# Summary for "4th Open Collaboration Meeting on Superconducting Linacs for High Power Beams" (SLHiPP-5)

**18-19 March 2015, ESS, Lund, Sweden**

**Valeri Lebedev**

**PIP-II Friday Meeting**
**April 17, 2015**
**Fermilab**

# ESS

- Located in Lund
  - Presently rent building in Medicon Village (N.E. suburb of Lund)
- 30 miles from Copenhagen airport

# Participants

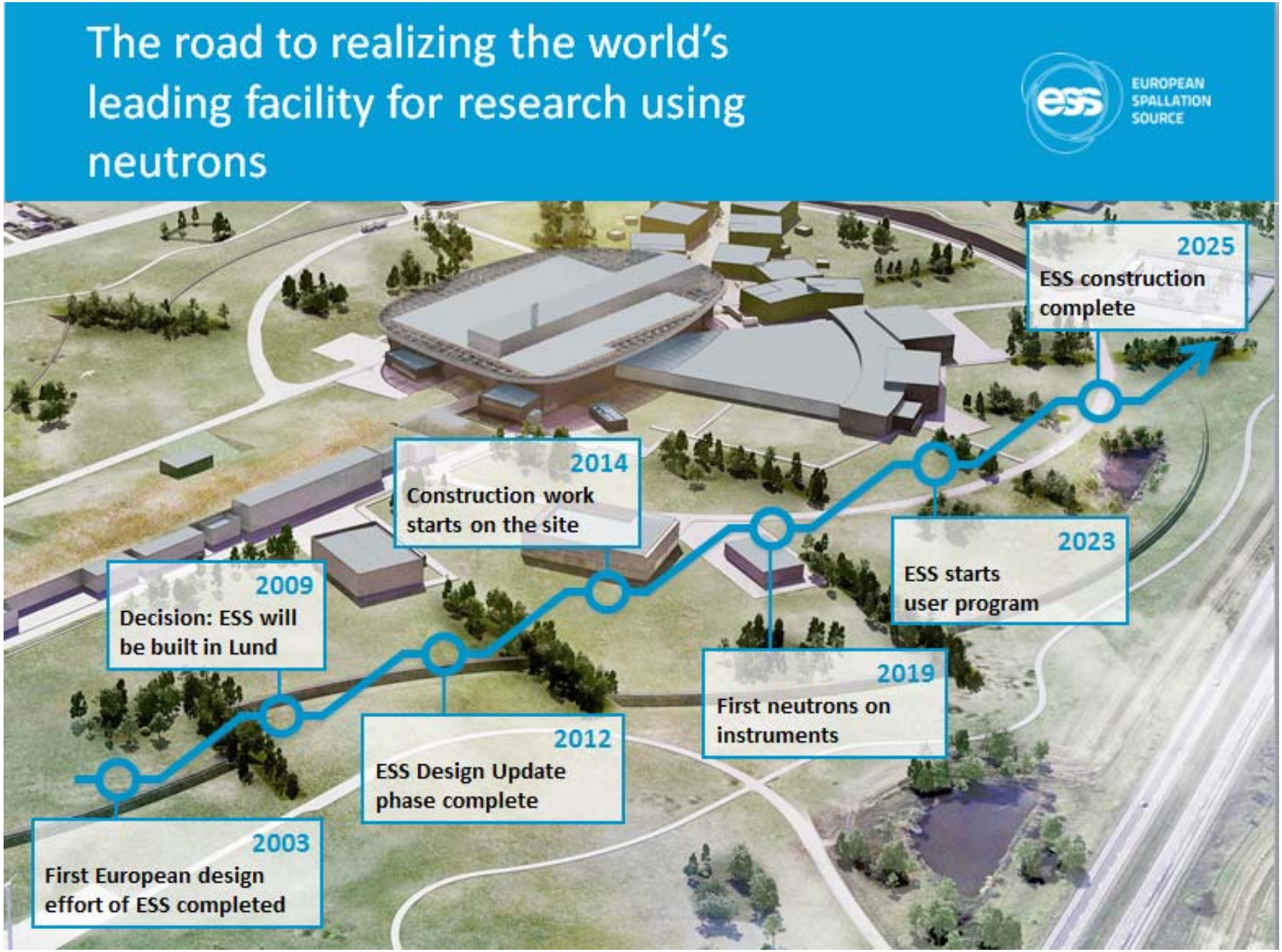
- 87 registered participants
  - ESS (40), Lund University, Uppsala University, LTH, ScandiNova Systems AB
  - CERN (11), GSI, KEK
  - CEA Saclay (4), CNRS IPN Orsay (2)
  - IMP/China (2), STFC/Oxford, MYRRHA/Belgium

# Program

https://indico.esss.lu.se/indico/event/286/timetable/#20150319

- Project reports
- SRF cavities
- Guided tour (modulator prototype)
- ESS site visit
- RF sources
- Accelerator operation
- SRF and cryo-modules

# ESS Project Status (Mats Lindroos)



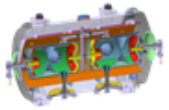
# ESS Project Status (2)

## COLLABORATION DURING (PRE-) CONSTRUCTION

Søren Pape Møller

Roger Barlow

Pierre Bosland



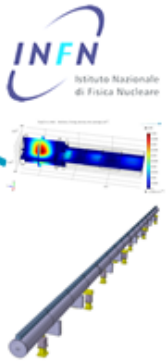
Sebastien Bousson

Ibon Bustinduy

Roger Ruber

Anders J. Johansson

The National Center for Nuclear Research



Santo Gamino

# ESS Project Status (3)

## Civil constriction proceeds

# ESS Project Status (4)

## 5 MW SCRF linac

Design Drivers:

High Average Beam Power

5 MW

High Peak Beam Power

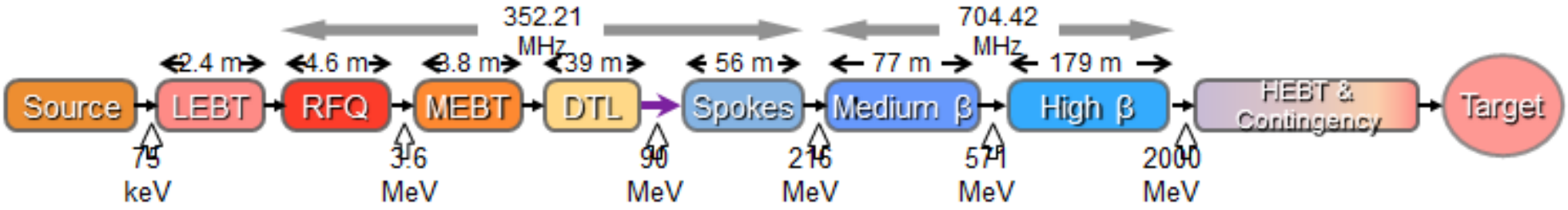
125 MW

High Availability

> 95%

Key parameters:

-2.86 ms pulses
-2 GeV
-62.5 mA peak
-14 Hz
-Protons (H+)
-Low losses
-Minimize energy use
-Flexible design for future upgrades



# ESS Project Status (5)

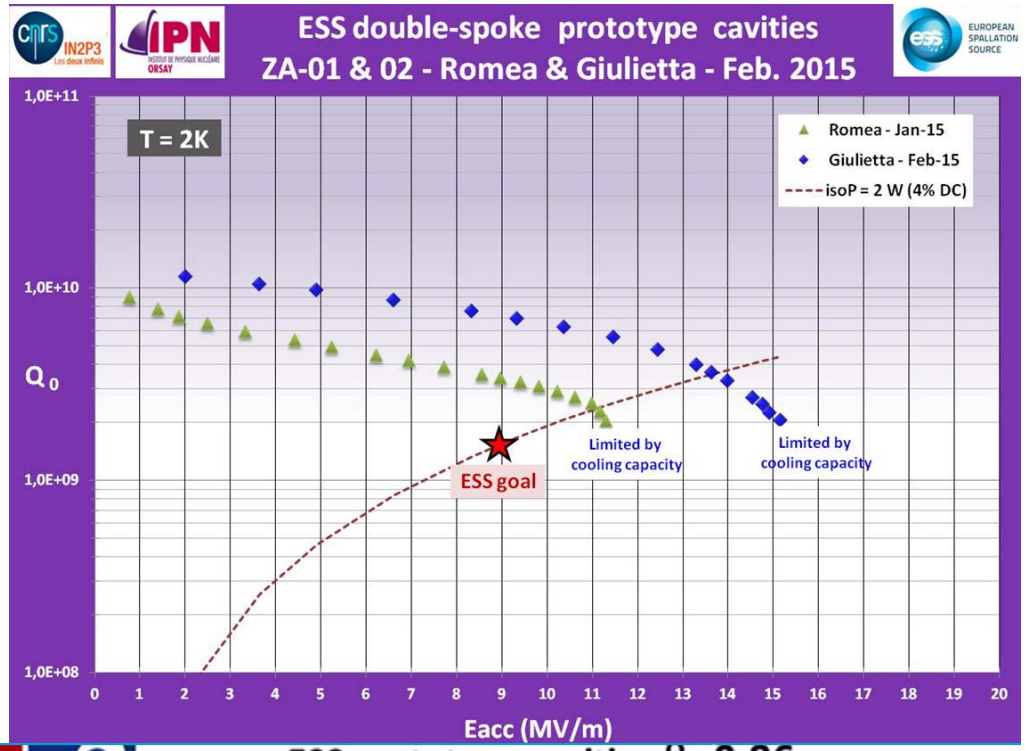
## Cavity Prototypes

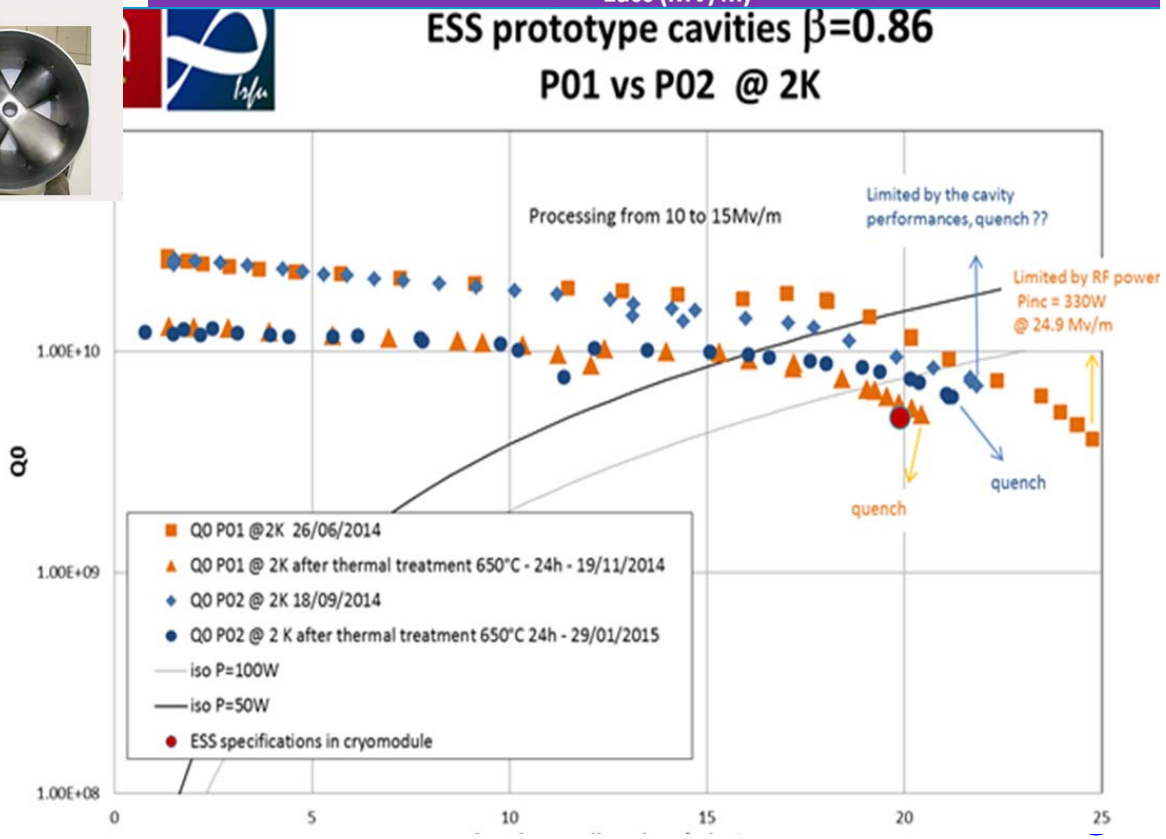
The 3 spoke cavities prototypes:

named: Romea, Giulietta and Germaine

View of the cavity inside: the spoke bars

- High b Elliptical Cavity installed in Helium Tank



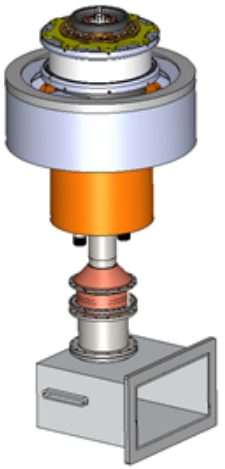



# ESS Project Status (6)

## WP8 1.2 MW IOT Prototype Update

**Current Status:**

- Two contracts place in September 2014
- One contract with Thales/CPI
- One contract with L3
- Delivery in 24 months
- Factory Acceptance at L3 and CERN
- Kick-off meetings and one Preliminary Design Report approved

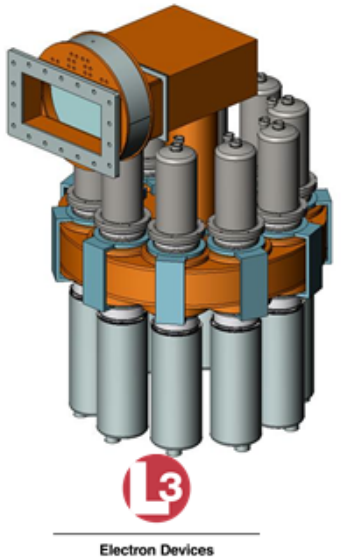


Pre-tender
CPI Cartoon

**Next stages:**

- Single beam IOTs/beam sticks being developed by both suppliers
- Complete thermal, mechanical and RF modelling
- Complete Preliminary and Final Design Reviews
- Identify auxiliary supplies: Ion pumps, solenoid, filament
- Identify RF drivers (up to 2 kW)

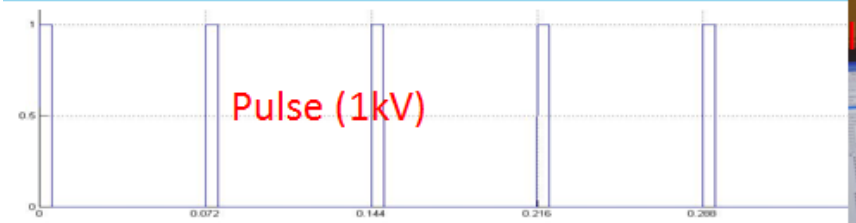
| Parameter | | Comment |
|---|---|---|
| Frequency | 704.42 MHz | Bandwidth > +/- 0.5 MHz |
| Maximum Power | 1.2 MW | Average power during the pulse |
| RF Pulse length | Up to 3.5 ms | Beam pulse 2.86 ms |
| Duty factor | Up to 5% | Pulse rep. frequency fixed to 14 Hz |
| Efficiency | Target > 65% | |

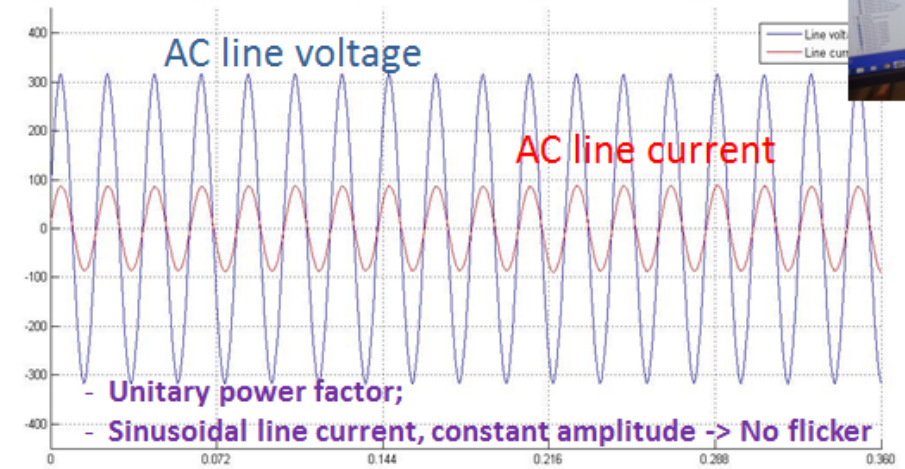


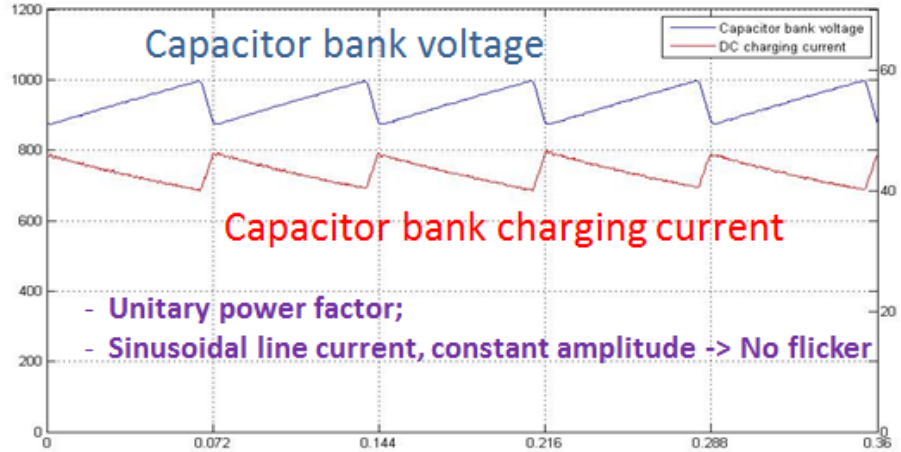
# ESS Project Status (7)

## WP16: Reduced Scale Modulator Prototype - Testing of Low Voltage stage at full power

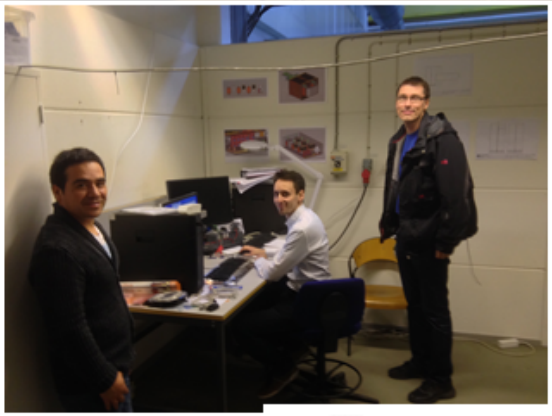
EUROPEAN SPALLATION SOURCE



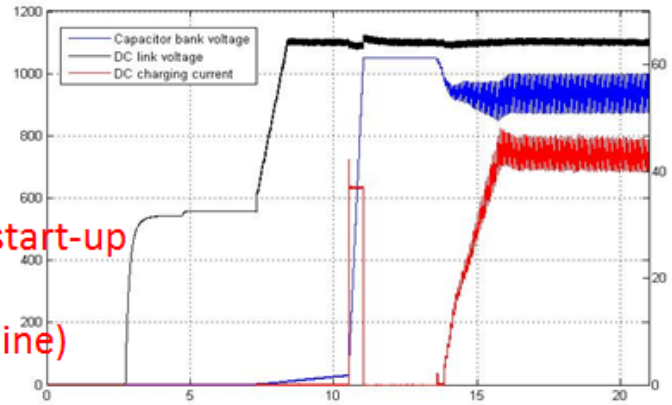




Controls & Human Machine Interface (labview)



Low voltage power converter stage

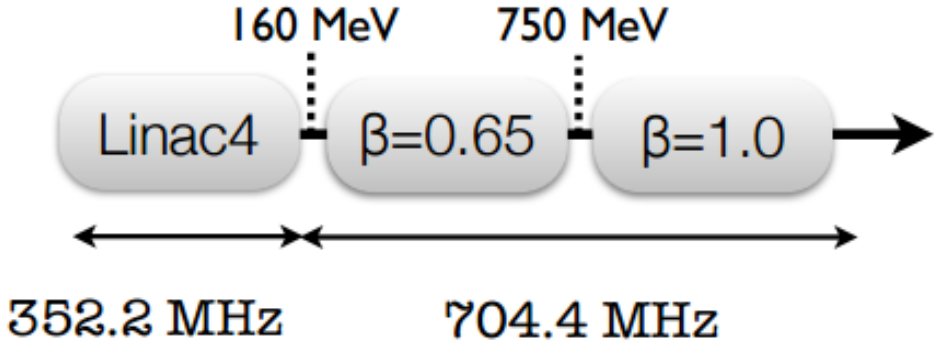
Automatic start-up sequence (state machine)



# SPL R&D at CERN (Frank Gerigk)

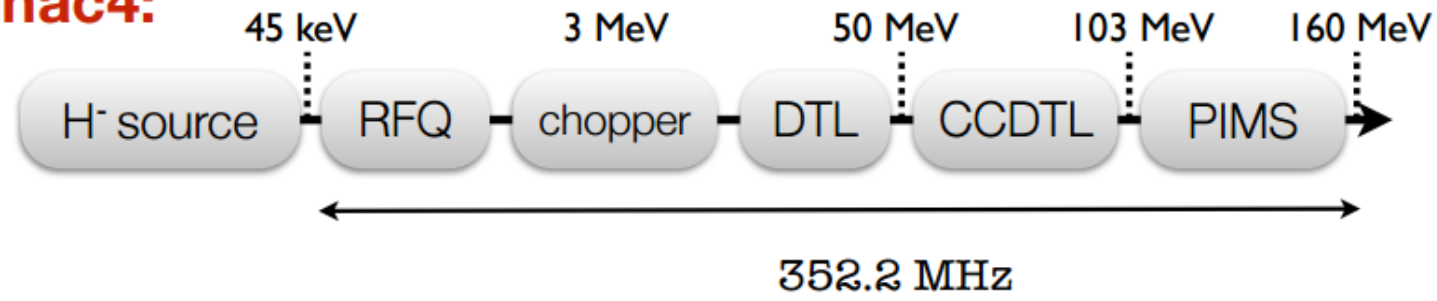
- MOTIVATION
  - Develop CERN expertise on SC multi-cell cavities, including the necessary infrastructure.
  - Option for LHC (or FCC) injector upgrade.
  - Driver for high-power proton physics (neutrino, RIB)

SPL:




- Linac4 Status
  - Commissioned up to 10 MeV (LEBT, RFQ, chopper line, DTL1).
  - Installation of DTL2 and 3 until June 2015.
  - 50 MeV commissioning from end of July 2015.
  - Installation of CCDTL 1,2,3, fine-tuning of CCDTL 2-7, conditioning of CCDTL 4,6,7 until October 2015
  - 100 MeV commissioning starting in October 2015

Linac4:

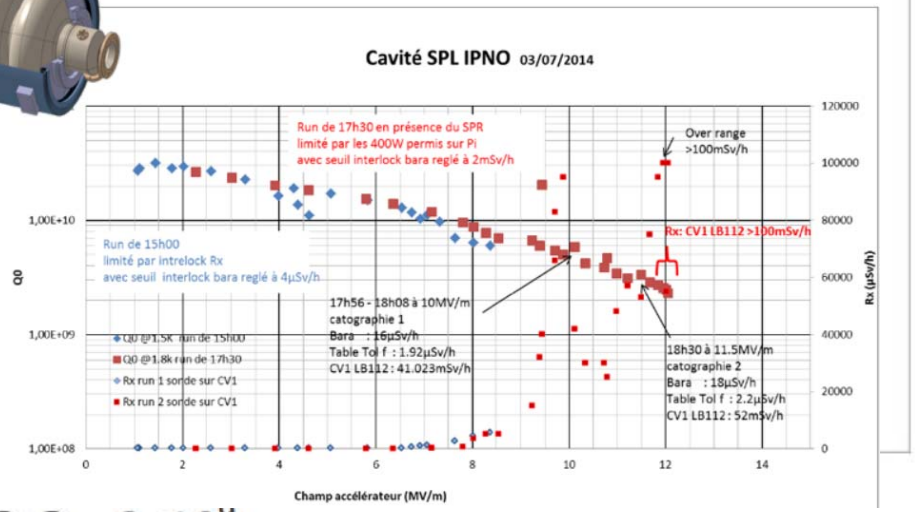


# SPL R&D at CERN (2)

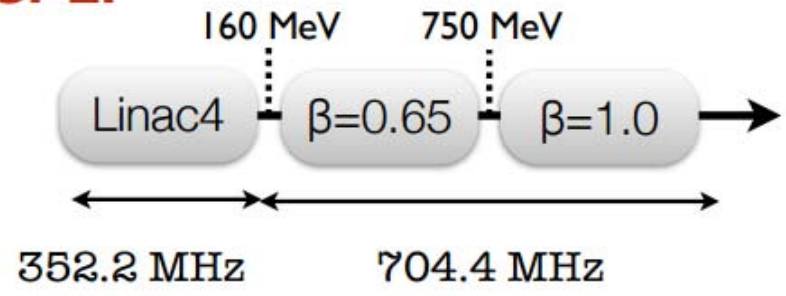
EUCARD - SPL TYPE BETA = 0.65 CAVITY
FROM IPN ORSAY, TESTED WITH HELIUM TANK

## + Status SPL cavities

Franck Peauger, CEA




**SPL:**




- β=0.65: IPNO, June 2014: 12 MV/m (quench) @ $Q_0$=2x10$^9$,
- β=1: 4x RI cavities, 1x CEA collaboration (Eucard), 1 under construction at CERN,
- August 2014: first cold test of SPL1 (5-cell), surface treated at CERN: a few MV/m.
- September 2014: Eucard cavity achieves 20 MV/m (quench) @ $Q_0$≈5x10$^9$
- December 2014: He tanks at CERN via CEA.
- December 2014: 2nd cold test (repaired compensation of magnetic field, He-processing,), Initial $Q_0$=1.2x10$^{10}$, field emission onset 5-6 MV/m, field probe connectors burnt at 9 MV/m, maximum field probably 15 MV/m, test stopped because of end-of-year shutdown and because of burnt connectors.
- Waiting for re-start of cryogenics in SM18 end of March 2015.

■ β=1 cavity exhibits similar results

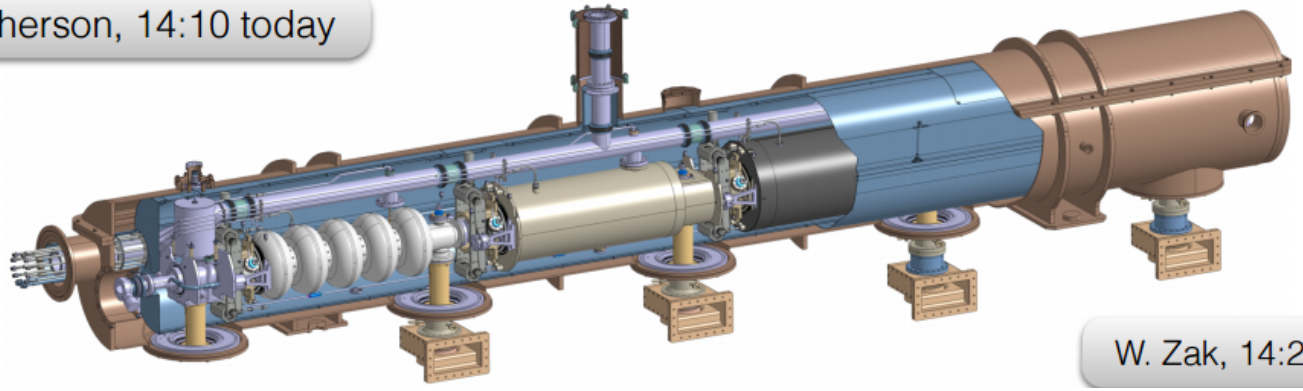
# SPL R&D at CERN (3)

## + Status cavities and cryomodule

L. Ferreira, 14:20 today

- New EP electrode fabricated and first treatment of cavity 2 took place last week.
- Improvement of high-pressure rinsing procedure (plexiglas cavity will be constructed).
- Cryomodule vacuum vessel expected for end of May 2015.
- Manufacture of magnetic shielding is launched, delivery foreseen for Nov 2015.
- MLI is ordered.
- Remaining drawings, orders, and assembly of cryomodule will be completed by TE-MME + BE-RF with support by TE-MSC and the assembly tooling developed by CNRS-IPNO.
- **Construction of 5 more cavities has been launched (CERN/Bmax).**
- **2015 goal is to have 4 cavities at high gradient (25 MV/m).**

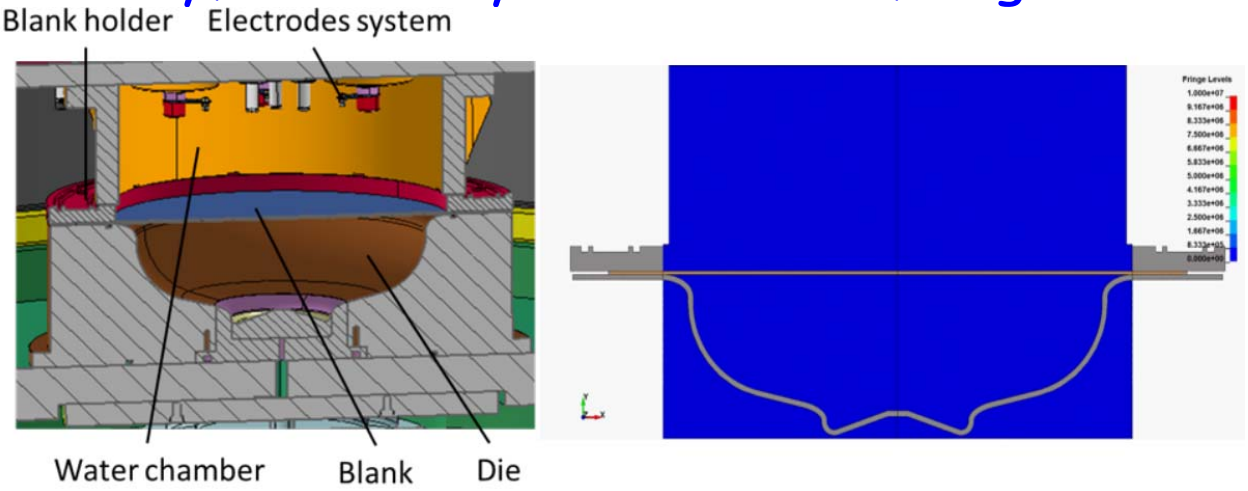
see: A. MacPherson, 14:10 today



W. Zak, 14:20 tomorrow

# SPL R&D at CERN (4)

- High velocity forming (electro-hydraulic-forming) of superconducting RF structures (S. Atieh)
  - High-velocity forming is a potentially alternative process. It involves a high-strain rate deformation, through a process lasting a few milliseconds, that allows reaching higher formability (larger plastic deformation, smaller spring-back).
  - Applications to copper and niobium have only recently been started using electro-hydraulic forming (EHF).
  - Advantages are expected in metallurgy, geometrical precision, reproducibility, suitability for economic, large series production.

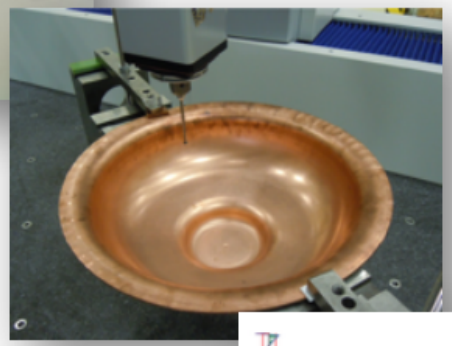


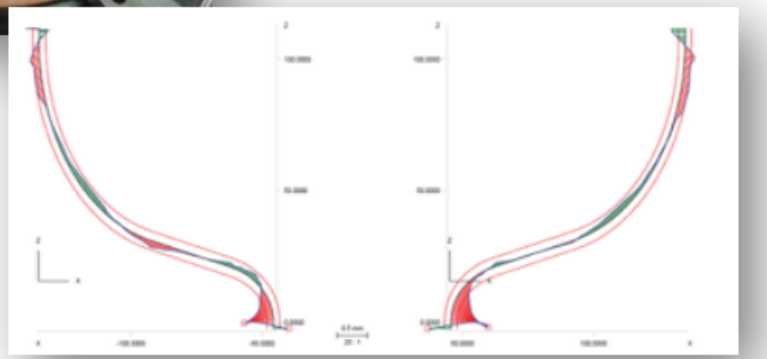

  - Full forming sequence made of 4 successive discharges.

# SPL R&D at CERN (5)

## + Experimental results

- 3 OFE half-cells formed
- Good fit in between the experimental results and the simulation
- Achieved shape accuracy: ± 150 $\mu$m
- (instead of 600 - 800 $\mu$m for deep drawing or spinning )
- High reproducibility





**Next:**

- Forming of 2 Nb half cells is ongoing, results expected for June 2015
- Parts Shaping for a full 5 cells SPL_Nb (β = 1) cavity in 2015

EN ENGINEERING DEPARTMENT

Bmax

S. Atieh EN-MME/Bmax collaboration

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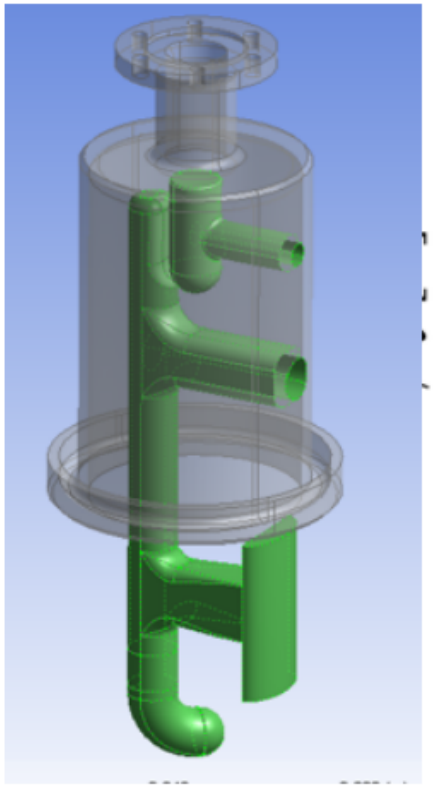
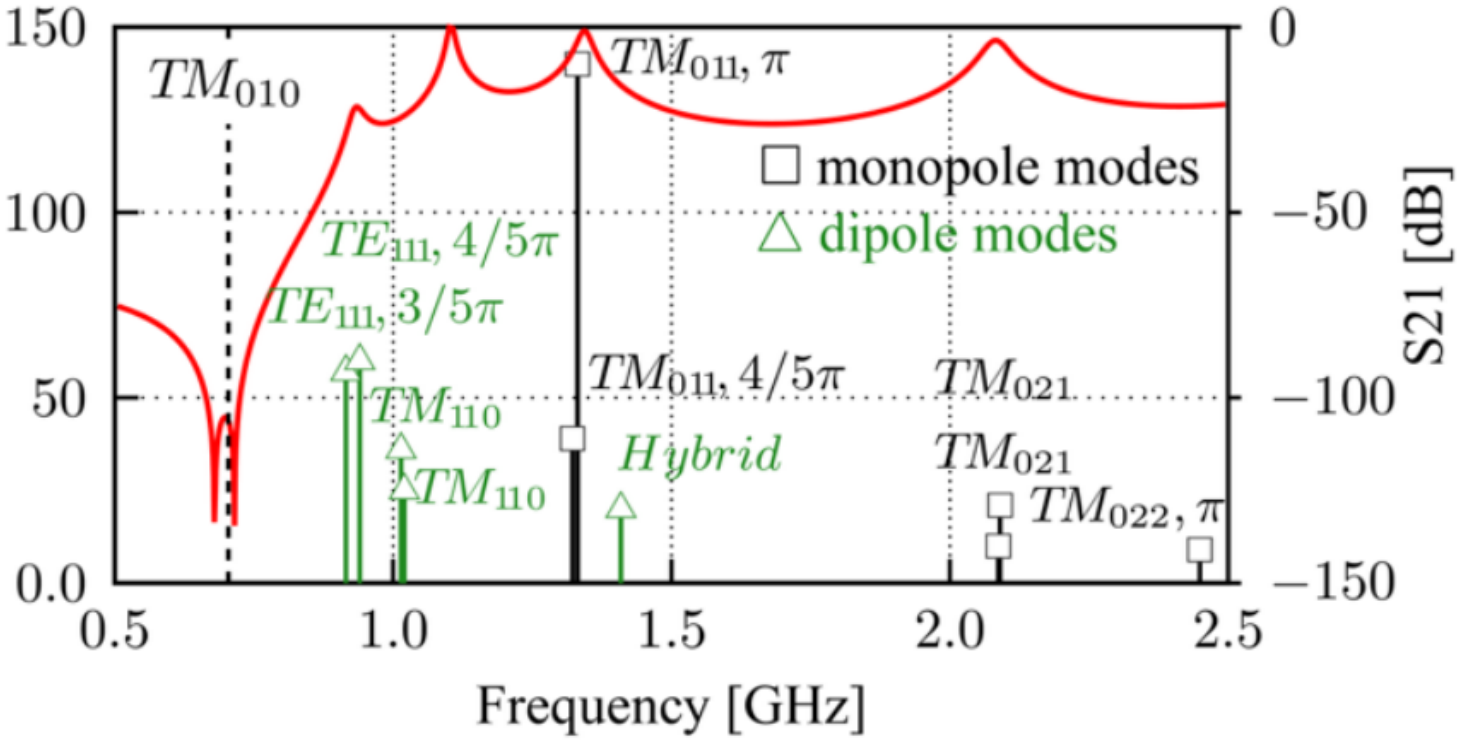
# SPL R&D at CERN (6)

## + HOM couplers






- Since CERN machines are always used with changing pulse patterns, we decided to keep the option of adding HOM couplers.
- First HOM coupler model has been 3D printed and Cu plated and was characterised successfully. Nb prototype under construction.

# SPL R&D at CERN (7)

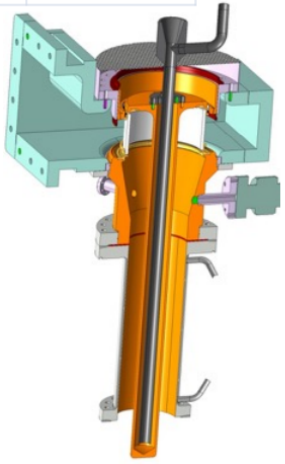
## Tests results

Coaxial window couplers have passed all the (mitigation) test programme

Cylindrical window couplers have arced during full reflection test on some phases even at lower power

**Coaxial windows couplers have been selected as SPL couplers**

| Test repetition rate 50 Hz | Power level kW | Coaxial window coupler | Cylindrical windows coupler |
|---|---|---|---|
| ***TWC*** | ***1000*** | √ | √ |
| SW 100 µs | 1000 | √ | √ |
| ***SW 200 µs*** | ***500*** | √ | √ |
| SW 500 µs | 250 | √ | X |
| ***SW 1 ms*** | ***250*** | √ | X |
| SW 2 ms | 250 | √ | X |



**Cylindrical window Coupler**

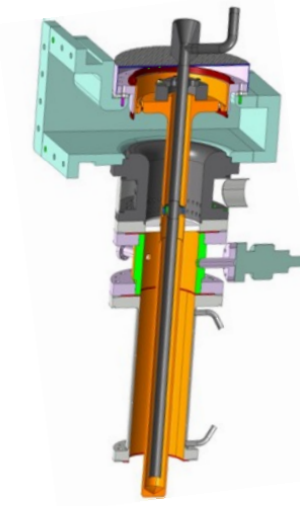
**Both designs have the same:**

Double walled tube

Matching waveguide without doorknob

Contacts ring including DC capacitor

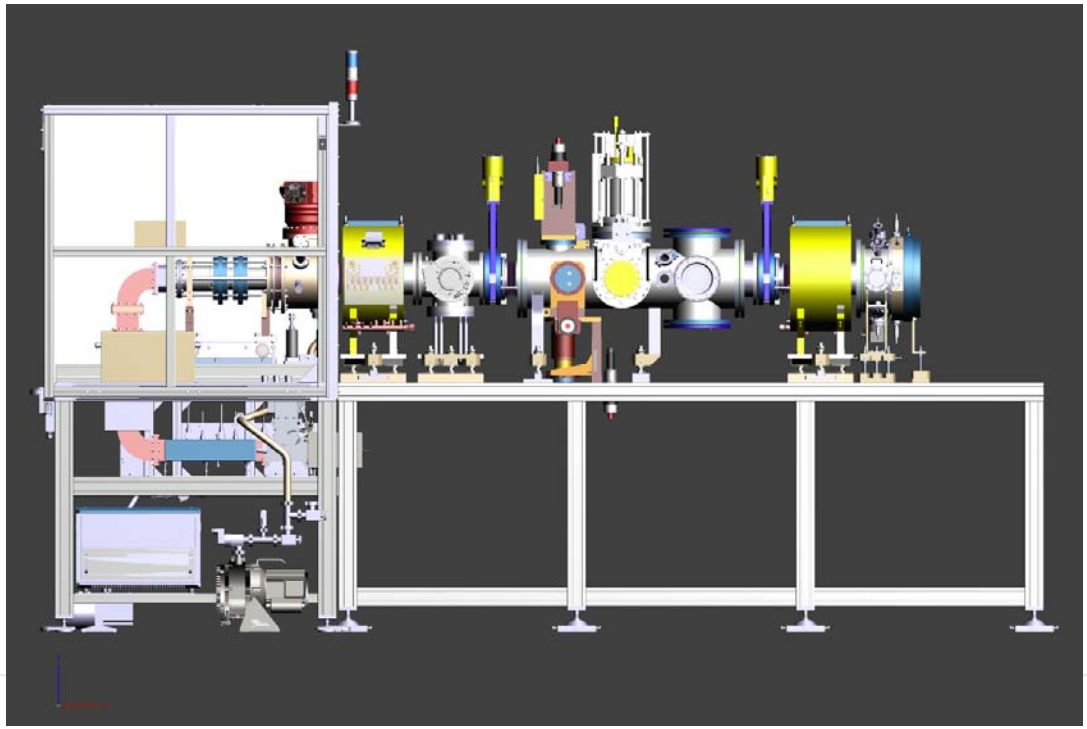
Interface to cryomodule flange & RF + vacuum gasket

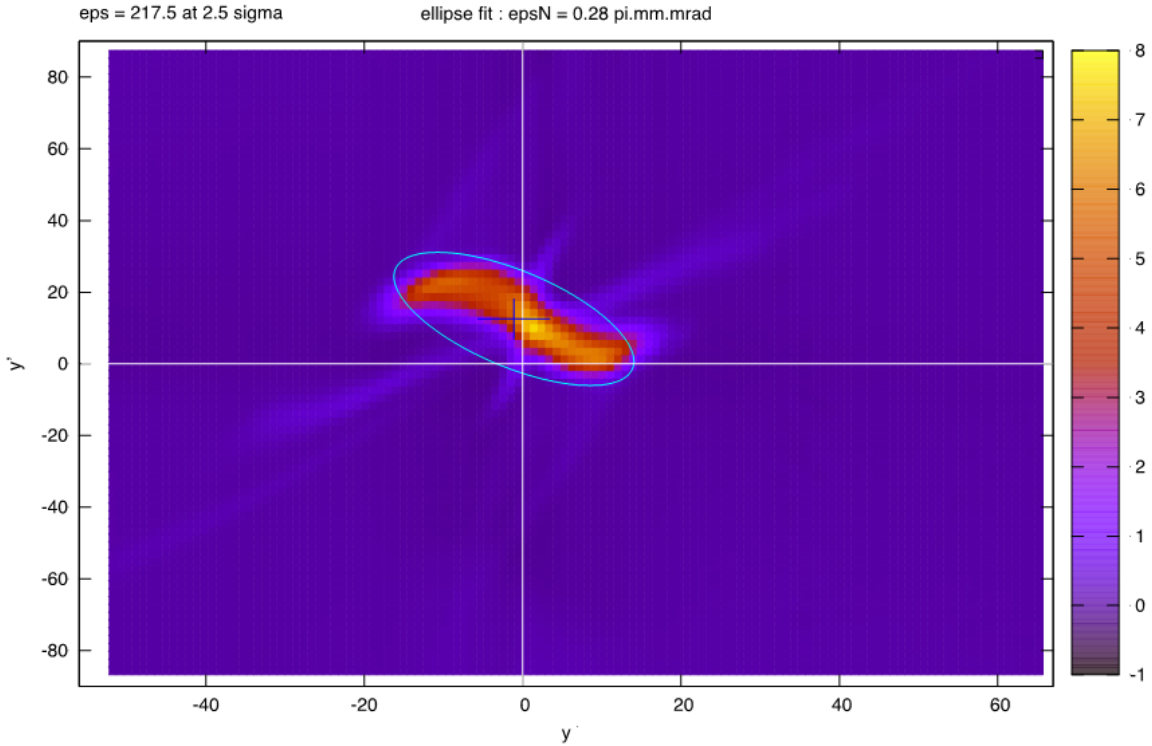


**Disk window Coupler**

# Progress in Design and Construction of the MYRRHA LEBT (Dirk Vandeplassche)

- MYRRHA is on slow path
- No Belgium government decision
  - safety related issues from new regulations (Fukushima)
- Mostly LEBT activities
  - Horizon2020 project MYRTE ready to start
    - 12 M€ total, 9 M€ granted
    - 4-year activity
  - First emittances are measured





# The FAIR accelerator complex and its cryogenic supply (Holger Kollmus)

- Review of FAIR with main focus on cryogenics

# LCLS-II Cryogenic Systems: Cryomodule, Distribution, and Cryoplant (Greg Hays)

## LCLS-II will use 1.3 GHz cryomodules.

- Use existing designs to the extent possible to optimize cost and schedule
  - LCLS-II SRF linac closely based on *XFEL / ILC / TESLA* design
  - Under development ~ 20 years with *> 1000 cavities* to be made and tested (incl. 800 for EuXFEL – completed 2015)
- FNAL has been working with these designs for ~10 years in ILC context
  - Two 1.3 GHz cryomodules built and tested: CM1 and CM2
  - Significant improvements to lab infrastructure to support SCRF development and Production
- JLAB has built ~100 SCRF cryomodules over the last 30 years
  - JLab CEBAF and 12 GeV Upgrade machines
  - SNS

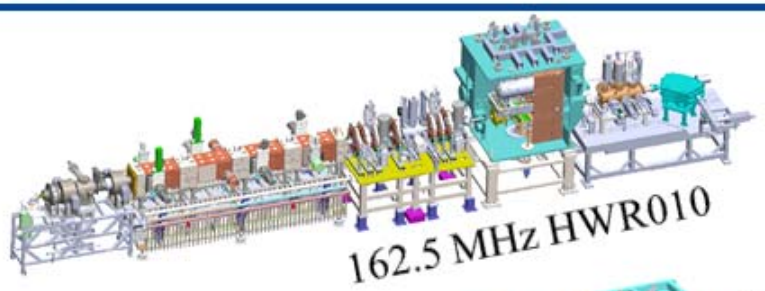
➢ FNAL responsible for the CM design, in collab with JLab & SLAC

➢ Procurement/fabrication/assembly/test shared by FNAL and JLab

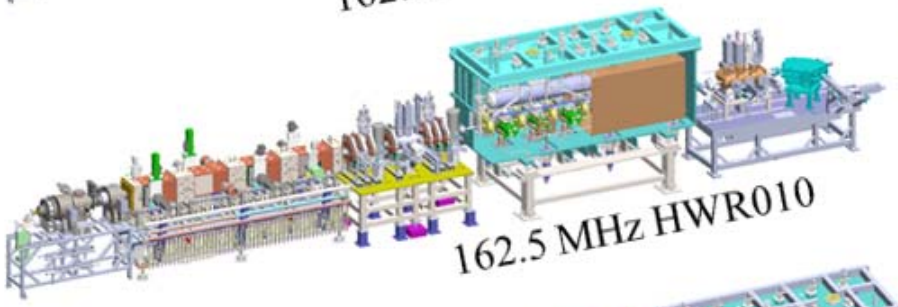
➢ **Cooperation and assistance from DESY/XFEL and CEA Saclay has been extremely beneficial.**

# ADS Project and Material Irradiation Facility in China (Yuan He, IMP)

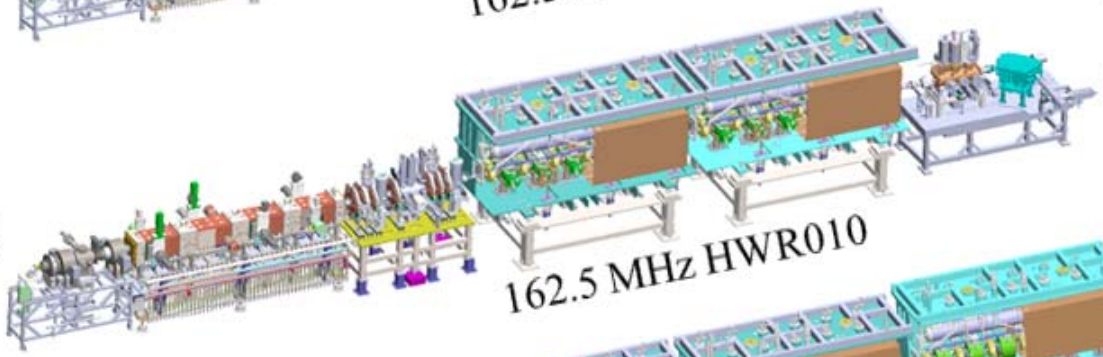
## Demo of SRF LINAC for CIADS in 2011-2016



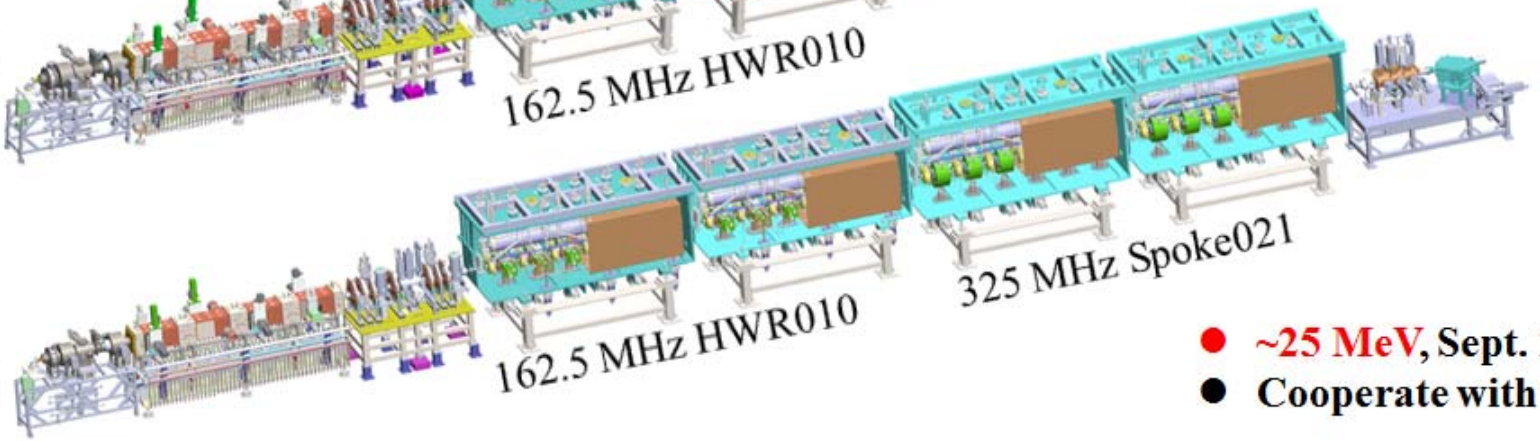

- ECRIS + LEBT + RFQ + MEBT + TCM1, 2.5 MeV
- RFQ commissioning, validate CM design.
- Ongoing to CW at 10 mA




- ECRIS+LEBT+RFQ+MEBT+CM6, 5 MeV
- Beam commissioning in March 2015




- ECRIS + LEBT + RFQ + MEBT + 2xCM6 +HEBT, 10 MeV
- Dec. 2015—Feb. 2016




- ~25 MeV, Sept. 2016 – 2017
- Cooperate with IHEP