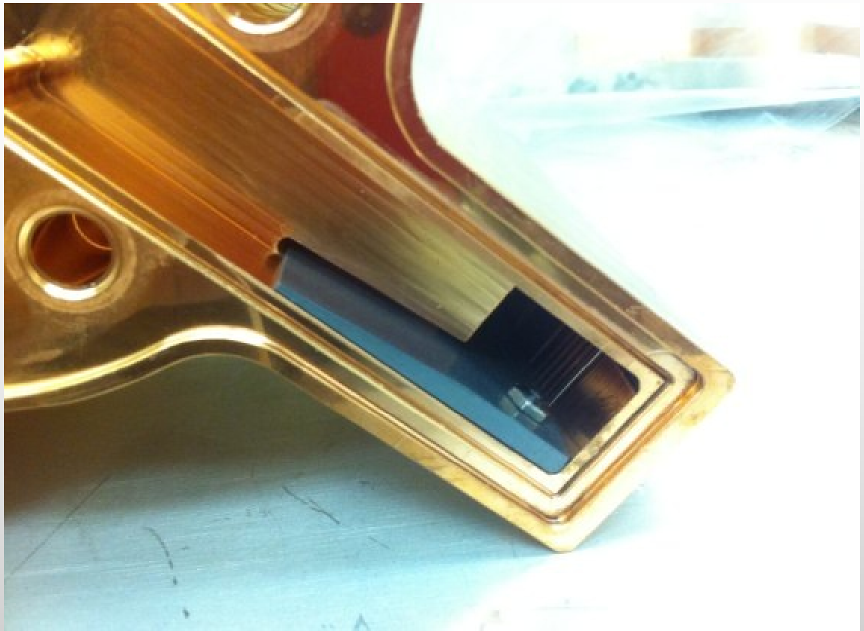




| PARAMETER | VALUE |
|---|---|
| Type | TW- quasi CG |
| Frequency ($f_{RF}$) | 5.712 [GHz] |
| Phase advance per cell | $2\pi/3$ |
| Structure Length | 1.8 m (102 cells) |
| Iris aperture (a) | 6.8-5.8 mm |
| group velocity ($v_g/c$): | 0.034-0.013 |
| Quality factor (Q) | 8800 |
| Shunt imp. (r) | 67-73 [M$\Omega$/m] |
| RF input power | 40 MW |
| $E_{ACC\_average}$@ $P_{IN}$=40 MW | 33 MV/m |
| Rep. Rate ($f_{rep}$) | 100 Hz |
| Average dissipated power | 2.3 [kW] |

# TW accelerating structures fabrication (COMEB)





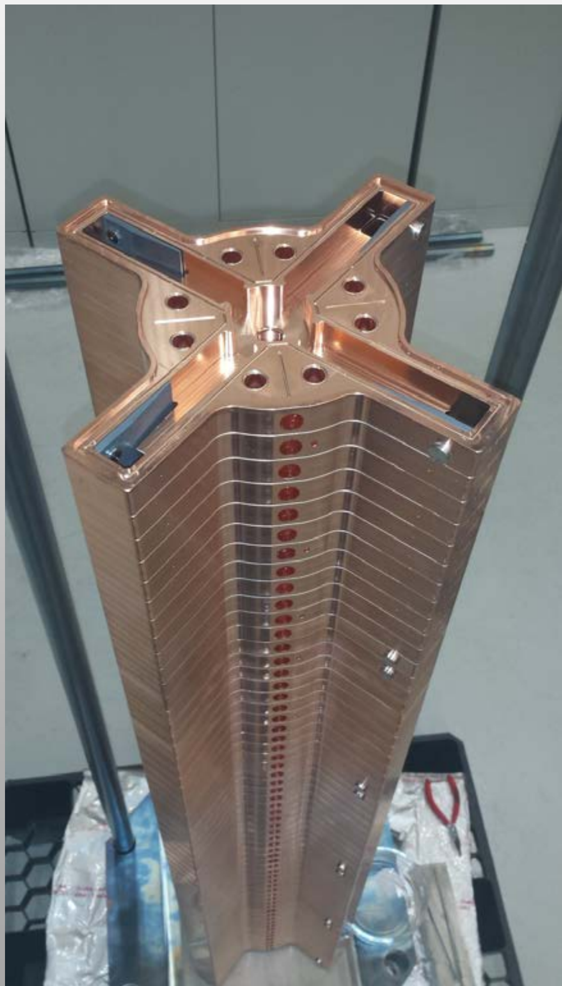
C-Band Accelerating structures with HOM dampers

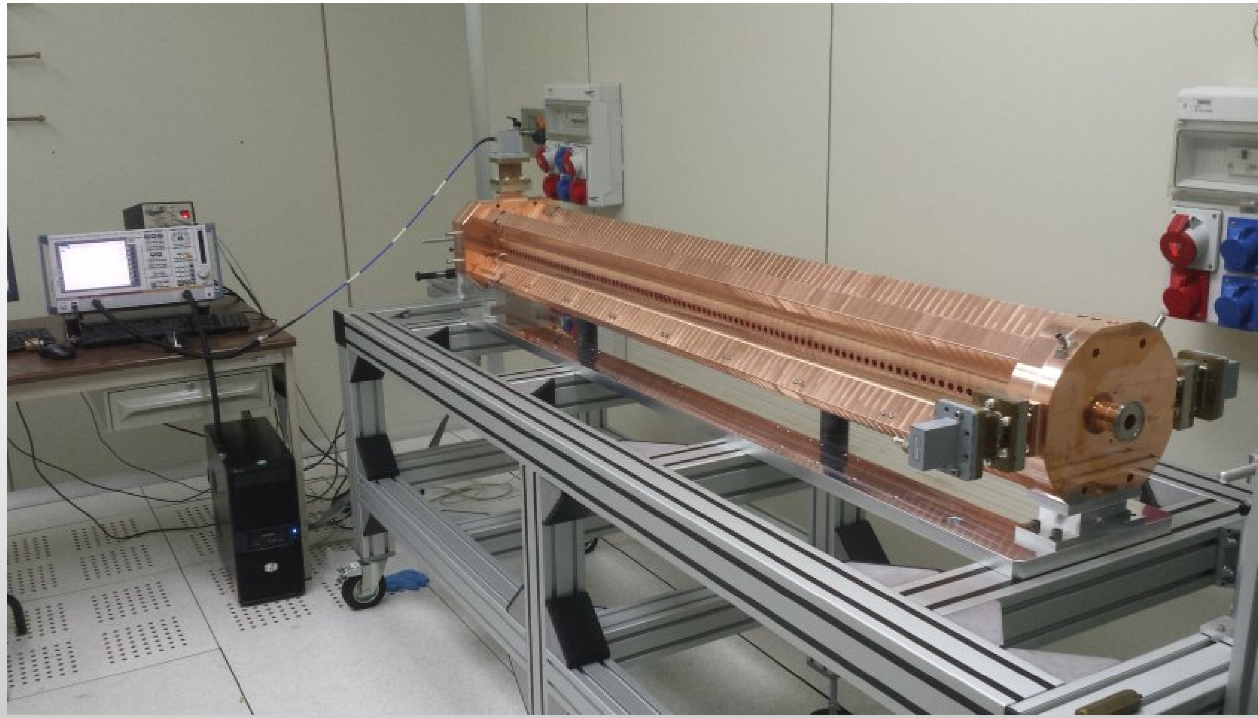
# Fabrication of the C-band structures

The modules have been brazed @ Comeb Company and INFN-LNF while the final two steps brazing have been done at LNL-INFN (Legnaro)

# Fabrication of the C-band structures

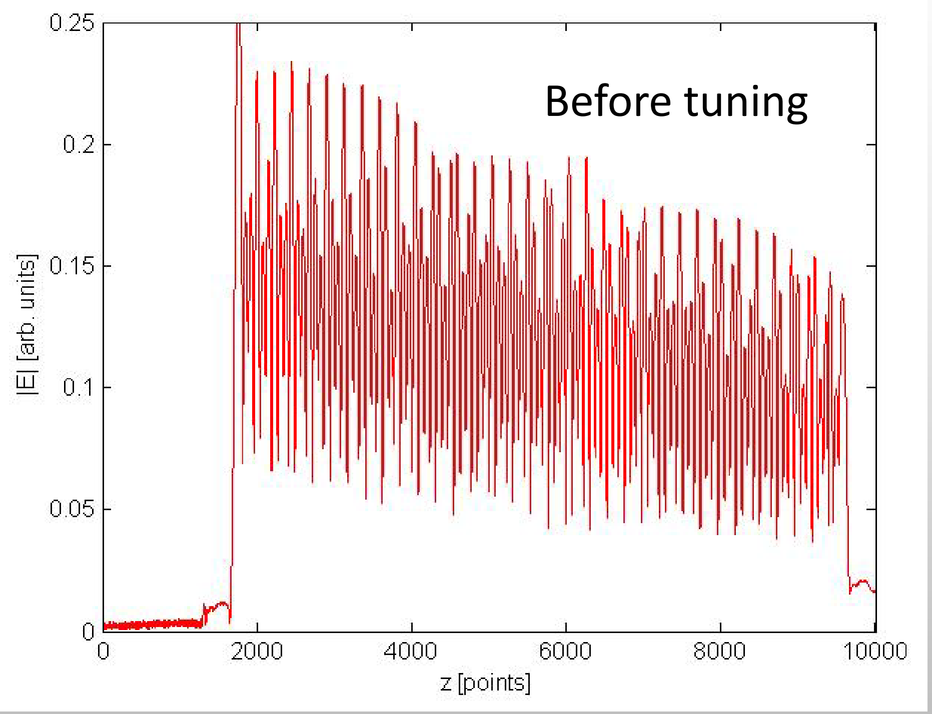
Assembled structure before brazing

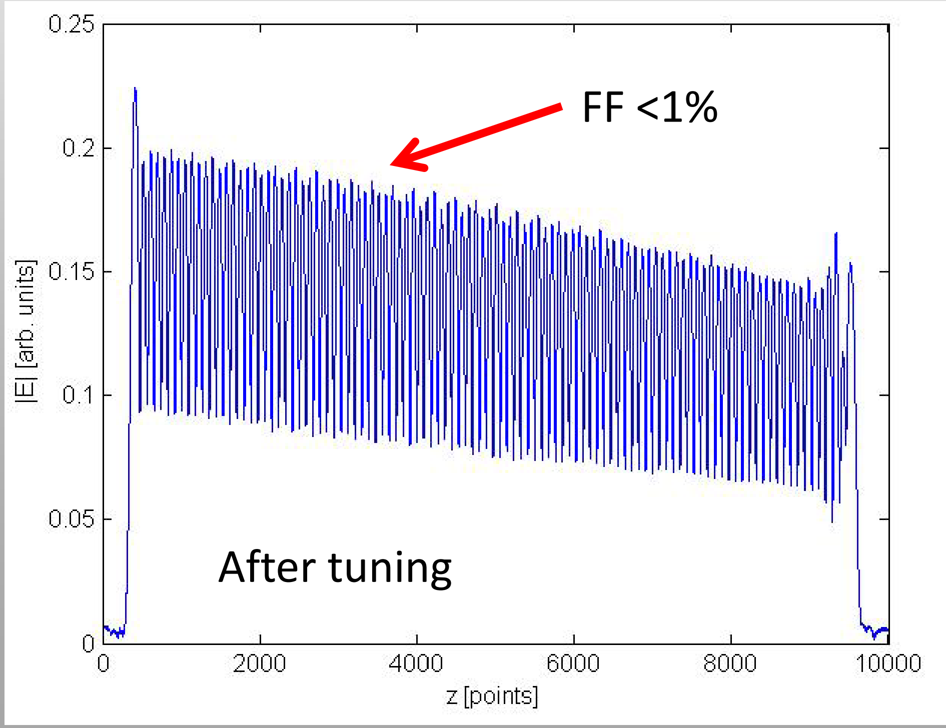




Final Structure under RF test

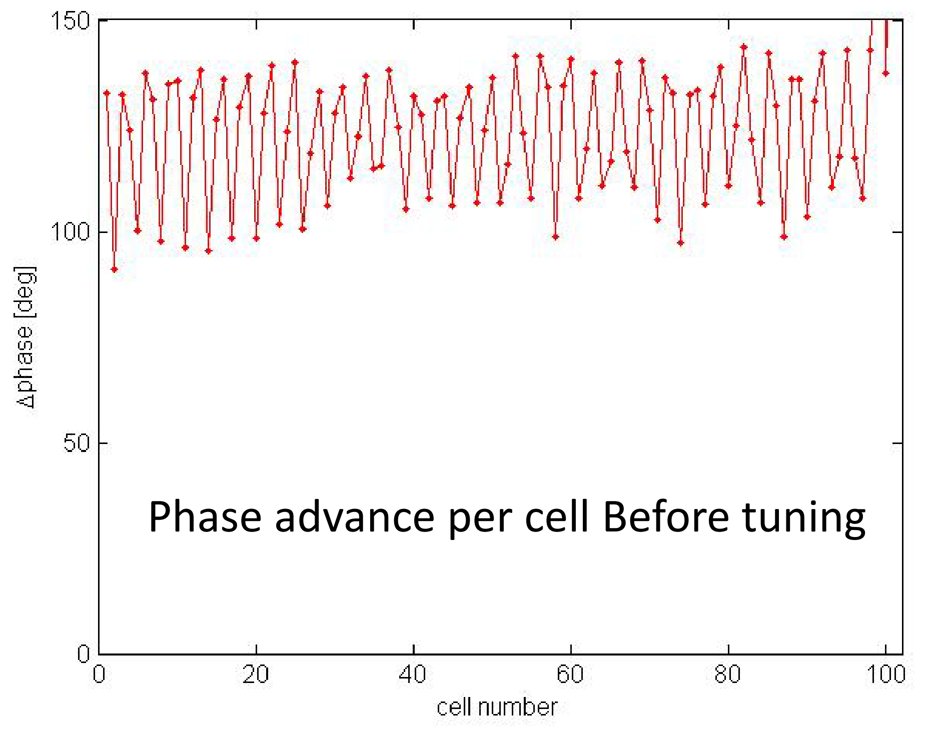
# C-Band accelerating structure
# Low power RF tests and tuning

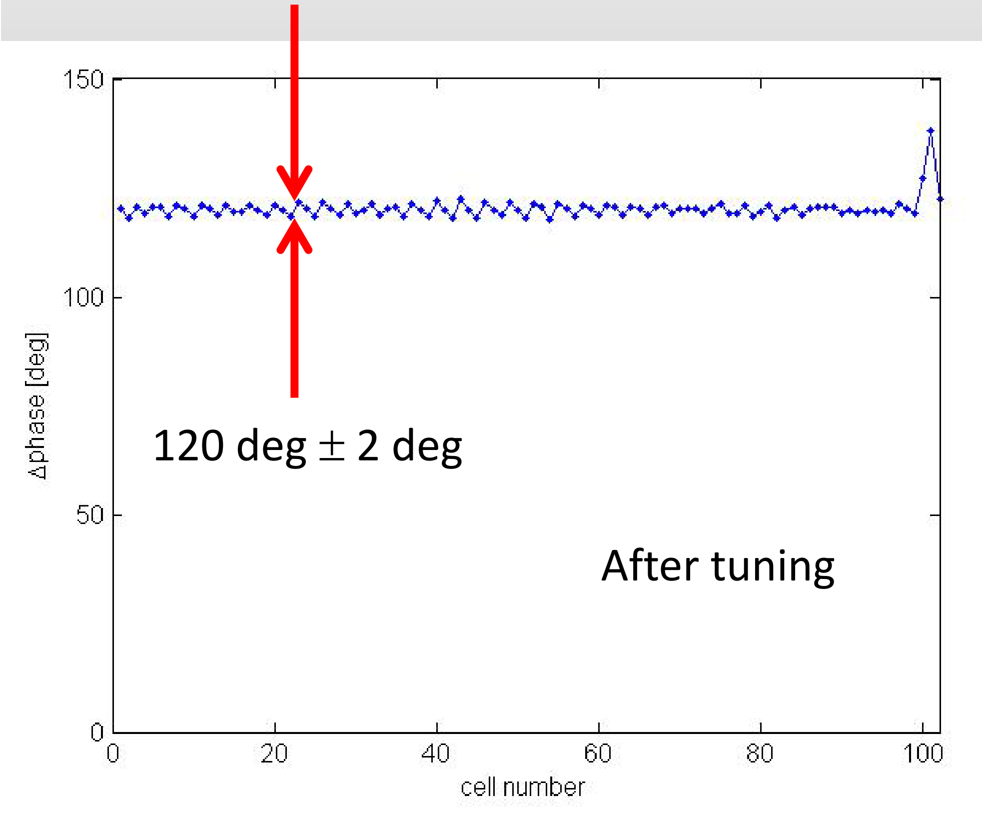



Procedure adopted for tuning D. Alesini et al., JINST 8 P10010, 2013

# C-Band accelerating structure
# Low power RF tests and tuning



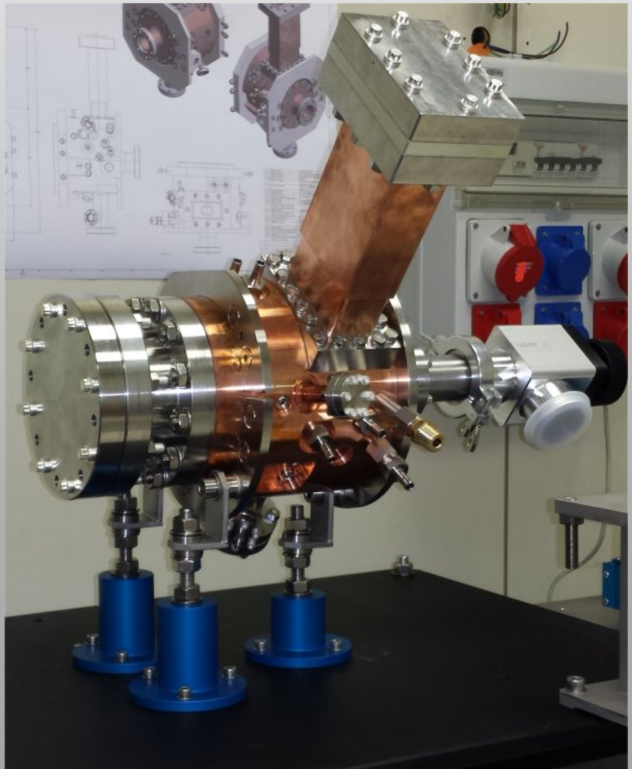



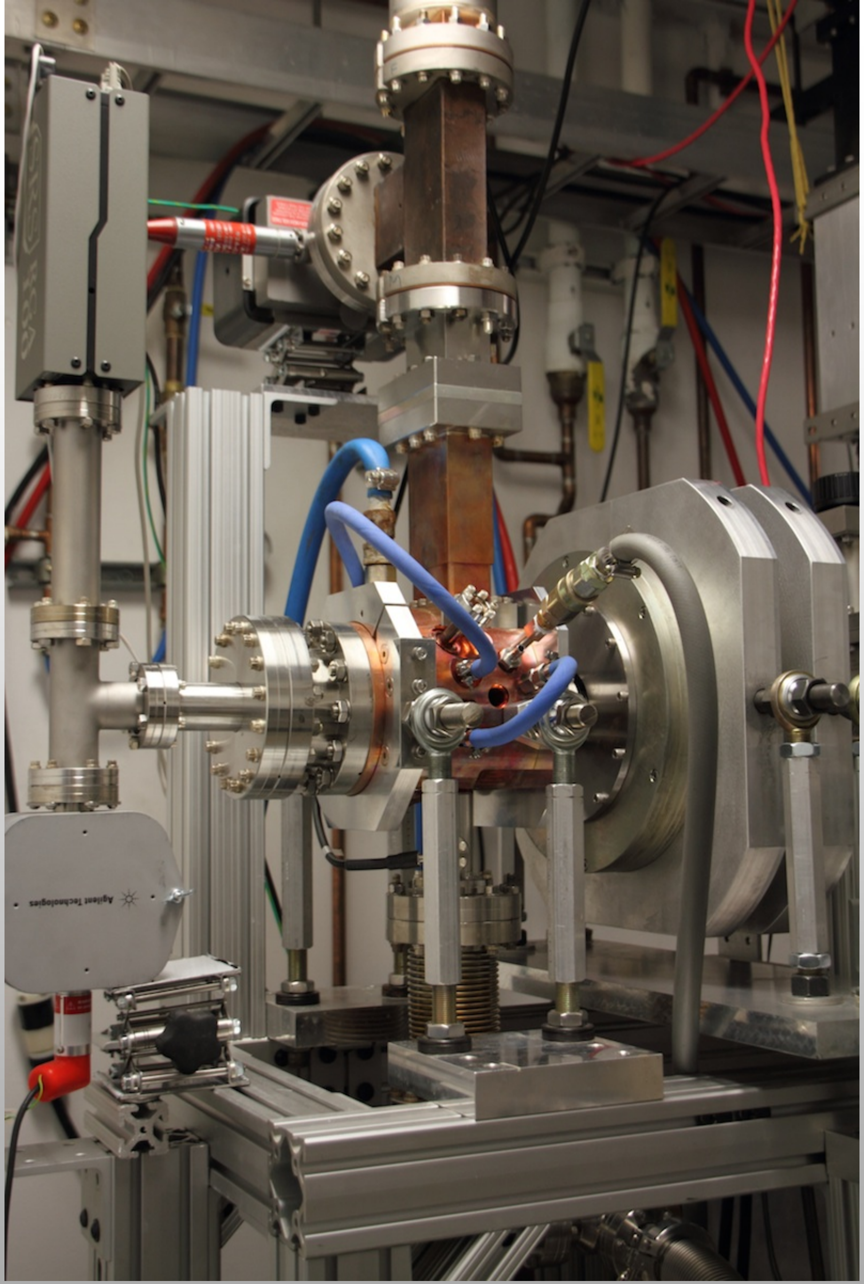
# S Band GUN

The RF GUN of the ELI NP GBS will be a 1.6 cell gun of the BNL/SLAC/UCLA type implement several new features recently integrated in the new gun developed for the SPARC photo-injector

**the structure has been realized without brazing but using special gaskets.**

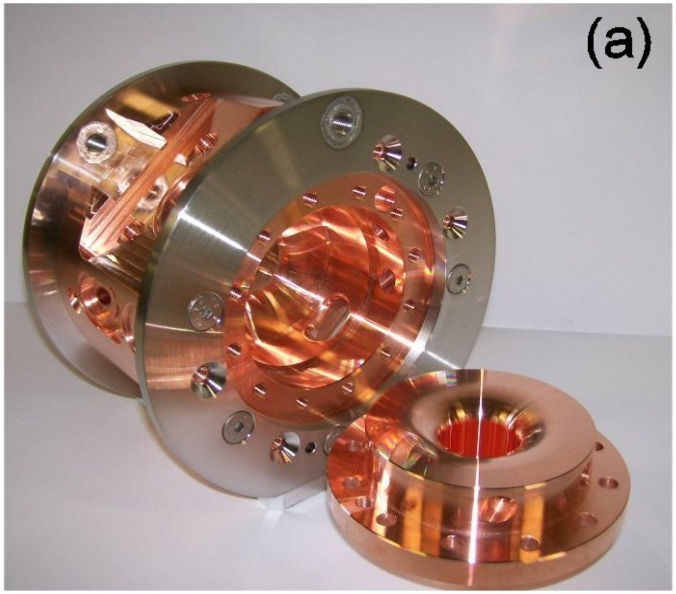
**(request for a patent under submission…).**

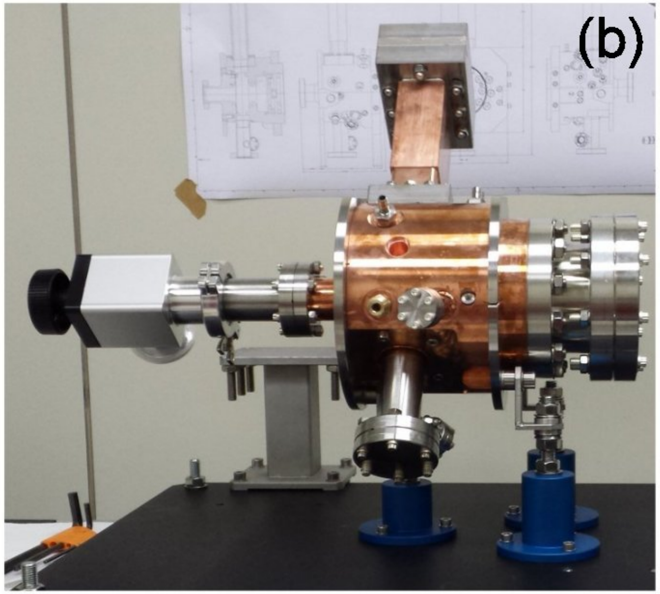


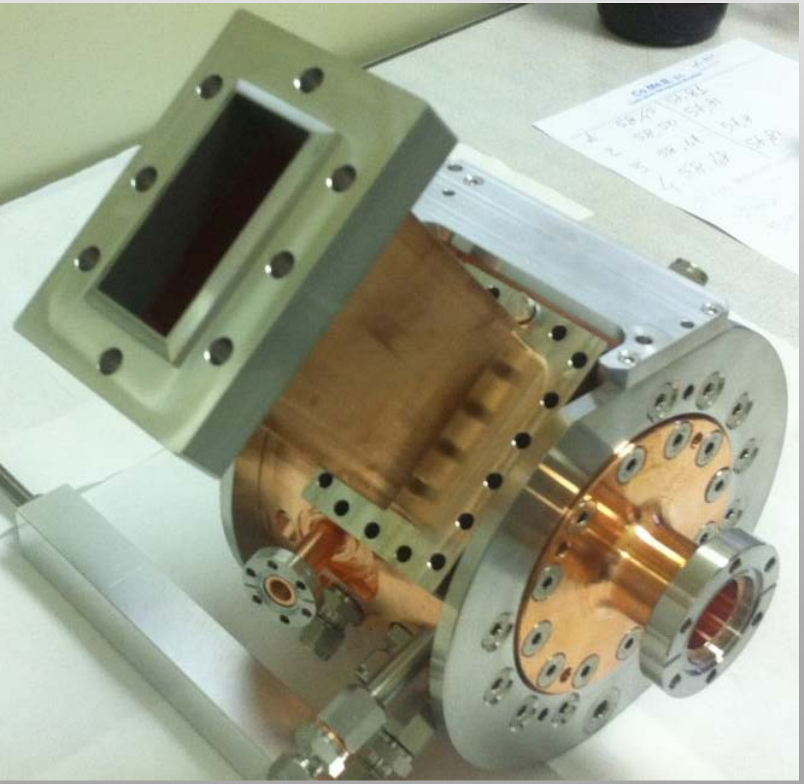


**Test of the new SPARC gun successfully done at UCLA reaching 92 MV/m peak cathode electric field**

# S Band GUN

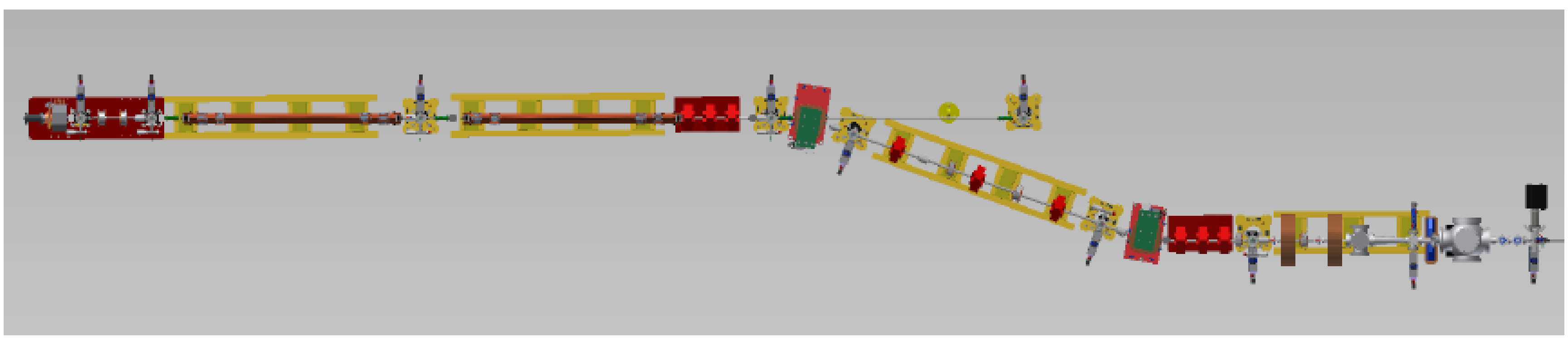


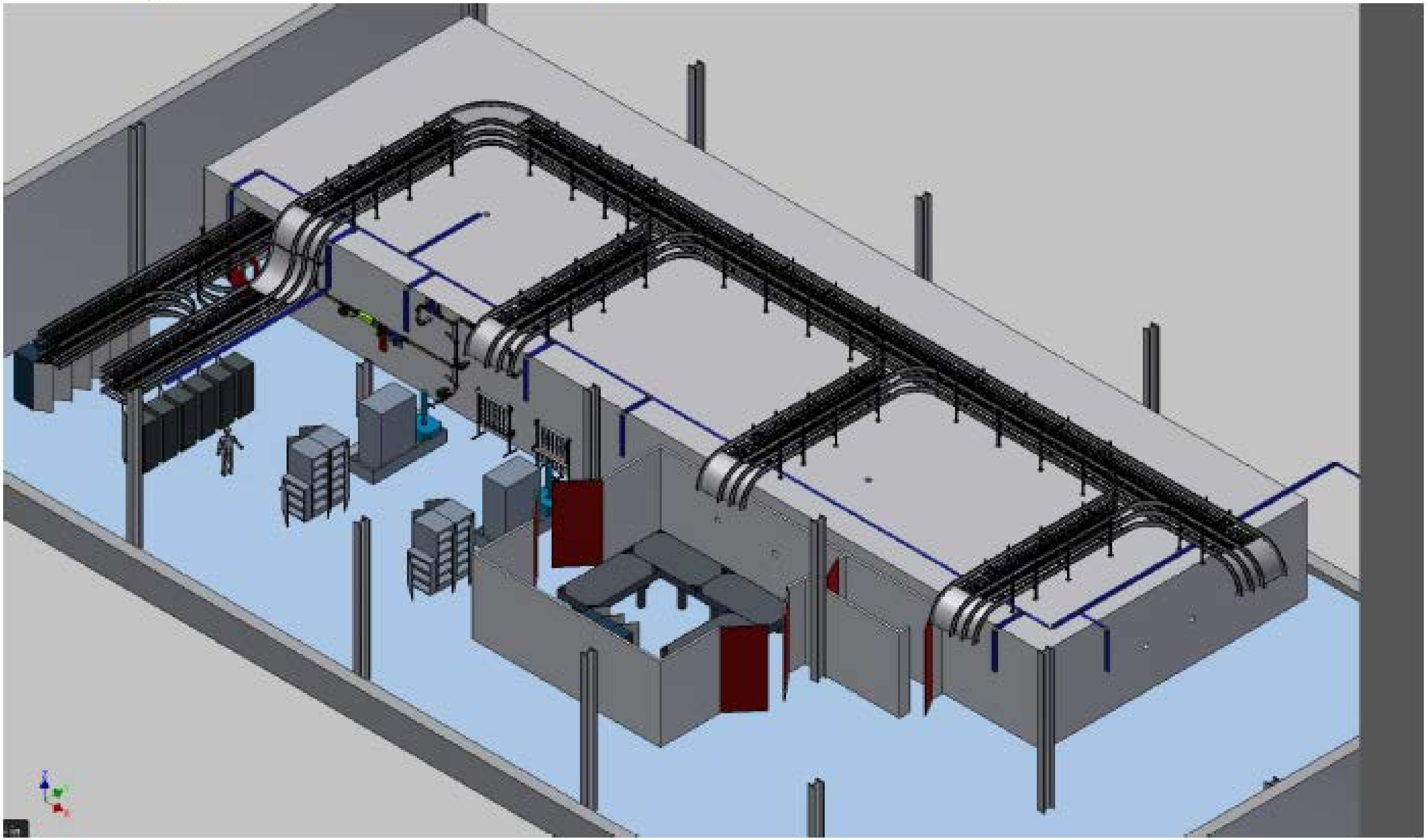



| *Parameters* | *Value* |
|---|---|
| $f_{res}$ | 2.856 GHz |
| $Q_0$ | 15000 |
| $E_{surf\_peak\_iris}/E_{cathode}$ | 0.85 |
| Coupling $\beta$ | 3 |
| $P_{in\_peak}$@$E_{cathode}$=120MV/m | 13 MW |
| Filling time $\tau_F$ | 560 ns |
| Frequency sep. 0 and $\pi$-mode | 38 MHz |
| Pulsed heating @ 120 MV/m (2 $\mu$s RF pulse) | <60 °C |
| Reflected power | 25% |
| Average dissipated power | 1 kW |

# The STAR Project:
# Southern european Thomson source for Applied Research



# STAR Infrastructure layout



UNIVERSITÀ DELLA CALABRIA

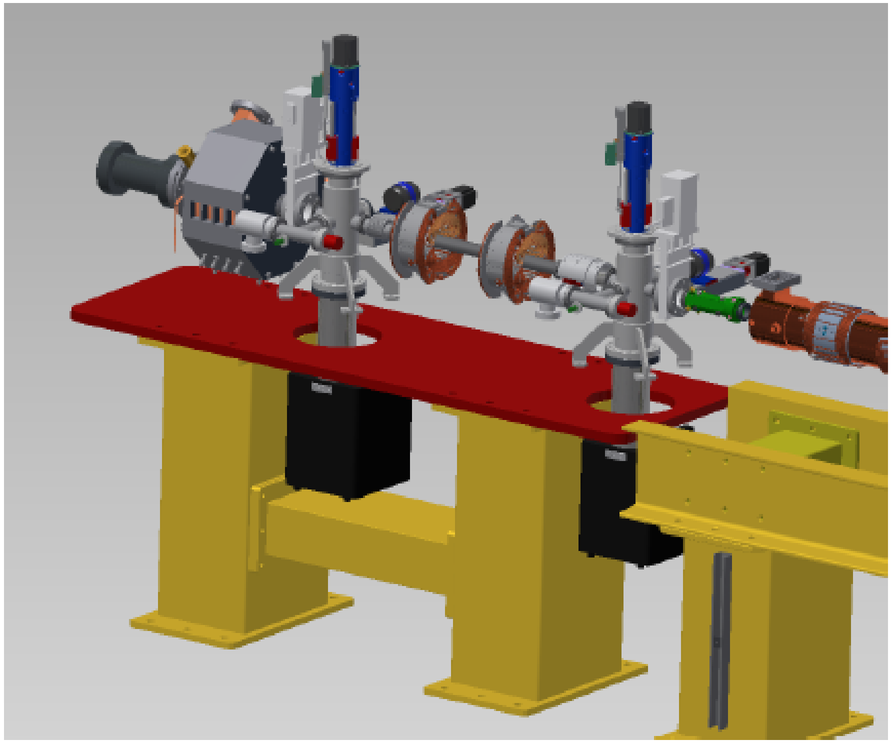
cnism

MaTeRiA

INFN

Sincrotrone Trieste
Elettra and FERMI lightsources

# Photoinjector Layout



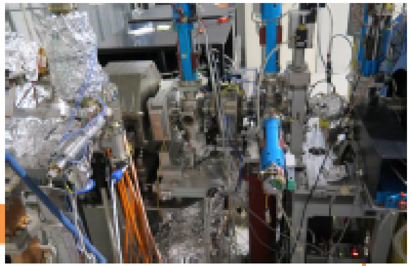


Table 1: Specifications of the RF Photoinjector System

| Parameter | Value |
|---|---|
| Input power | 9.5 MW |
| Output Energy | 5 MeV |
| Operating Frequency | 2.856 GHz |
| Normalized emittance* | ≤ 1.0 micron at 500 pC |
| Repetition rate | Up to 100 Hz |
| Quality factor $Q_0$ | 13,800 |
| Shunt impedance $R'_{shunt}$ | 60 MΩ/m |
| Peak surface field | 102 MV/m |
| Peak cathode field | 120 MV/m |
| External coupling factor (β) | 2.0 |
| Operating temperature | 40° C |
| Materials | OFHC grade 1 copper, cross-forged 316L SST flanges, Aluminum stands |
| Magnetic permeability of flange material | < 1.05 |
| RF flange type | LIL |
| Braze materials/steps | 3-steps: 25/75, 35/65, 50/50 Au/Cu |
| Material certs | To be delivered to customer |
| Fasteners | All metric |
| Warranty | 1 year from delivery |

Vendor: RadiaBeam Europe

# STAR @UNICAL

# STAR infrastructure

# STAR infrastructure

# STAR Bunker

# LNF Participation in HL-LHC Project

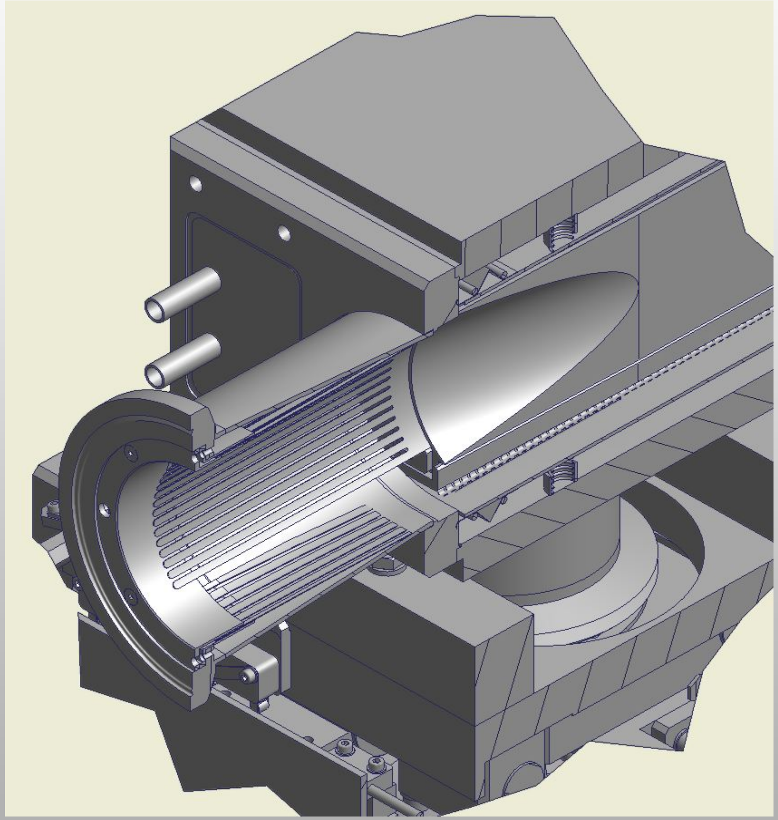
## Participants (Accelerator Division)

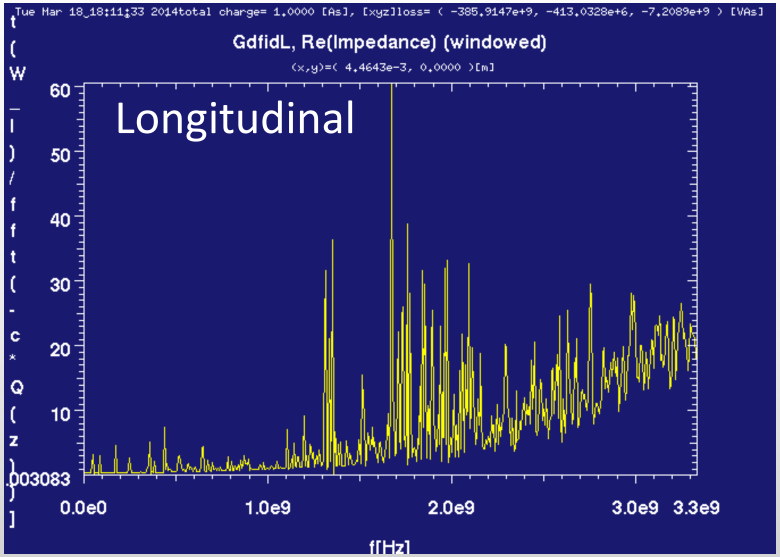
1. Zobov Mikhail - Local Coordinator
2. Alesini David
3. Drago Alessandro
4. Gallo Alessandro
5. Frasciello Oscar
6. Milardi Catia
7. Tomassini Sandro

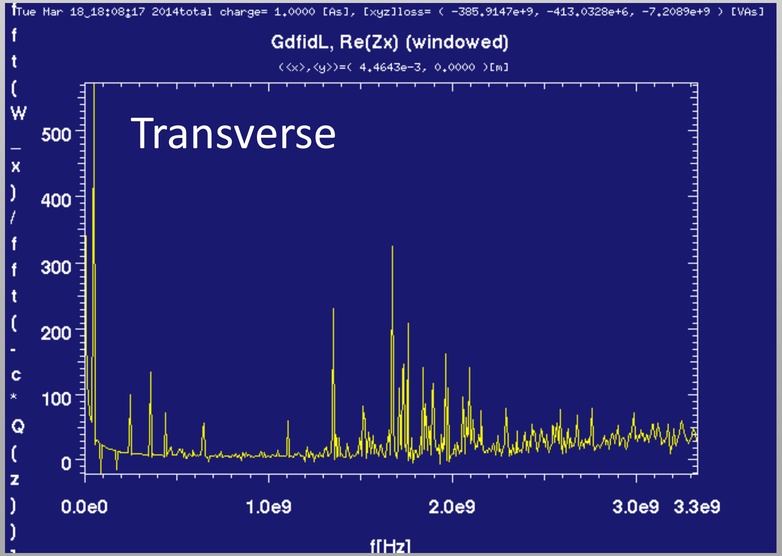
## Subjects to Study for LHC Upgrade (WP2)

1. Optics and beam-beam effects studies
2. Impedance calculations of LHC collimators
3. Electromagnetic design of 800 MHz cavity
4. Electromagnetic design and impedance studies for SPS coaxial slotted kicker
5. Collective effects studies (e-cloud)

# LHC Collimators Impedance Calculations



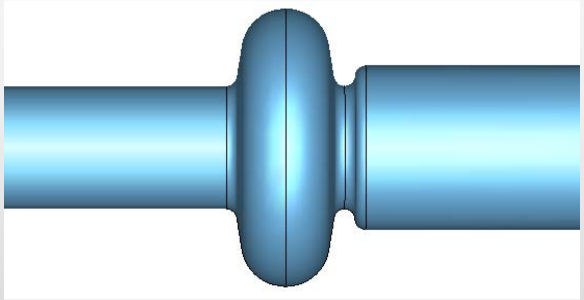


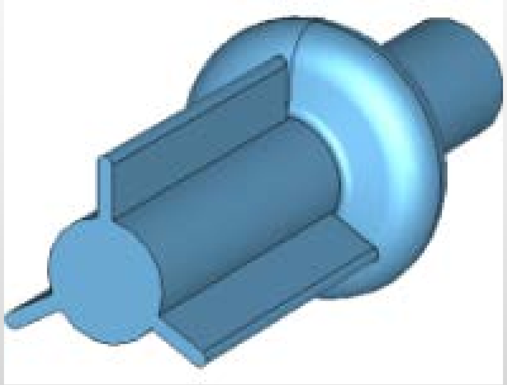




*O.Frasciello, S.Tomassini, M.Zobov*

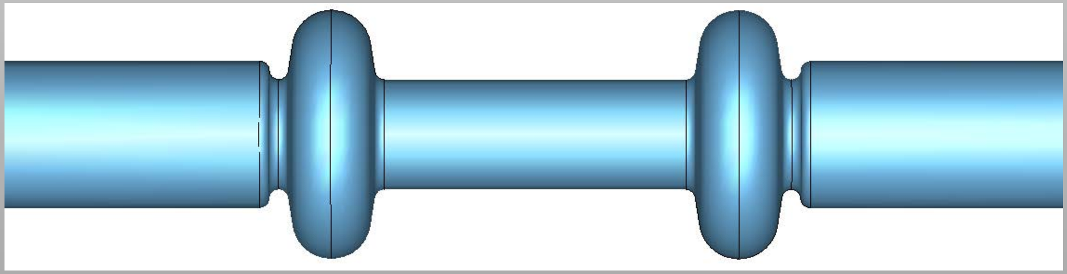
# 800 MHz Cavity Design Solutions for:

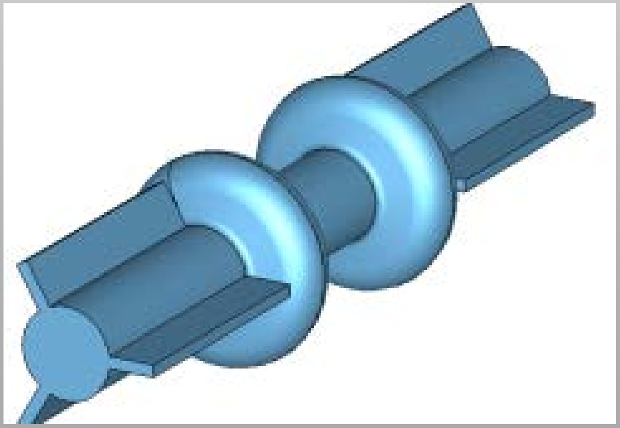
## Single cavity





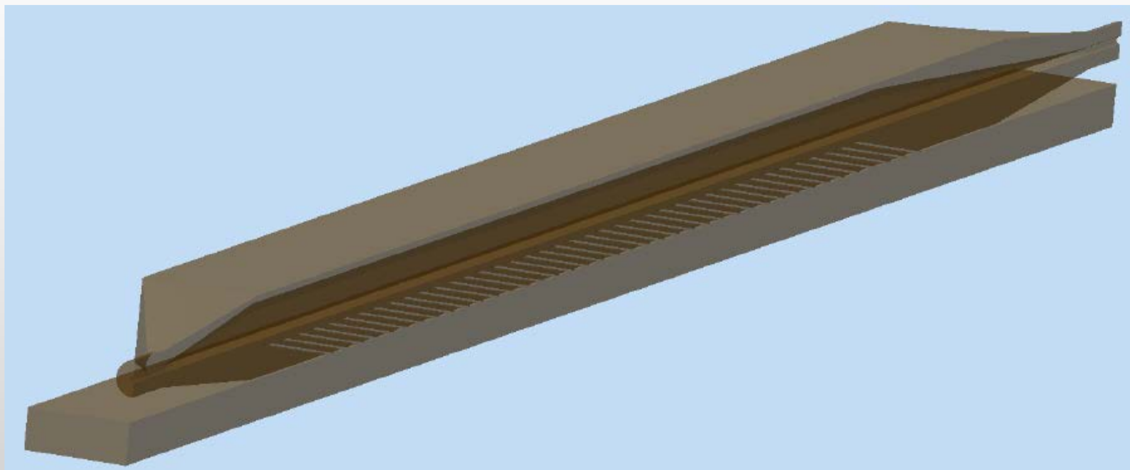
## Two Cavities

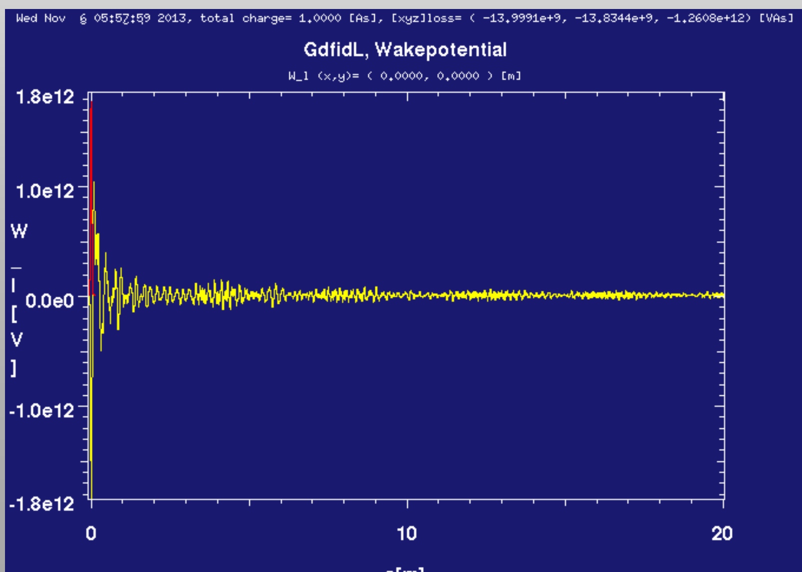


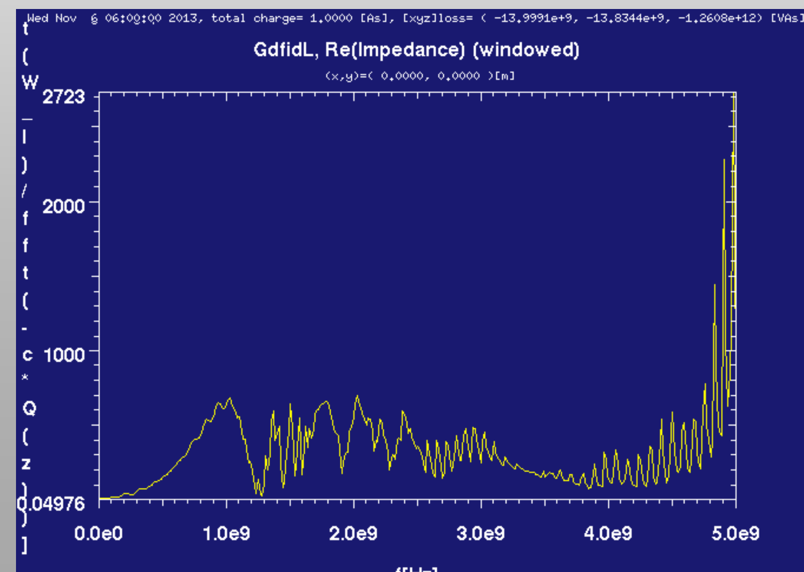


*A.Gallo, M.Zobov*

# Impedance of the Coaxial Slotted Kicker for SPS Intra-bunch feedback

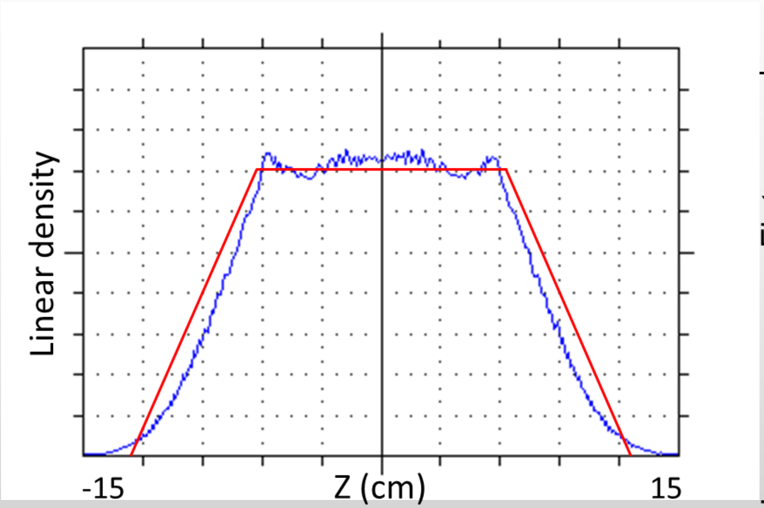


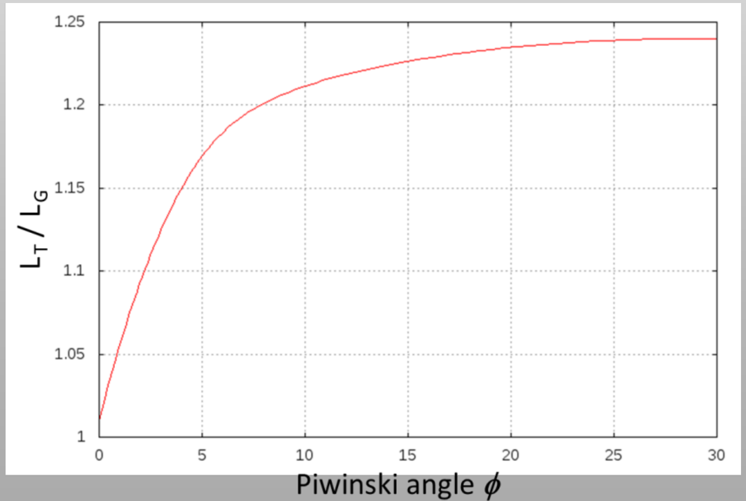


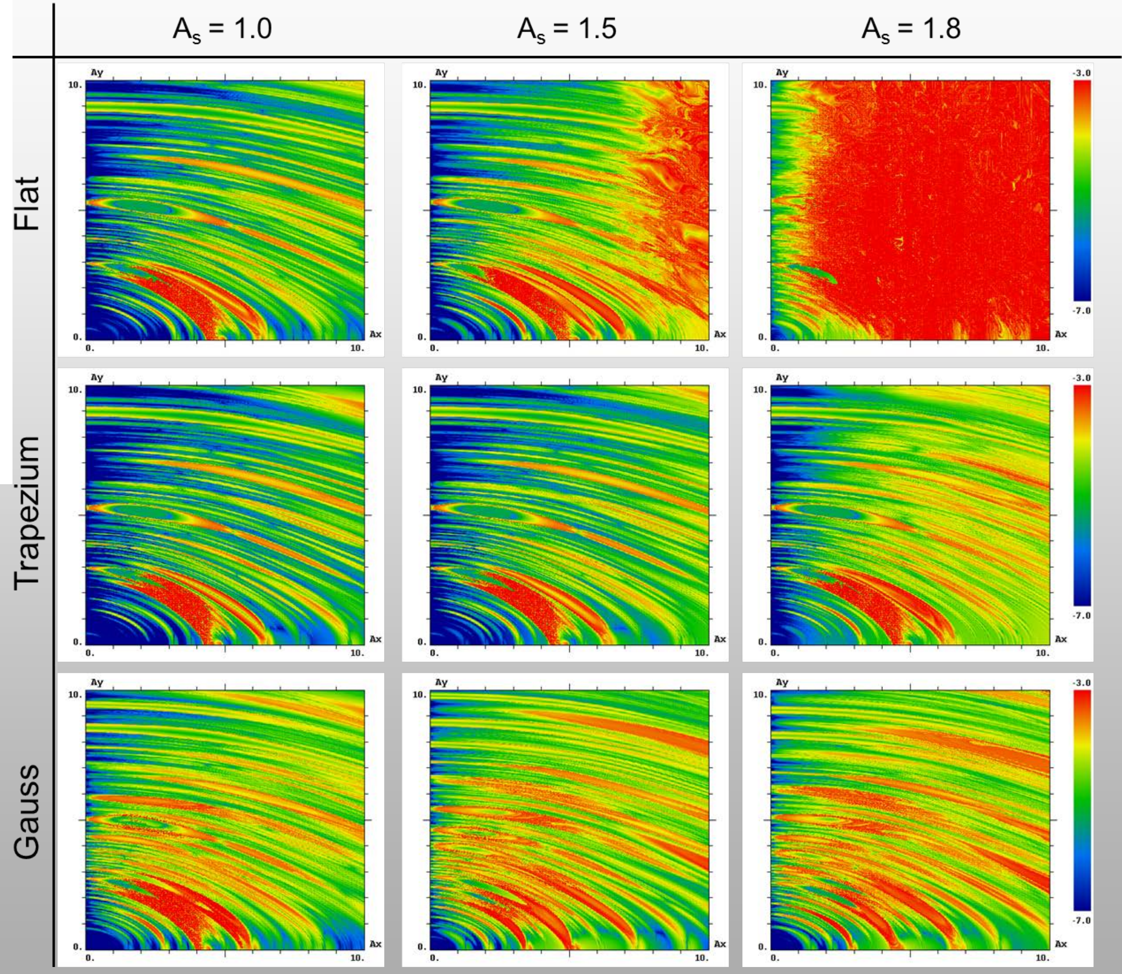




*D.Alesini, A.Drago. A.Gallo, M.Zobov*

# Study of flat beam collisions for LHC upgrade



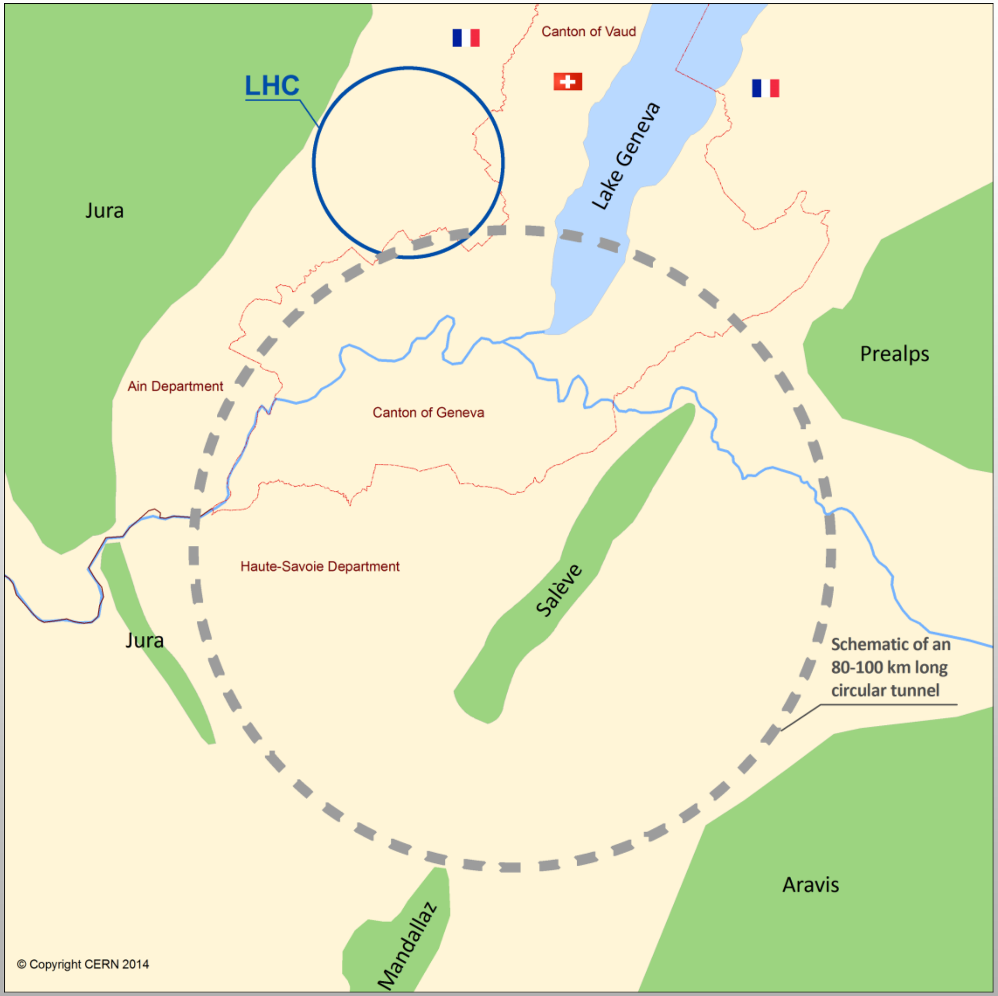




*M.Zobov, D.Shatilov*

# FCC- Future Circular Collider study

- pp collider (FCC-hh) $E_{beam}$= 50 TeV -> defines infrastructure
  - B = 16 T $\Rightarrow$ 100 km
  - B = 20 T $\Rightarrow$ 80 km
- $e^+e^-$ collider (FCC-ee) $E_{beam}$= 40-175 GeV -> as intermediate step
- e-p option
- Infrastructure in the Geneva area
- International collaboration is taking shape: *First ICB at CERN in September*




CDR and cost review for the next European Strategy Update in 2018

# FCC Horizon 2020 Design Study Proposal

## submitted to Brussels on
## 2 September 2014 and now APPROVED!

EuroCirCol

key aspects of 100 TeV energy frontier hadron collider:

conceptual design, feasibility, implementation scenario

# DA-LNF Collaboration with FCC

- MDI studies for FCC-ee (convenership)
- Contribution to MDI studies for FCC-hh (in the EuroCircol framework)
- Contribution to IR optics Design for FCC-ee

- Contribution to design of cryo-magnet beam-pipe system for FCC-hh (Res. Div., in the EuroCircol framework) INFN Mi & Ge
- Impedance Budget evaluation for FCC-ee (Univ. La Sapienza)

# Machine Detector Interface

Challenge : maximize performance (integrated luminosity) for experiments with tolerable experimental conditions.

Minimize synchrotron radiation in the IR region :

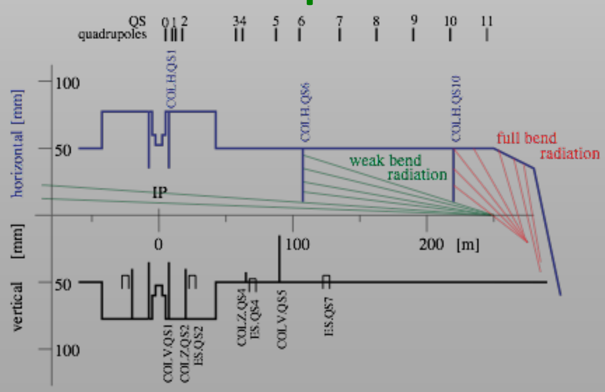
Bends as weak as possible and as far as possible from IP

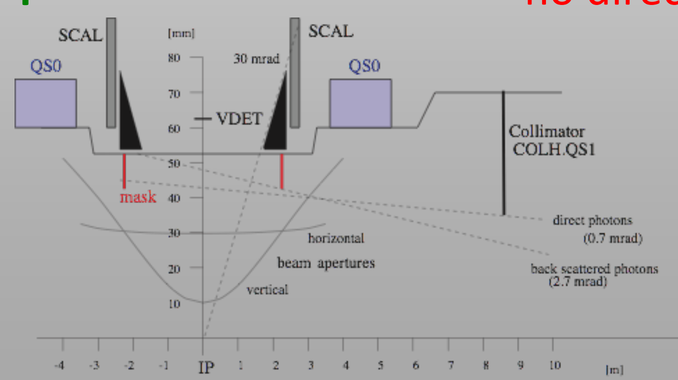
Quads have to be strong and close to IP
- minimize offset from quad axis
- be careful with vertical halo/tails

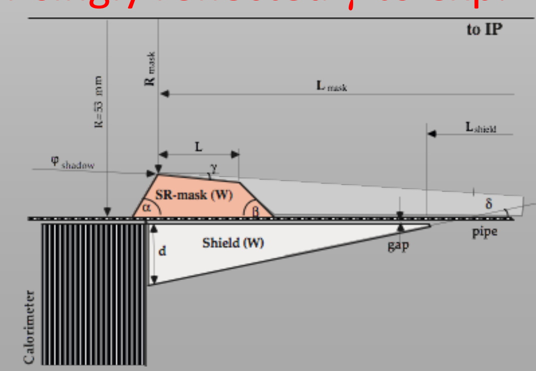
SR Monte Carlo : H.B. CERN-OPEN-2007-018 integrated in G4

~100 collimators to reduce MIB
no direct or singly reflected γ to exp.

LEP example of an optimized IR



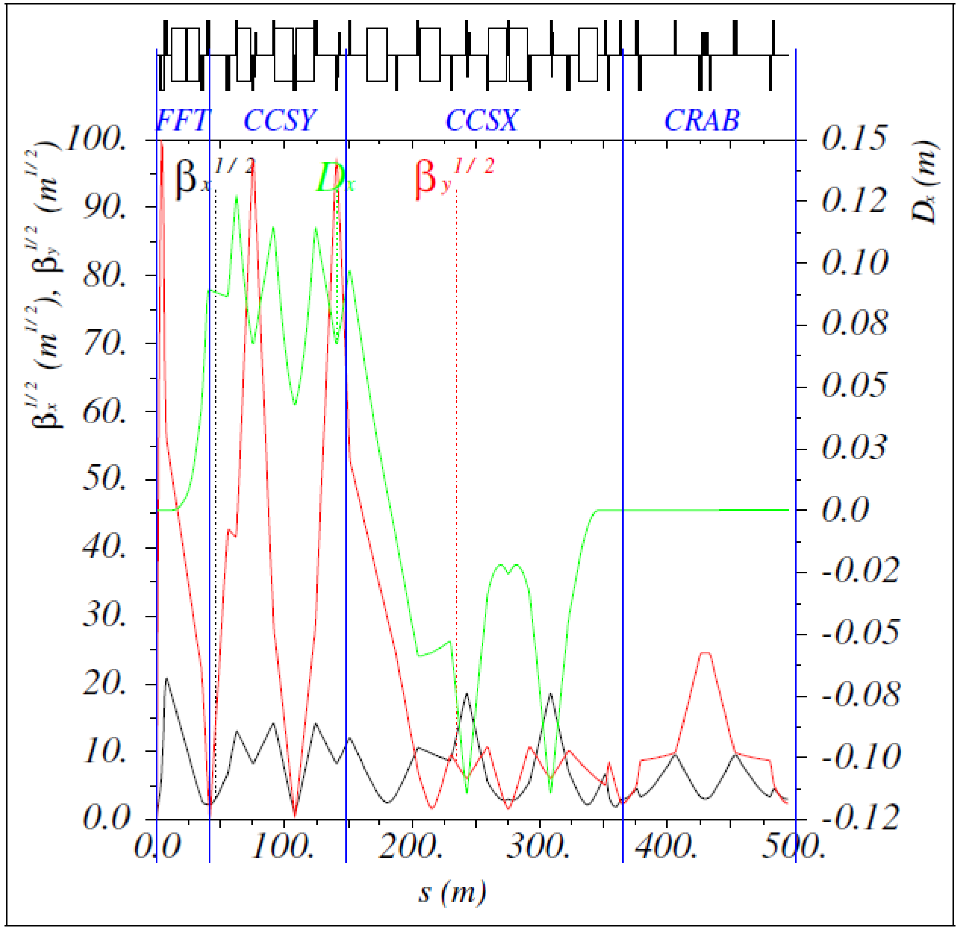




M. Boscolo, H. Burkhardt

**developing generic tools for FCC IR studies**

# IR optical layout

- Ultra-low β* requires local correction of chromatic effects (copied from Linear Colliders).
  - *Requires dipoles in the 'straight section' → additional SR.*
  - *Lengthens the IR very significantly.*
- Example on this slide was designed by BINP with L* = 2m.
  - *Long sections are needed for the chromatic corrections.*
- The problem of dynamic aperture is coming from high order aberrations that are difficult to compensate.
  - *An when compensated in an ideal machine, how robust it is to machine errors.*




Chromatic correction

# Possible Contribution of DA-LNF

- The LNF Accelerator Division could give, in principle, a larger contribution to FCC than what it is foreseen now.
- However, many technical services of the DA are strongly involved in the internal and EU activities
- Possible larger contribution mainly on beam dynamics study for FCC-TDR

# ARC VACUUM CHAMBER DESIGN for new ESRF low emittance Ring @ LNF-INFN

Our proposal is to verify the feasibility of the arc vacuum chambers realization in aluminum instead of stainless steel.

The aluminum would have many advantages summarized below:

1-Reduction of costs

2-Reduction design time

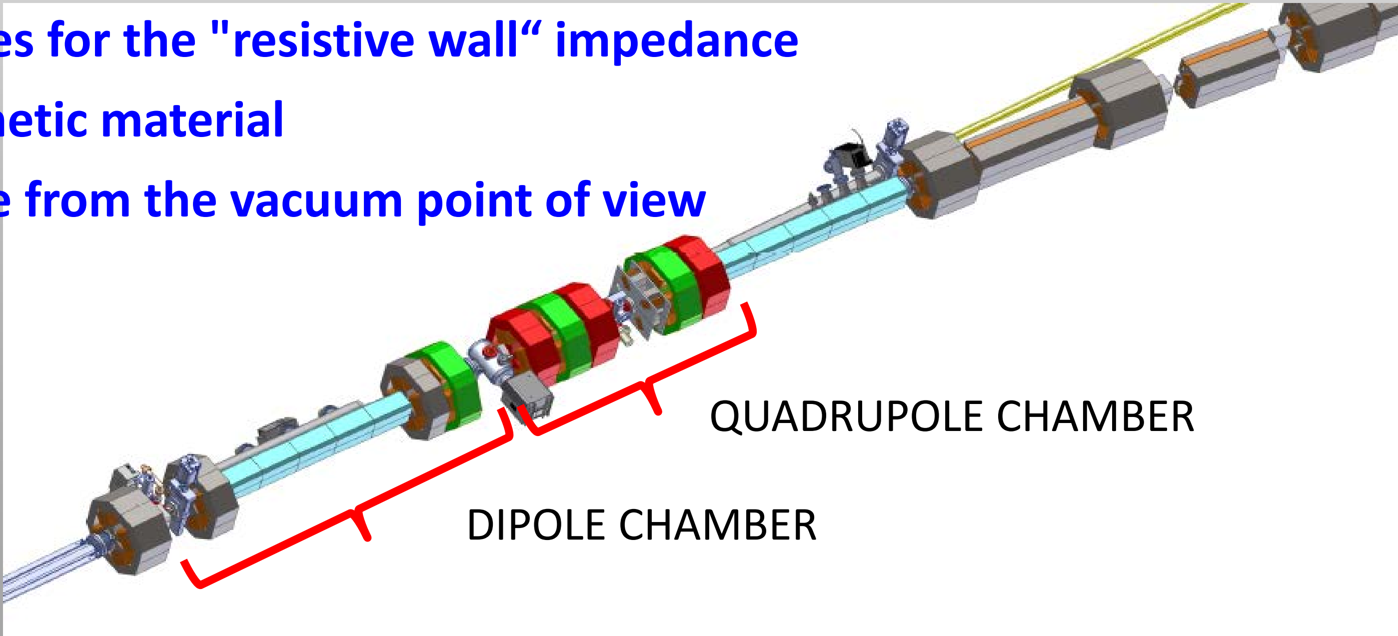
3-Reduction of realization time

4-Reduction of the time to acquire the material

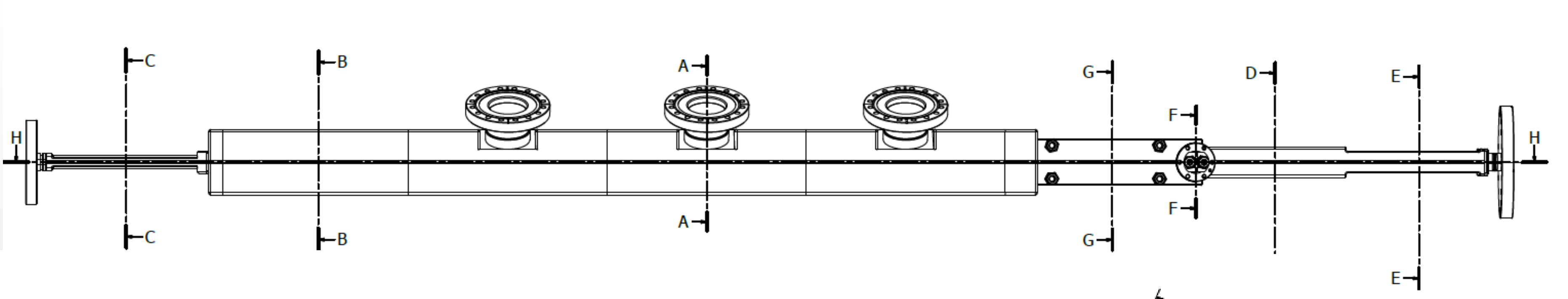
5-Better performances for the "resistive wall“ impedance

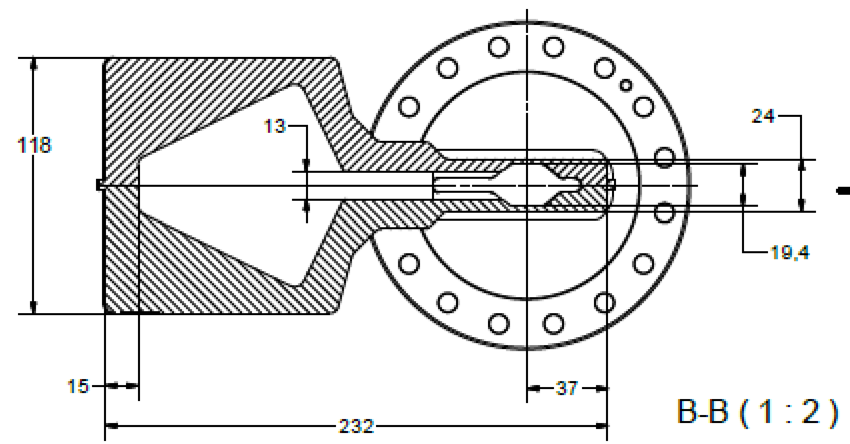
6-Completely a-magnetic material

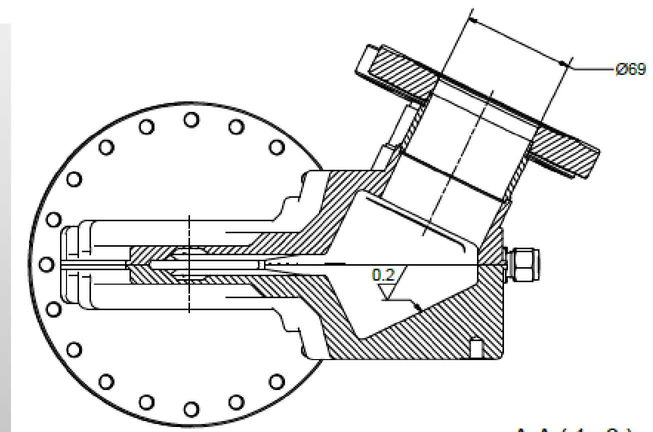
7-Better Performance from the vacuum point of view

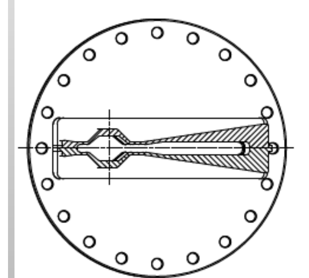


# DIPOLE CHAMBER: DETAILS



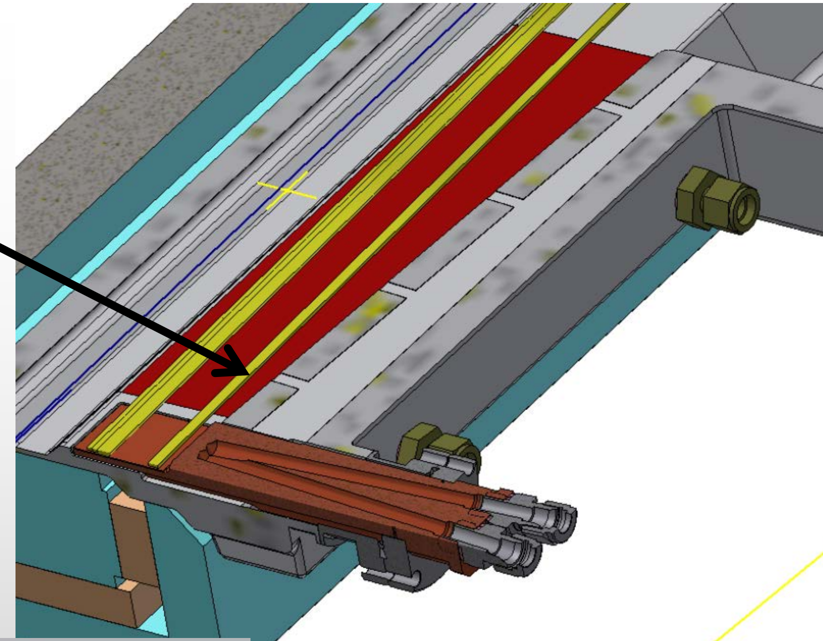



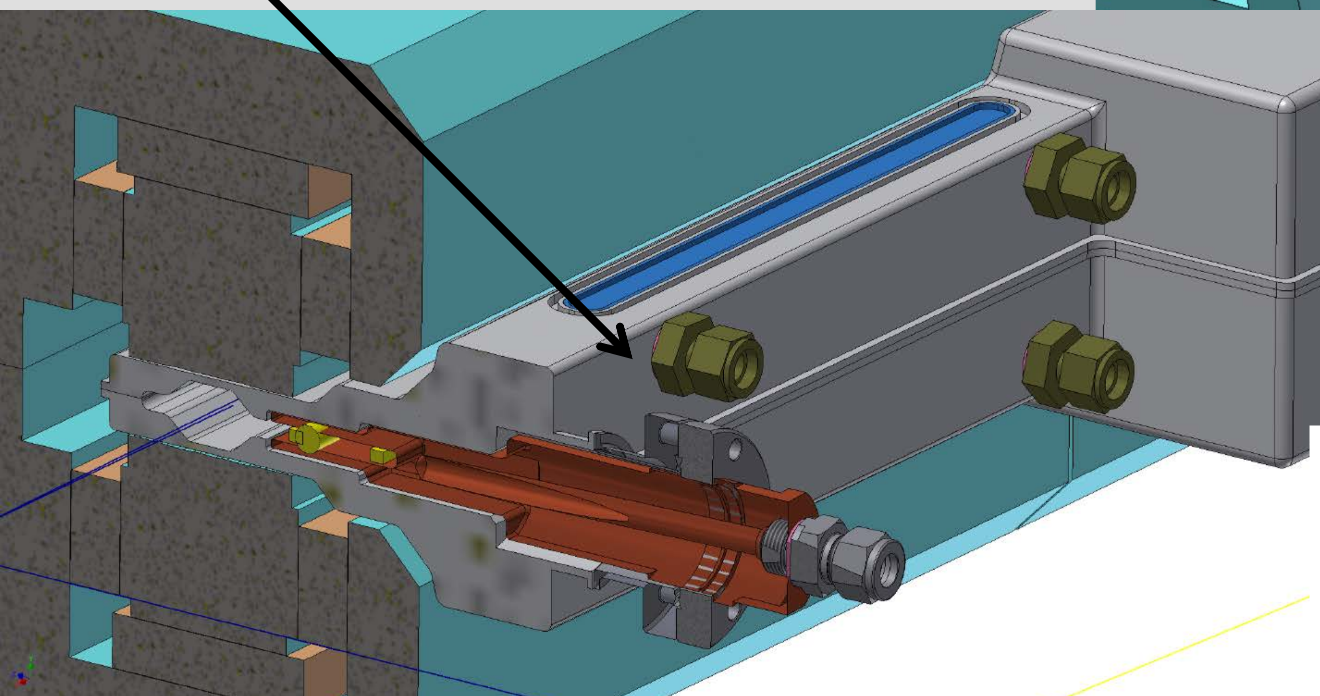

-Calculated deformation of the gap due to the vacuum pressure: 40-70 μm

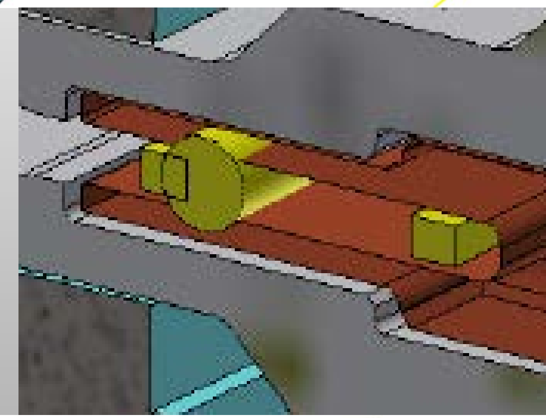
-19.4 mm vertical gap (instead of di 20 mm). This distance can be easily changed into 20 mm

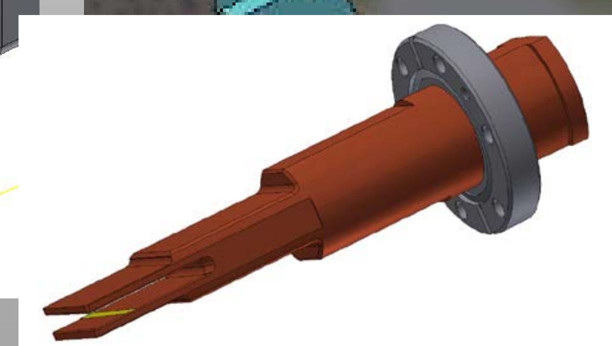
# DIPOLE CHAMBER: ABSORBERS



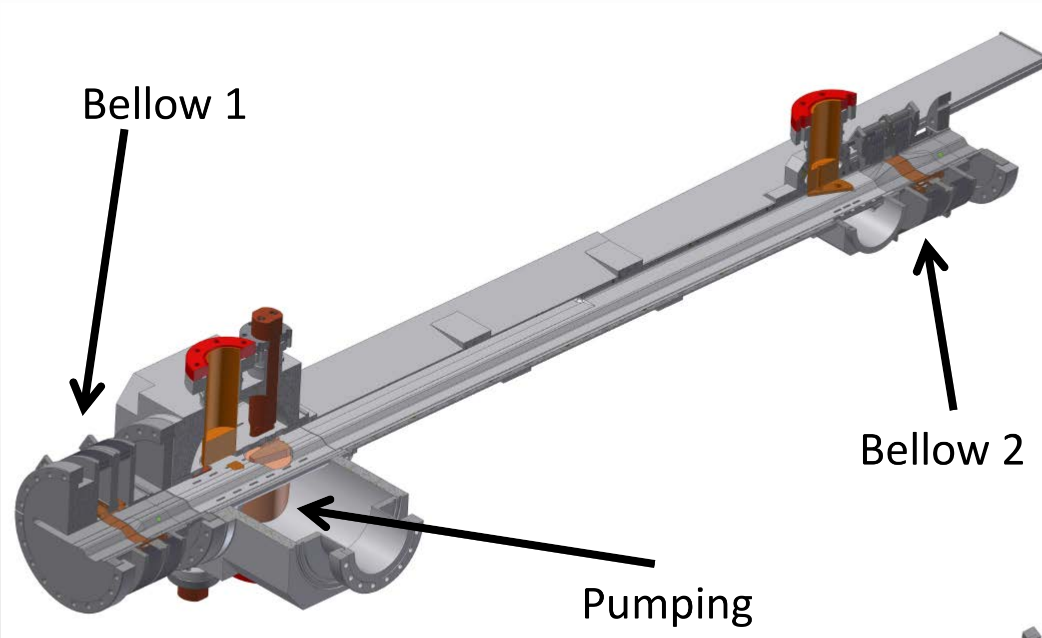

**Two parallel cooling channels directly integrated on the chamber: total estimated power from the light beam 35 W**





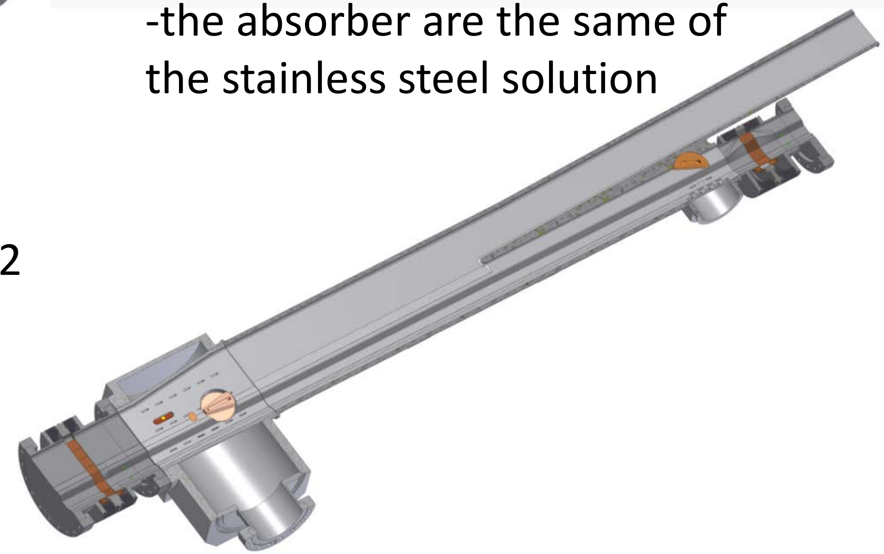


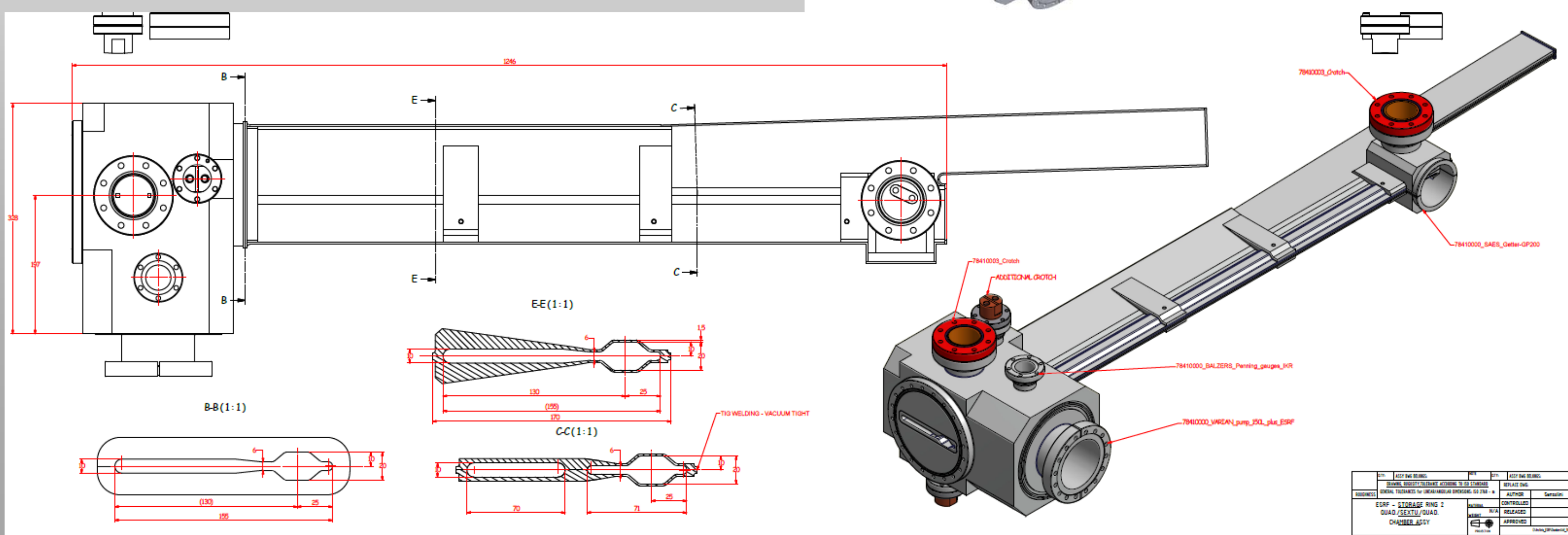
# QUADRUPOLES CHAMBER: GENERAL



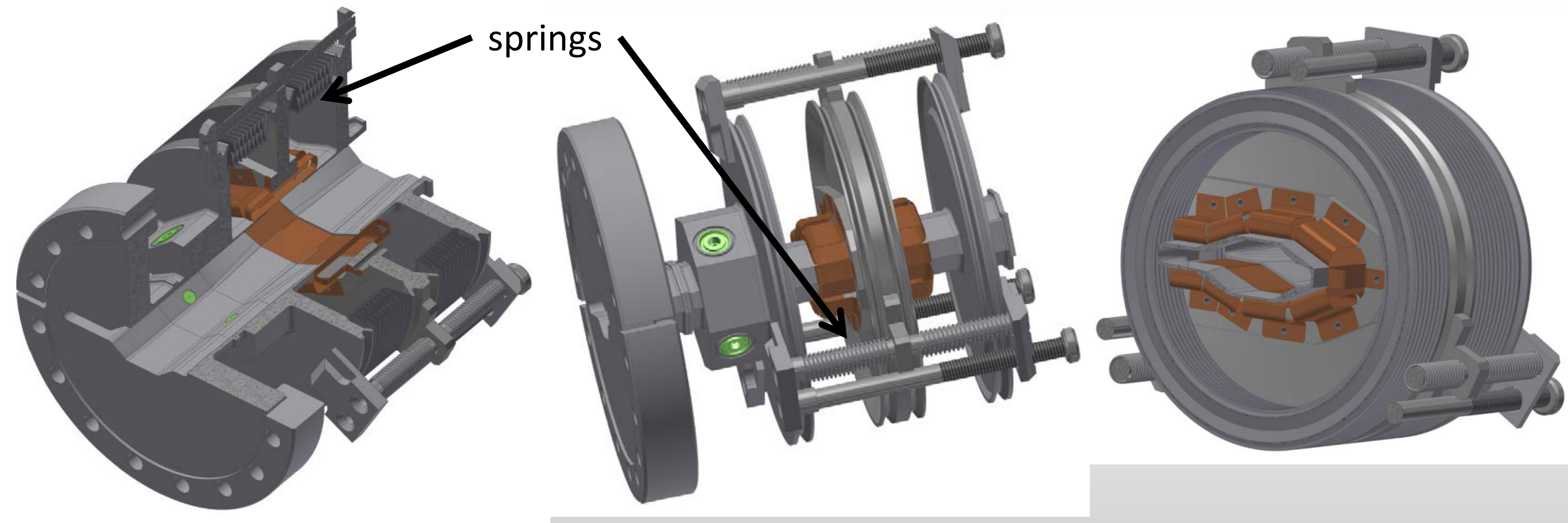

-The design avoid discontinuities and steps

-the absorber are the same of the stainless steel solution





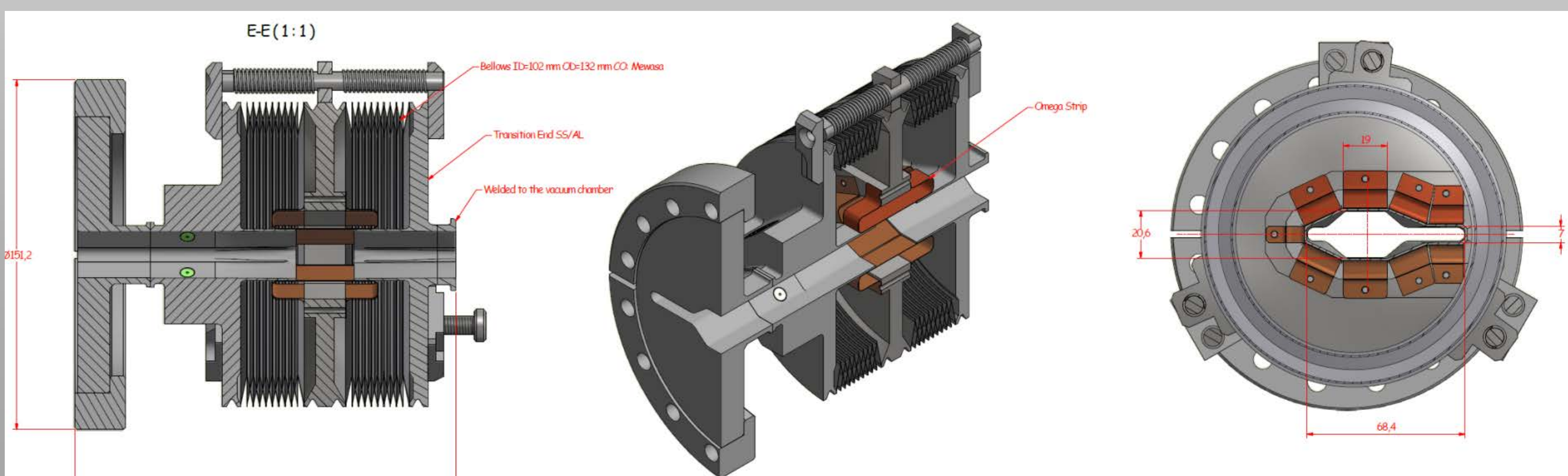
# QUDRUPOLES CHAMBER: BELLOW




Excursion -20 mm in compression (to compensate the bake-out dilatation of the dipole chamber) and +5 mm in expansion

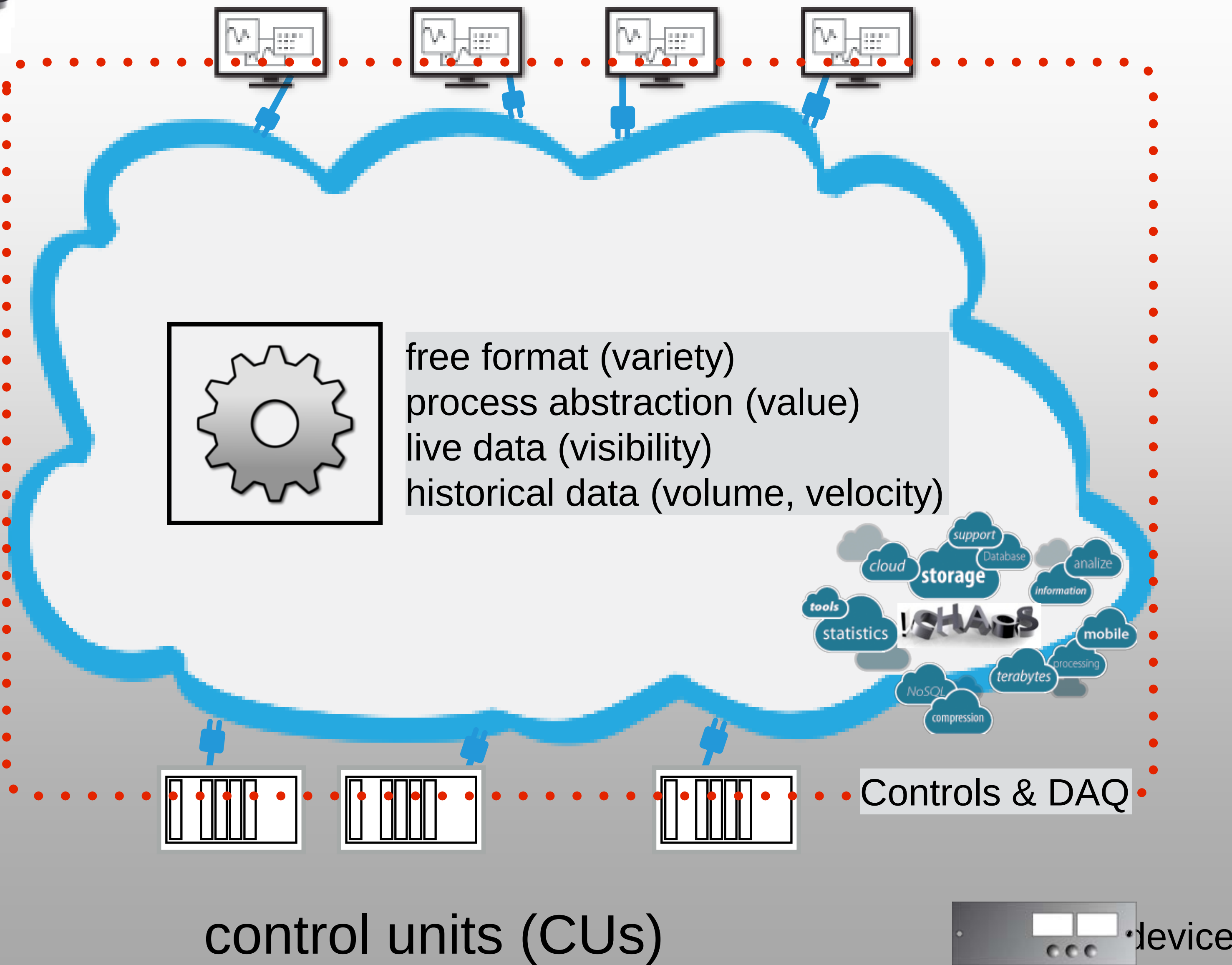
Terminal flange with space for bpm

Possibility to cool the bellow

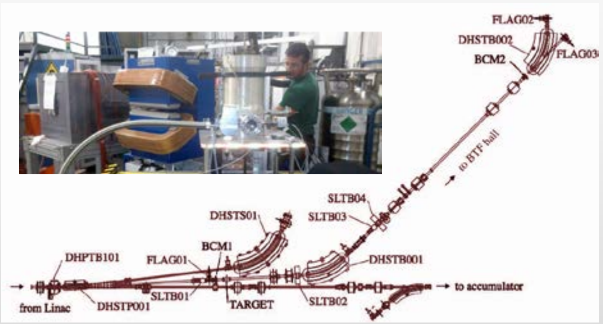


# !CHAOS

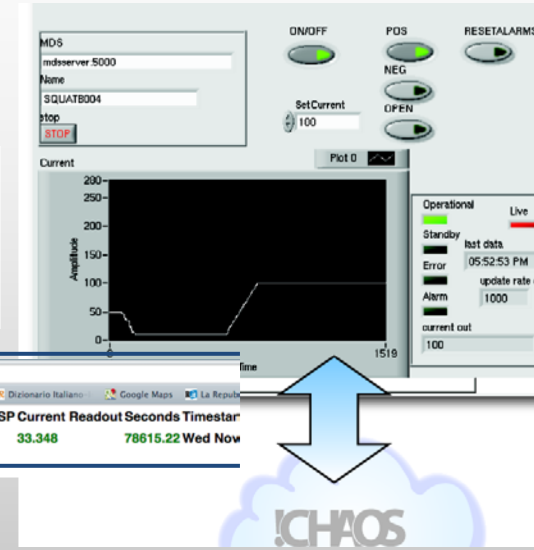
control room



# !Chaos @ BTF

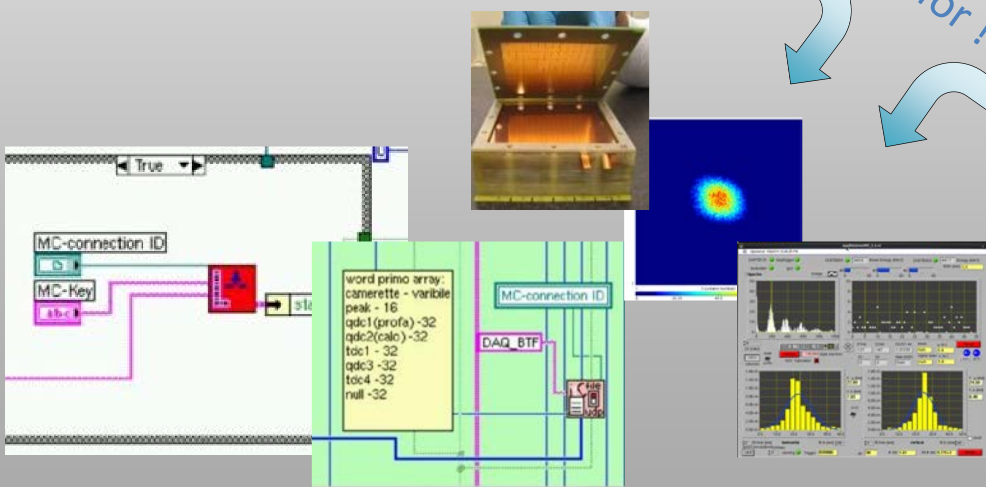



FROM SINGLE MAGNET CONTROL


IT developped for !CHAOS

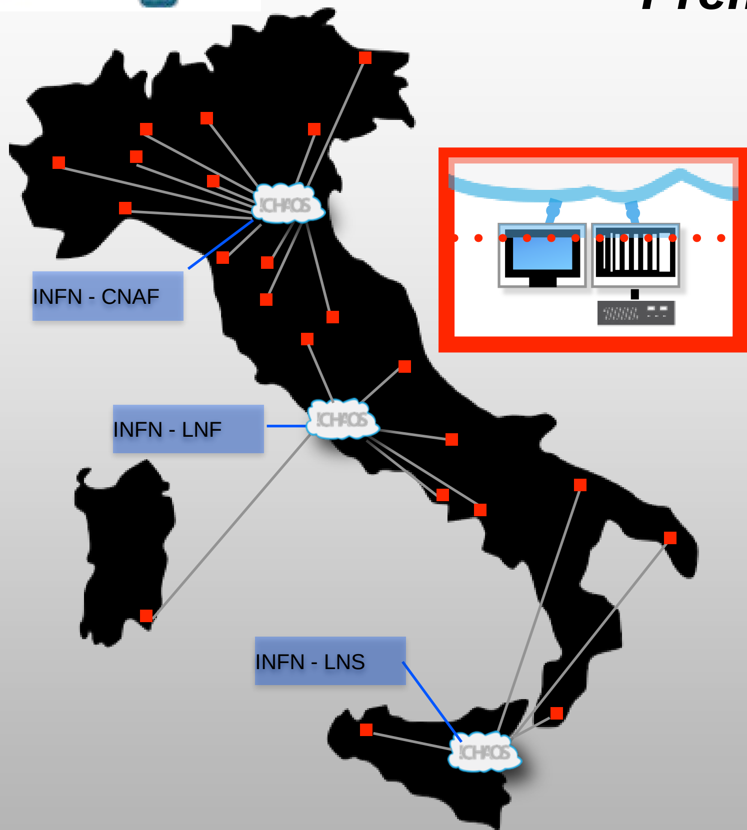
BTF DIAGNOSTICS accessing !CHAOS




UP TO DAFNE MAG TERMINAL

but !CHAOS is more...

***Premiale INFN "!CHAOS: A Cloud of Controls"***




INFN-LNF (Laboratori Nazionali di Frascati)
INFN-TV (Sezione di Tor Vergata)
INFN-PG (Sezione di Perugia)
INFN-CNAF (Centro Nazionale Tecnolgie Informatich
INFN-PD (Padova)
INFN-LNS (Laboratori Nazionali di Catania)
National Instruments (NI)

ADF Solaris

a prototype of Control as a Service, an infrastructure at national level which realizes a cloud of services and procedures distributed and shared over the LAN/WAN, which allows the monitoring and control of any hardware device, system, or intelligent component and carries a network of resources to provide processing services, data logging and archiving.

# Thank you for attention!

# External programs

- ELI-NP 66 M€ -> LNF: 2000 k€/y x 5 years
- STAR 7M€ -> LNF: 150 k€/y x 3years
- HL-LHC ….. -> LNF: 100 k€/y x 2 years
- FCC 3 M€ -> LNF: 50 k€/y x 3 years
- ESRF 100 M€ -> LNF: 100 k€/y x 1years

Scientific staff:

| Permanent | Temporary | Fellow | PhD | TOT |
|---|---|---|---|---|
| 23 | 14 | 12 | 9 | 58 |

| | TEMPO INDETERMINATO | TEMPO DETERMINATO | ASSEGNISTI/BORSISTI | OSPITI /DOTTORANDI ASSOCIATI ALTRE SEZIONI |
|---|---|---|---|---|
| LABORATORIO | Serio Mario | | MASCIO Roberto | |
| | Stella Angelo | | PUTINO Francesco | |
| | GHIGO Andrea | | | |
| | Gallo Alessandro | | | |
| | Drago Alessandro | | | |
| | Pellegrino Luigi | | | |
| | Buonomo Bruno | | | |
| | Stecchi Alessandro | | | |
| | Di Pirro Giampiero | | | |
| | Delle Monache Giovanni | | | |
| | Ligi Carlo | | | |
| DAFNE + Hi-LUMI+FCC | Guiducci Susanna | FOGGETTA Luca G. | FRASCIELLO Oscar | |
| | Biagini Maria Enrica | DE SANTIS Antonio | | |
| | Zobov Mikhail | | | |
| | Milardi Catia | | | |
| | Boscolo Manuela | | | |
| SPARC-LAB + EUROFEL | Chiadroni Enrica | DEL FRANCO Mario | BIAGIONI Angelo | GIRIBONO Anna |
| | Gatti Giancarlo | BINI Simone | ROVERE Andrea | FILIPPI Francesco |
| | Ferrario Massimo | ANANIA Maria Pia | SHPAKOV Vladimir | GIORGIANNI Flavio |
| | Vaccarezza Cristina | VILLA Fabio | POMPILI Riccardo | PALMER Dennis |
| | | | DANIELE Maddalena | CROIA Michele |
| ELI-NP + STAR | Alesini David | SABBATINI Lucia | BISESTO Fabrizio | CARDELLI Fabio |
| | Tomassini Sandro | DI PASQUALE Enrico | BORGESE Gianluca | PIERSANTI Luca |
| | | BELLAVEGLIA Marco | ROMEO Stefano | VANNOZZI Alessandro |
| | | CIOETA Fara | | MASSIMO Francesco |
| | | DI GIOVENALE Domenico | | |
| | | FALONE Antonio | | |
| !CHAOS | Mazzitelli Giovanni | MICHELOTTI Andrea | GIOSCIO Eliana | |
| | | GARGANA Riccardo | | |

# Technical Staff

Permanent 47 Temporary 8

| | TEMPO INDETERMINATO | | TEMPO DETERMINATO | ASSEGNISTI/BORSISTI |
|---|---|---|---|---|
| LABORATORIO | Coiro Oscar | Ceccarelli Riccardo | CASARIN Francesca | MASCIO Roberto |
| | Frasacco Umberto | Cecchinelli Alberto | DI RADDO Gianluca | PUTINO Francesco |
| | Gaspari Eugenio | Clementi Renato | ANELLI Federico | |
| | Mencarelli Claudio | Cacciotti Luciano | ROSSI Luis Antonio | |
| | Pella Stefano | Martinelli Moreno | STRABIOLI Serena | |
| | Pellegrini Donato | Piermarini Graziano | CHIMENTI Paolo | |
| | Battisti Antonio | Sorchetti Rossano | | |
| | De Biase Sandro | Zarlenga Raffaele | | |
| | Ceccarelli Giuseppe | Belli Maurizio | | |
| | De Giorgi Maurizio | Di Raddo Roberto | | |
| | Ermini Giuliano | Baldini Pietro | | |
| | Fontana Gianni | Quaglia Sergio | | |
| | Iungo Franco | Scampati Michele | | |
| | Bolli Bruno | Sprecacenere Alfredo | | |
| | Ceravolo Sergio | Baldini Gianfranco | | |
| | Martelli Stefano | Ciuffetti Paolo | | |
| | Sardone Franco | Galletti Francesco | | |
| | Lollo Valerio | Giacinti Olimpio | | |
| | Ferrazza Maria Rita | Marini Claudio | | |
| | Pellegrino Luigi | Giabbai Manuela | | |
| | Beatrici Angelo | Sensolini Giancarlo | | |
| | Paris Marco | Sperati Maurizio | | |
| | Troiani Mauro | Tranquilli Tullio | | |
| | Zolla Alessandro | | | |