First results of the CRFQ proof of principle
(Circular RadioFrequency Quadrupole)

Daniele Davino

`davino@unisannio.it`

Department of Engineering

University of Sannio, Benevento, Italy

CRFQ Collaboration team

- Daniele Davino, University of Sannio

- Luigi Campajola, Vittorio G. Vaccaro, Physics dept., University of Napoli

- Maria Rosaria Masullo, INFN

- Alessandro G. Ruggiero, Vincent Lo Destro, Brookhaven National Laboratory

- **Advisors**: Maurizio Vretenar (CERN), Augusto Lombardi (LNL, Italy).

Outline

- What is the CRFQ?

- RF & mechanical design

- Linear RFQ measurements
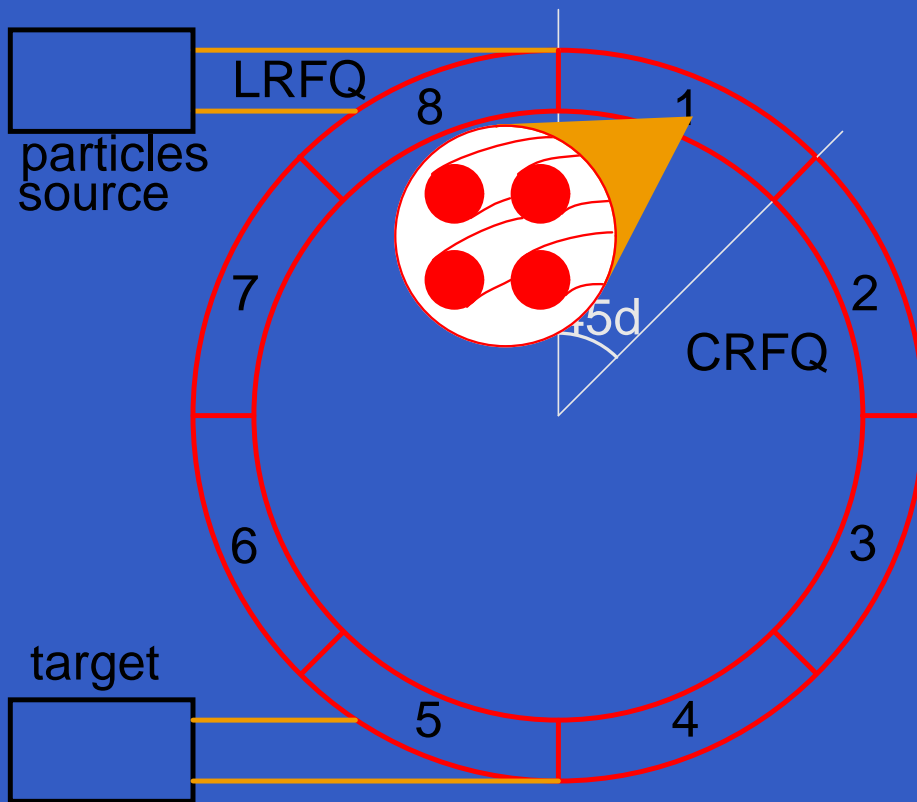
- Conclusions and foreseen
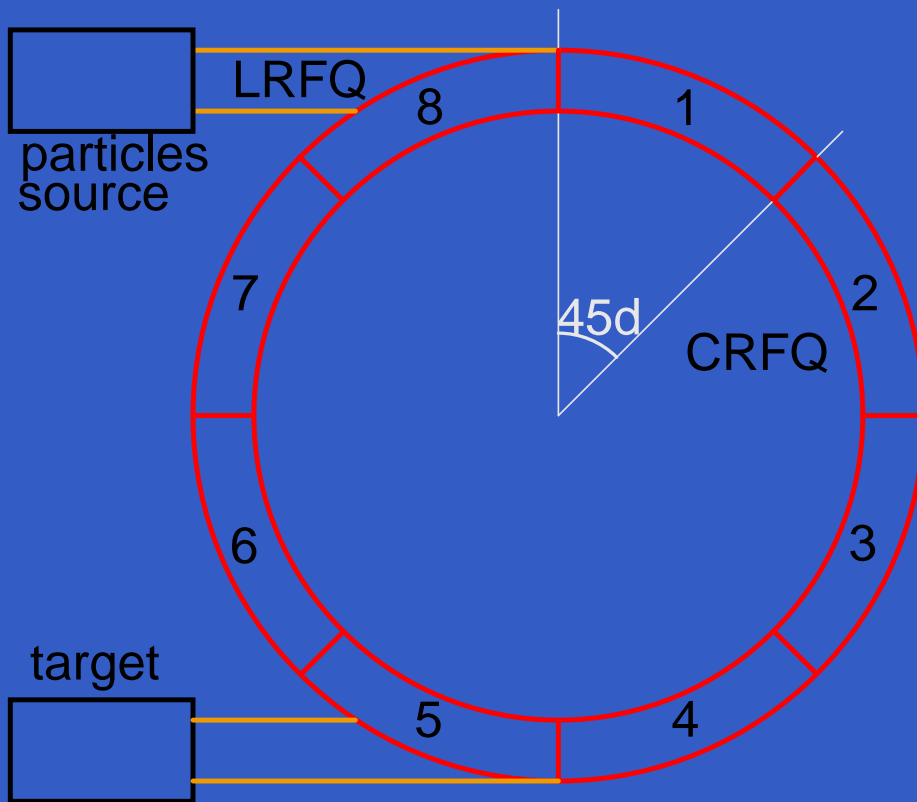
The CRFQ

- RadioFrequency quadrupole completely bent on a circle

A. Ruggiero, BNL-AP-65 note, 2001, available at http://www.bnl.gov
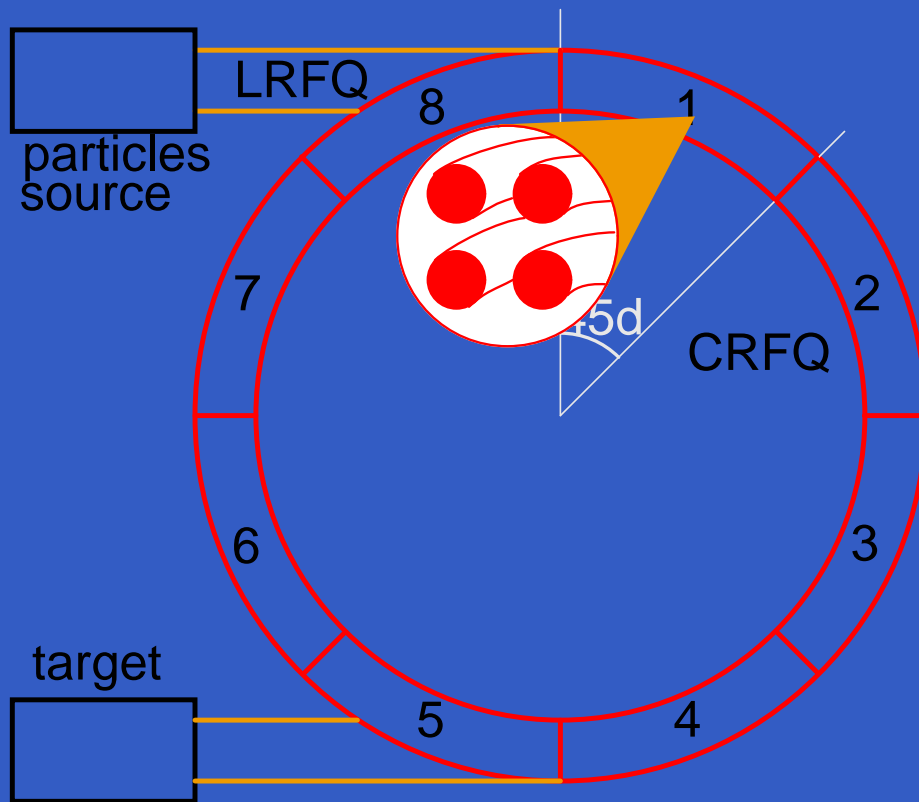
The CRFQ

- RadioFrequency quadrupole completely bent on a circle
- higher beam intensity, smaller beam dimensions
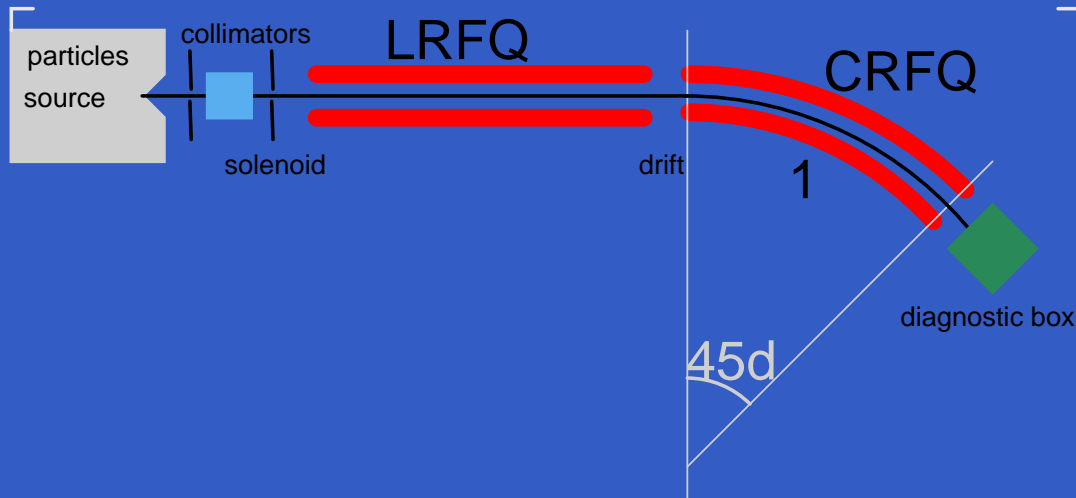
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The CRFQ

- RadioFrequency quadrupole completely bent on a circle
- higher beam intensity, smaller beam dimensions
- never tested before $\Rightarrow$ proof of principle!

A. Ruggiero, BNL-AP-65 note, 2001, available at http://www.bnl.gov

Aim of the CRFQ collaboration

- Made at *Laboratorio dell'Acceleratore*, University of Naples, Italy.
- Development of a 1mA proton source (40keV max energy).
- Design, build and test of a linear prototype to prove RF solutions & beam matching. No rods modulation.
- Design, build and test of a 45d sector to prove bending and focusing principle.
- Related items: beam diagnostics, low level RF, vacuum pumping, etc. .

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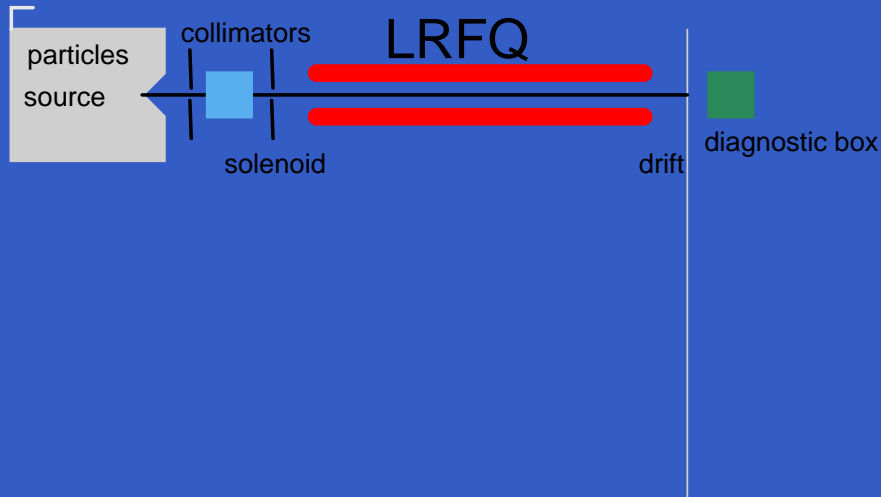
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Beam Parameters

Rods radius (4-rods RFQ)	5mm
Gap radius	5mm
Electrodes length	707mm
Input energy	30keV
Beam current	1mA
Transverse emittance	20π mm mrad
Longitudinal electric field distribution	$<\pm5\%$
Dipole mode error	$<\pm2\%$

RF Parameters

- RF power amplifier

f [MHz]	202.56
Power	<20 kW
Duty cycle	0.2%
Rods voltage	36 kV
Field flatness	$< \pm 5\%$
Transverse Rsh	$>73 \text{ k}\Omega\text{m}$

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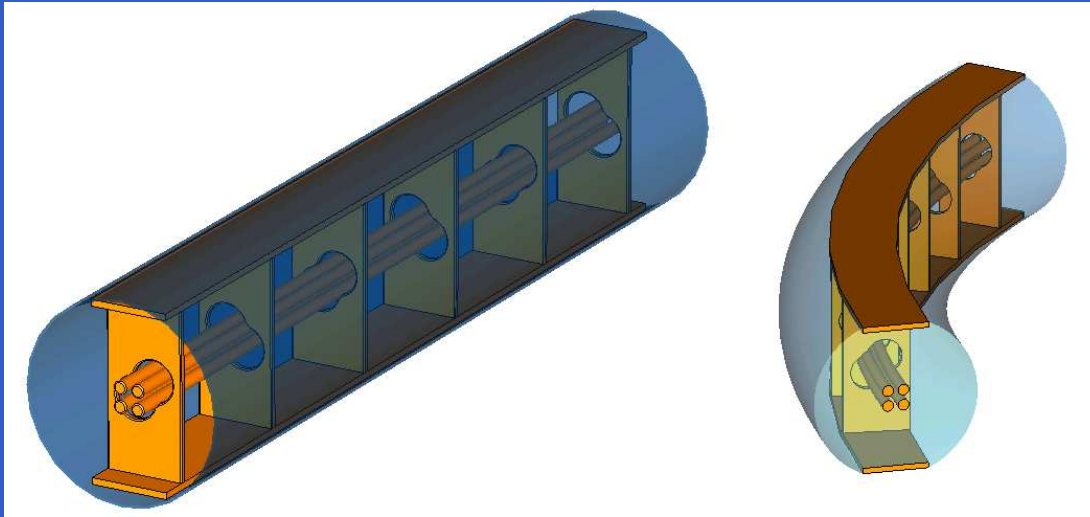
LRFQ & CRFQ design

The simplicity of construction, assembling and alignment of the curved sector has been used as the most important property

LRFQ & CRFQ design
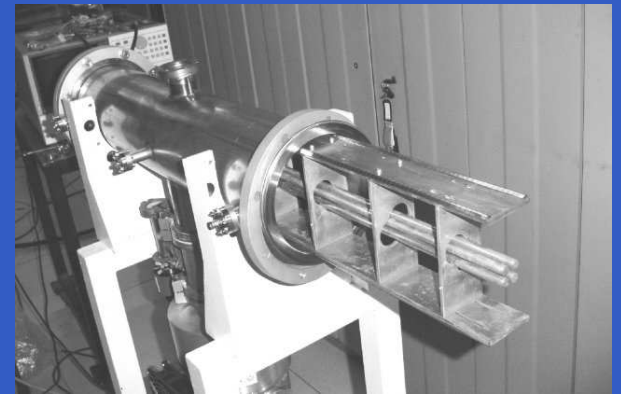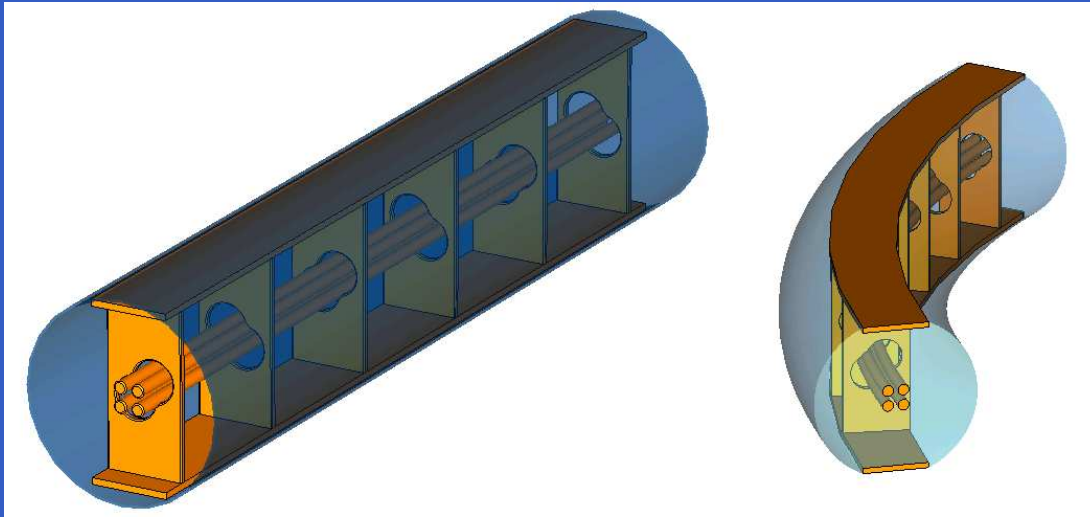
Electromagnetic field simulator (CST microwave studio): shapes optimization, quality factor , transverse shunt impedance, etc.
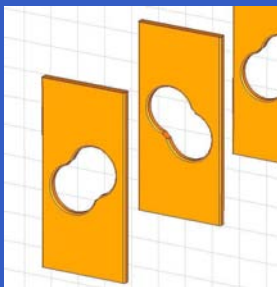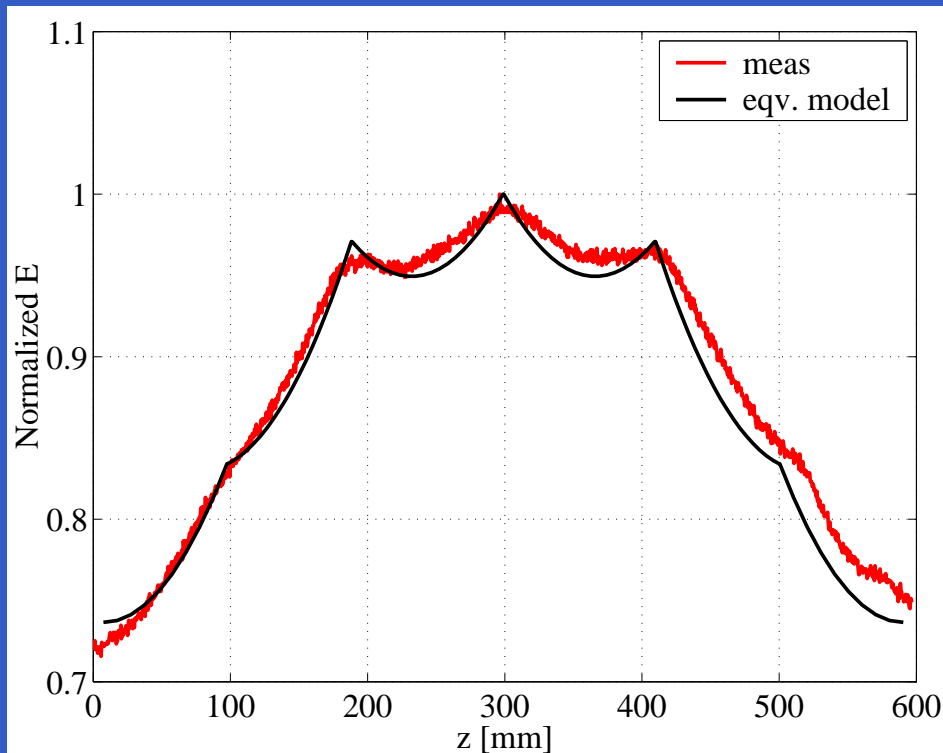
Equivalent model
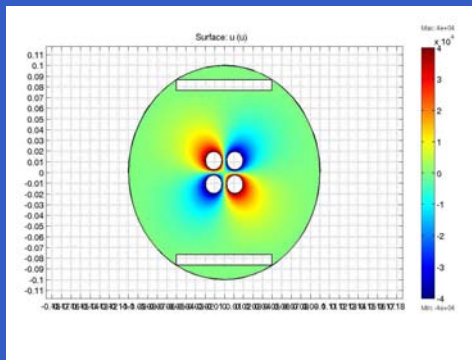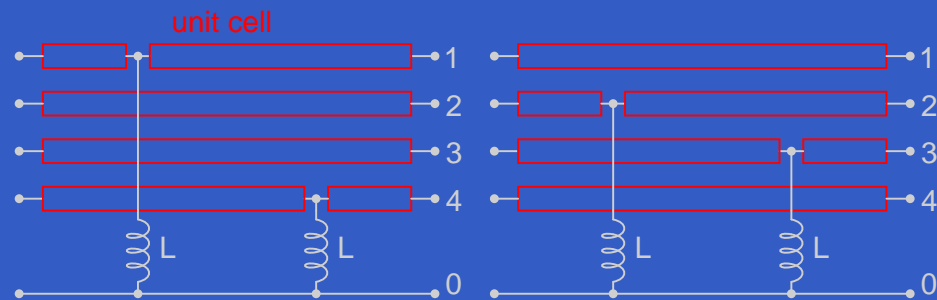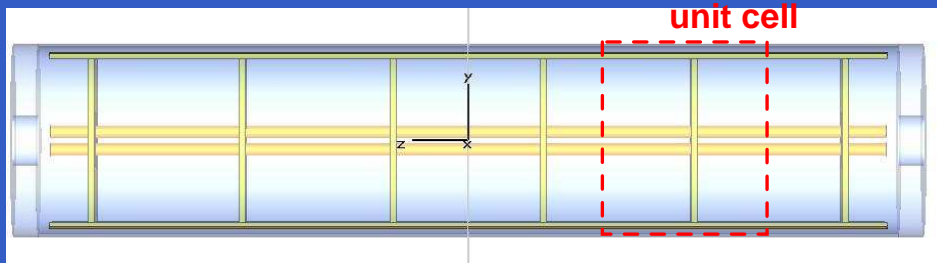
unit cell

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- Multiconductors
  transmission lines 1D
  model $\Rightarrow$ longitudinal
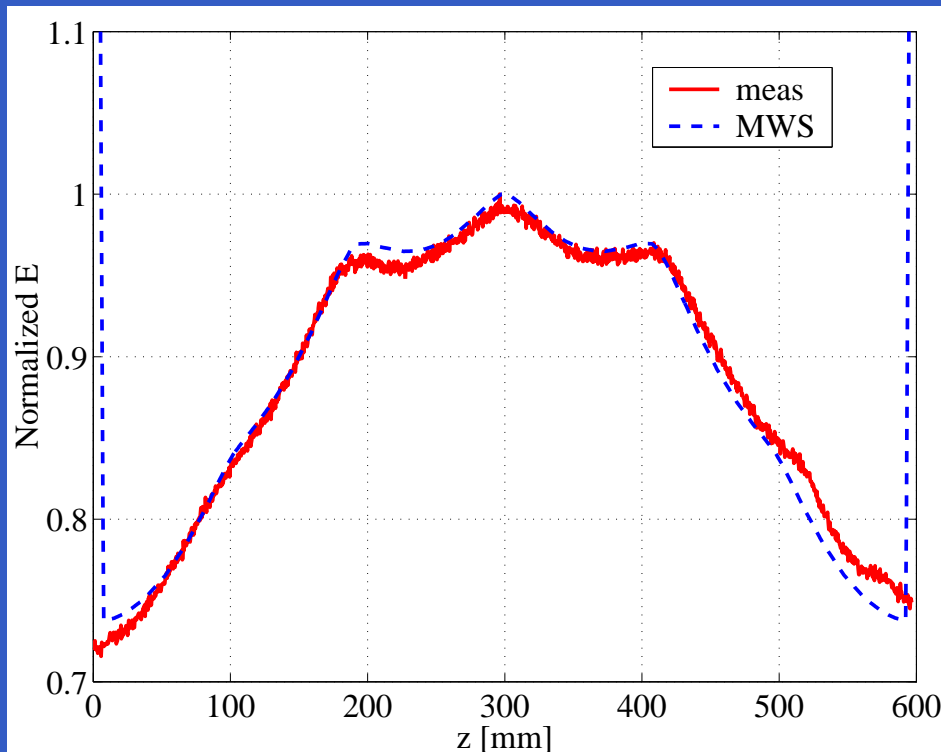 electric field distribution,
  dipoles errors, etc

V. Kapin, EPAC84, London, pp. 2191-2193

Equivalent model

- Multiconductors transmission lines 1D model $\Rightarrow$ longitudinal electric field distribution, dipoles errors, etc
- good agreement with experimental bead pulling (cold model)

Equivalent model

- Multiconductors transmission lines 1D model ⇒ longitudinal electric field distribution, dipoles errors, etc
- good agreement with experimental bead pulling (cold model)
- good agreement with numerical simulations (CST microwave studio)
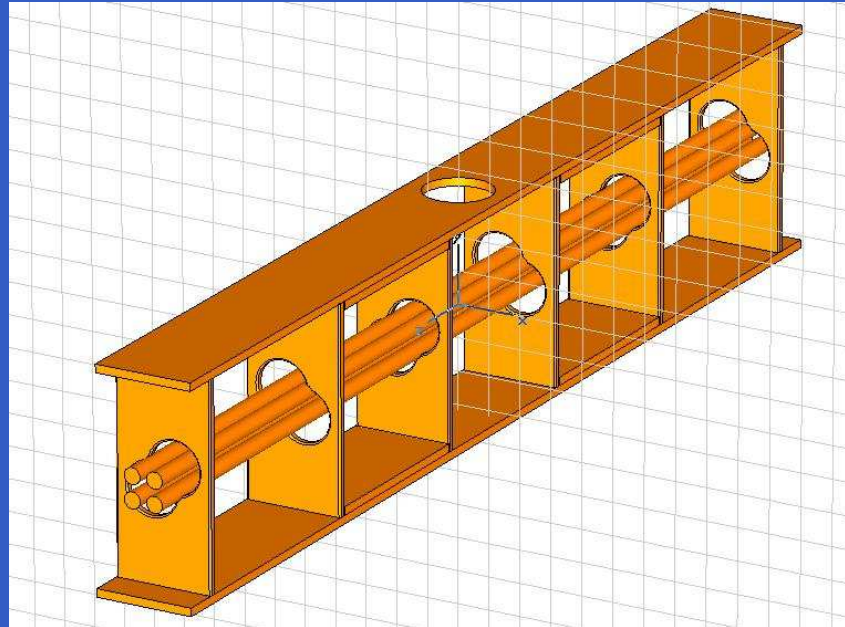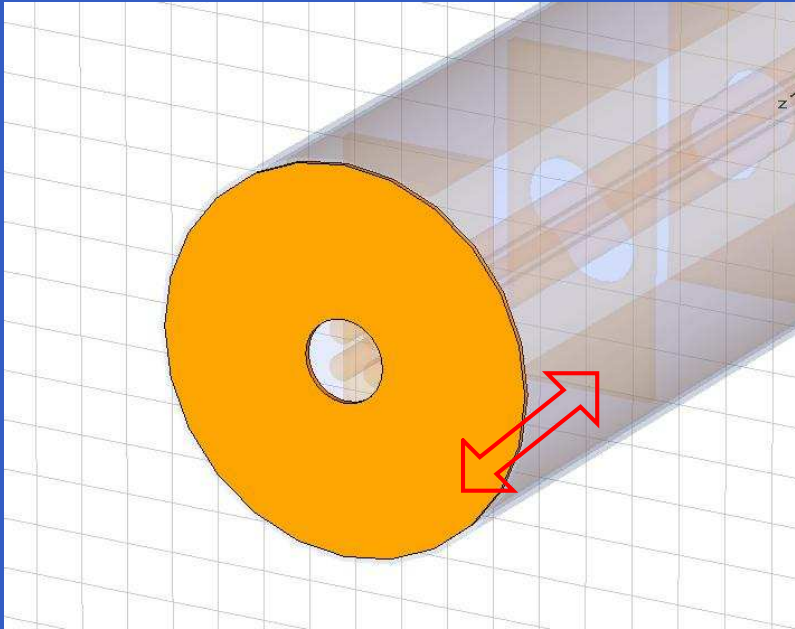
Construction details

- Six stems, center hole for power coupler, copper tiles for resonant frequency tuning

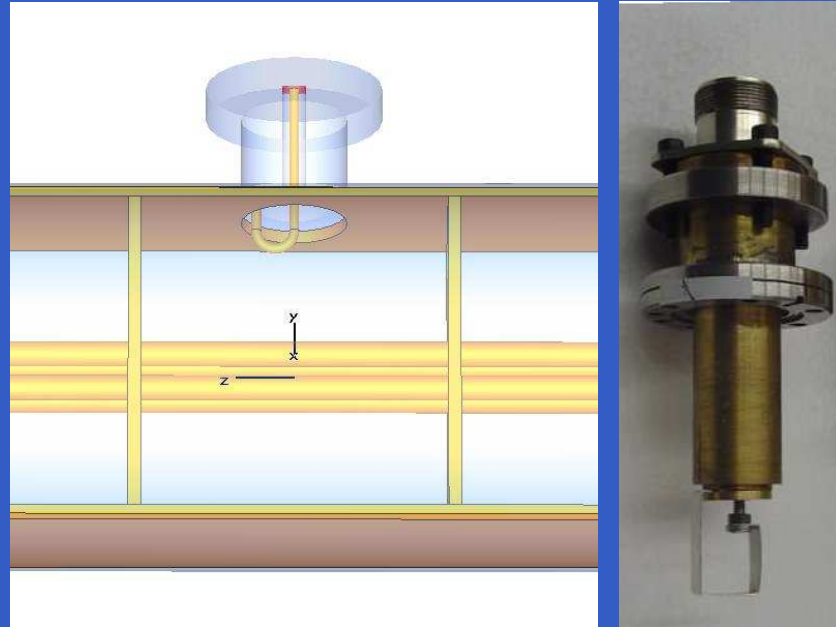# Construction details
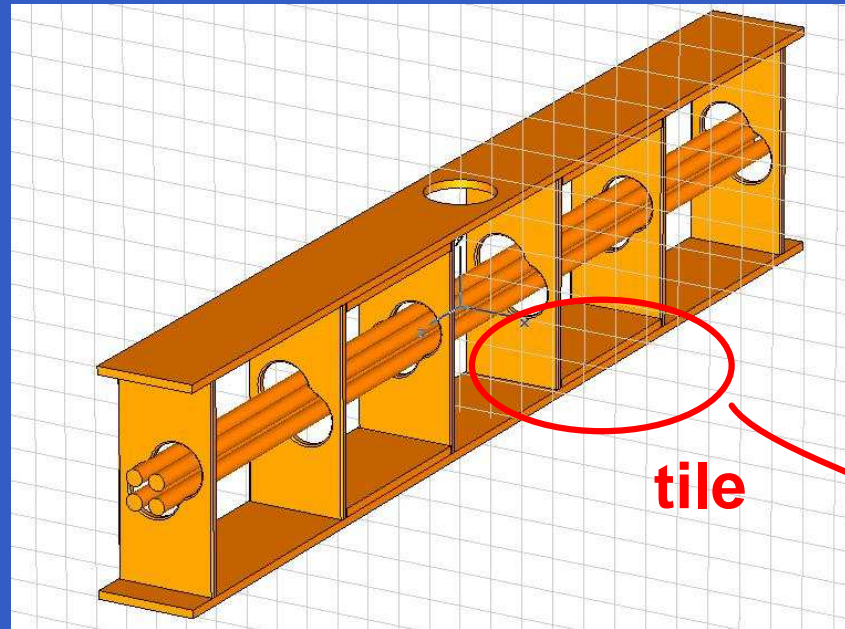
tile

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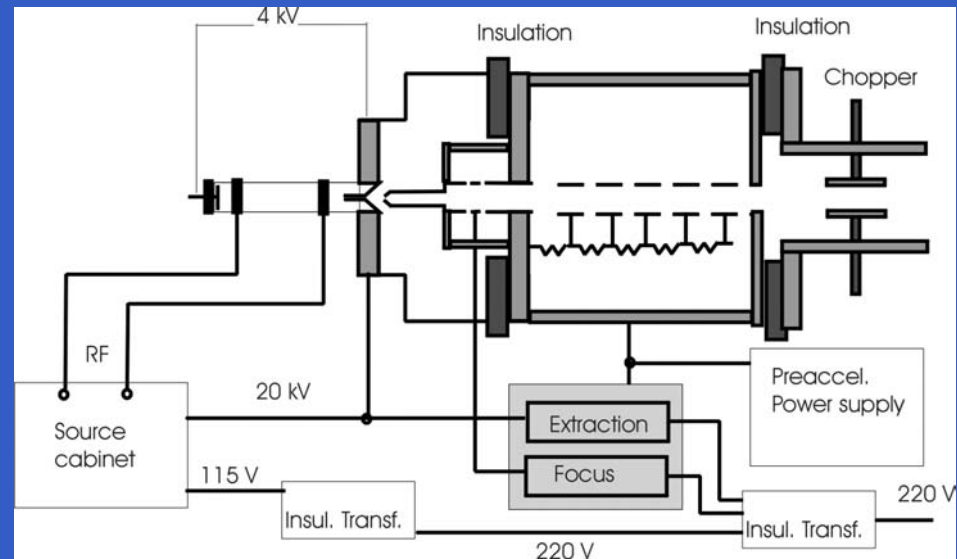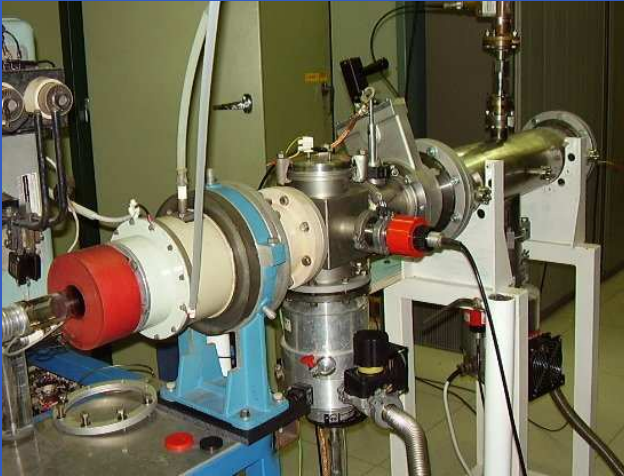
Construction details

- End disks for fine tuning (within few kHz) and electromagnetic shielding
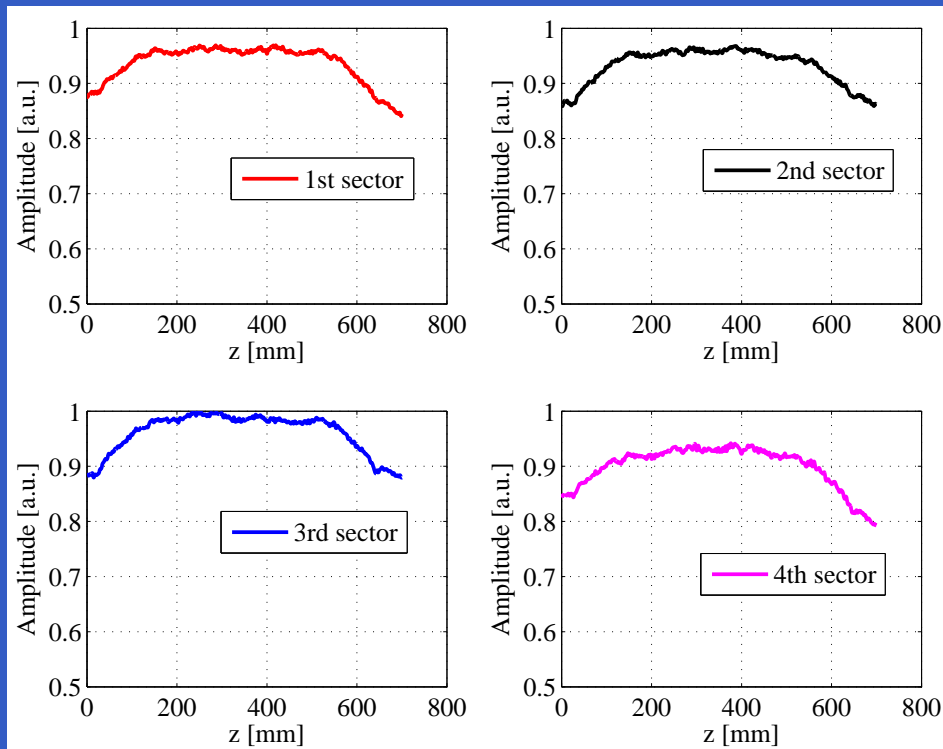
Construction details

- The RF coupler can rotate (the critical coupling is obtained by a low power network analyzer measurement)

Upgrade of the RF proton source

- 1mA beam available

- Electrostatic acceleration stage added (40keV max)

- Beam emittance is within specifications (about 20πmm*mrad),

Bead pulling (hot model)

- Bead pulling allows to know the longitudinal electric field distribution
- Four rods $\Rightarrow$ four sectors $\Rightarrow$ the comparison of the four measurements allows to know the dipoles and the quadrupole mode.

Bead pulling (hot model)
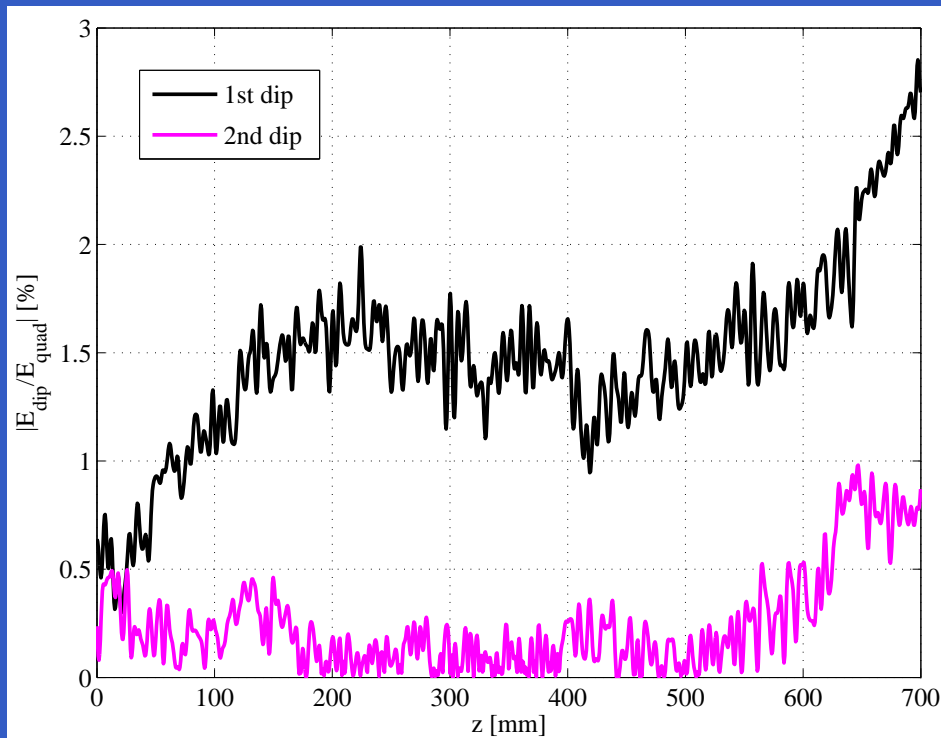
- Bead pulling allows to know the longitudinal electric field distribution
- Four rods $\Rightarrow$ four sectors $\Rightarrow$ the comparison of the four measurements allows to know the dipoles and the quadrupole mode.
- $\pm 1.5\%$ dipole
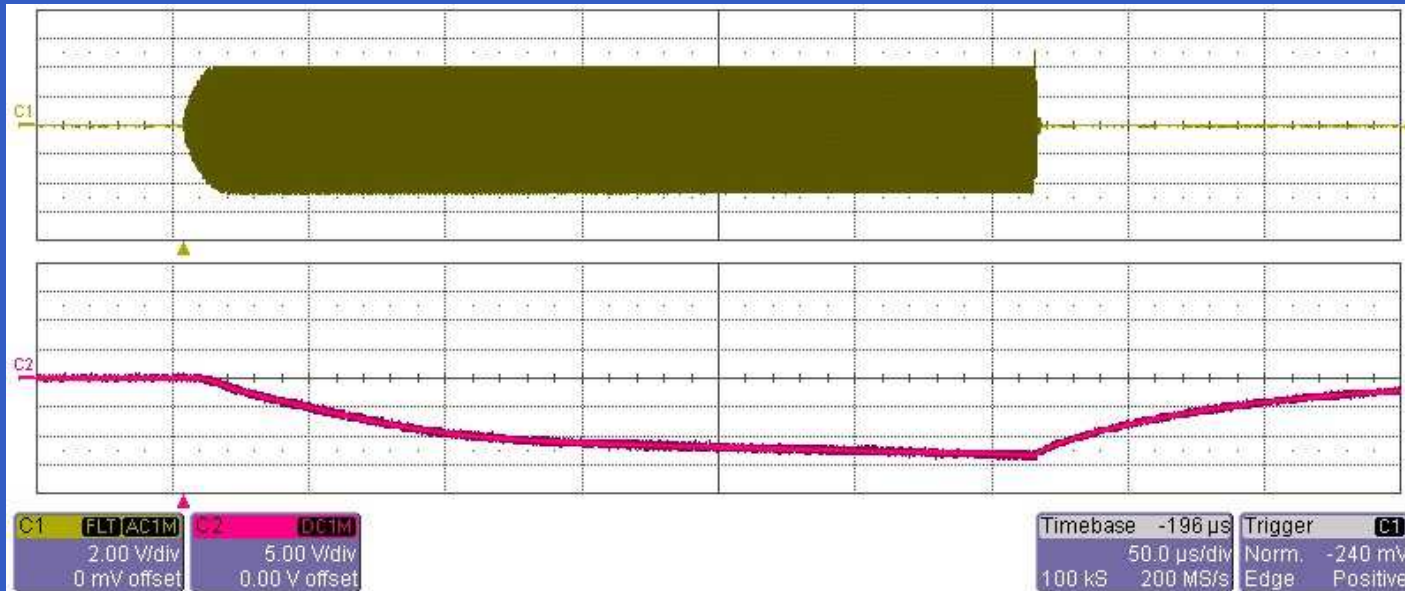
Vacuum & RF power tests
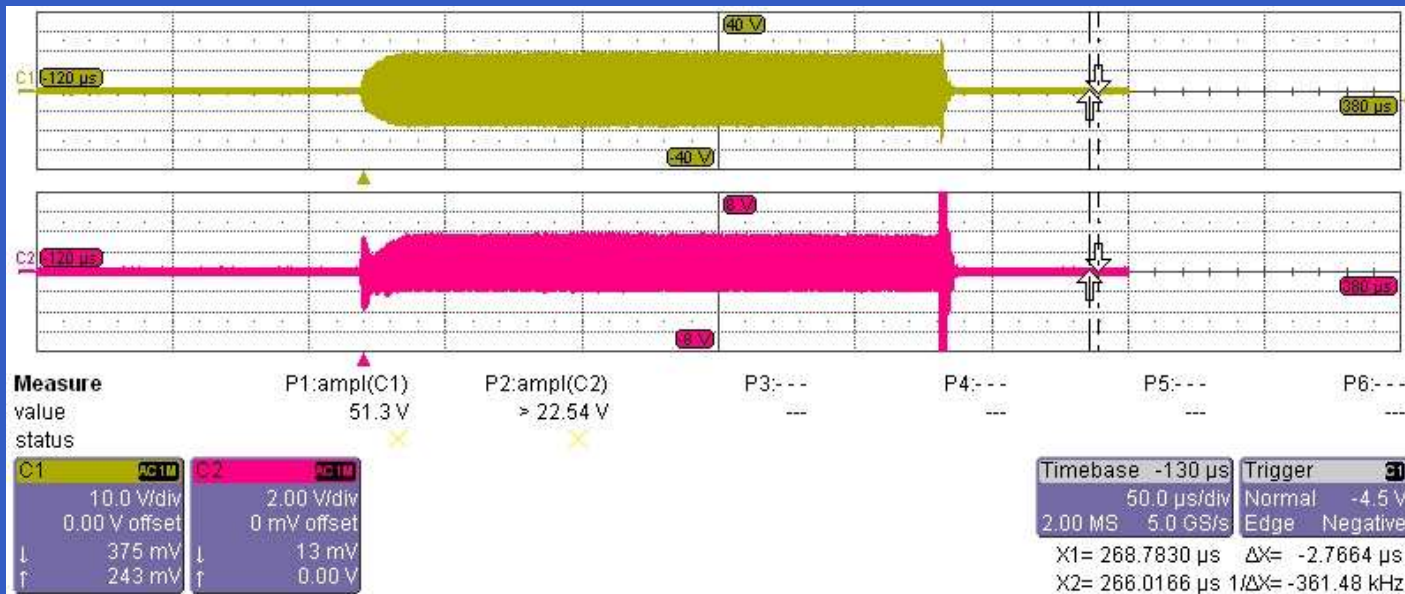
- Vacuum pressure: $2 \cdot 10^{-7}$ mbar with RF off (can be improved)

- $8 \cdot 10^{-7}$ mbar with 22kW (after conditioning)

- $1 \cdot 10^{-6}$ mbar with 22kW and proton beam

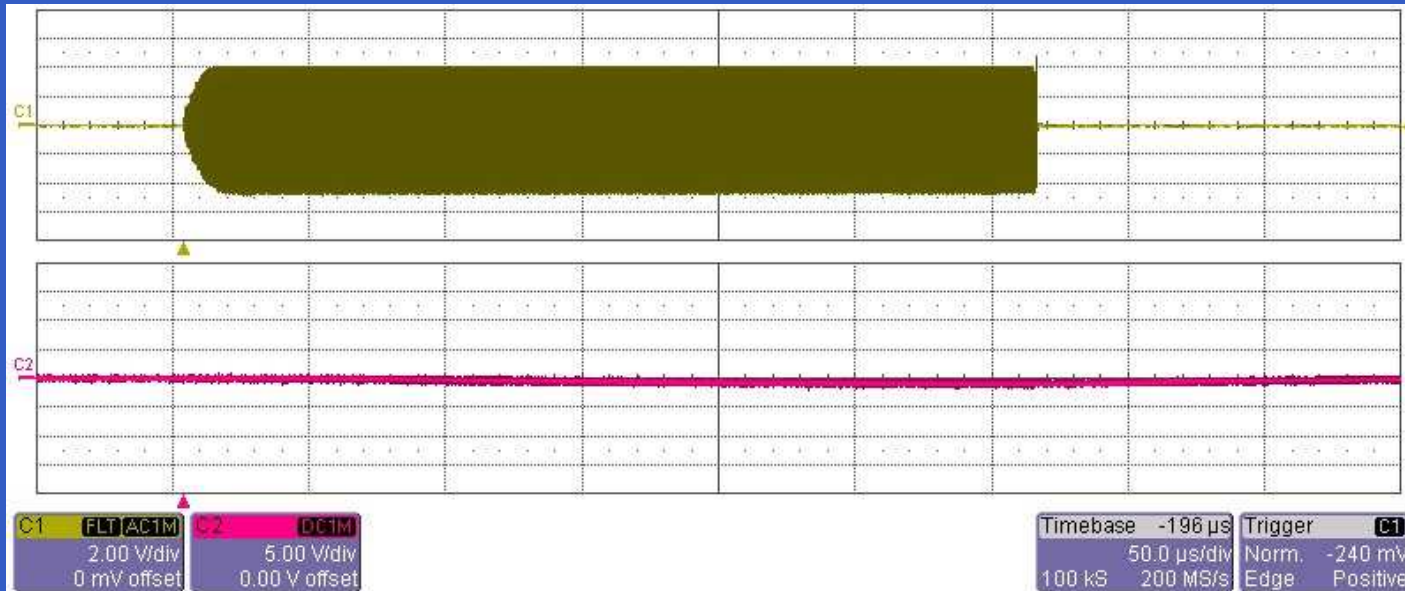- RF max: 38kW

First beam tests
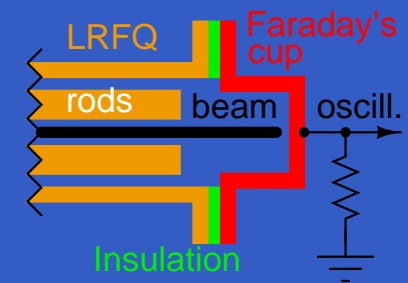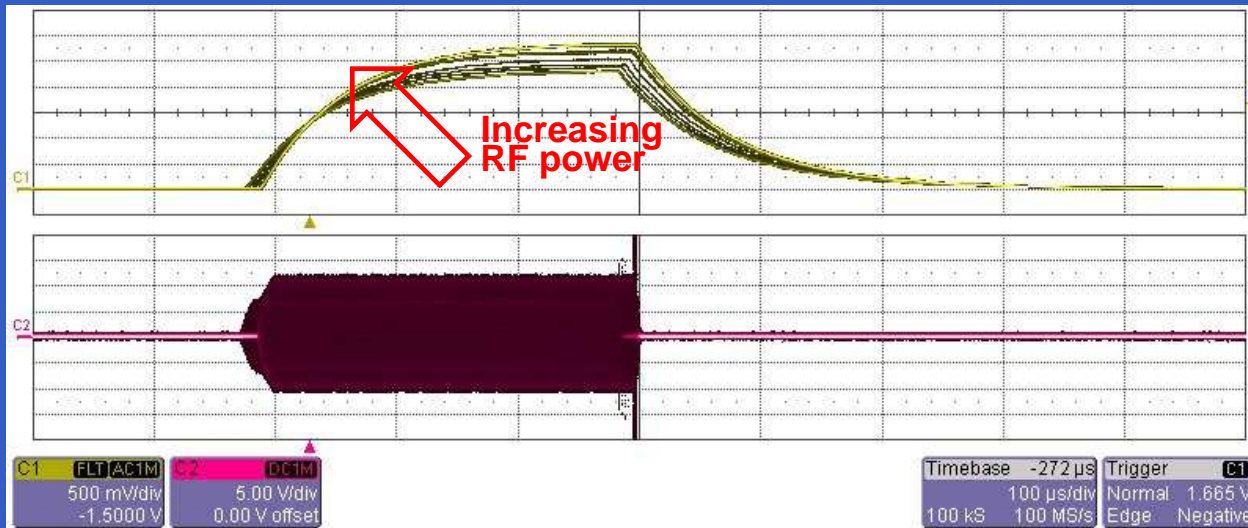
- Faraday's cup after the LRFQ
- Beam intensity signals (persistence option on the oscill.) vs. RF power (from 4.5kW to 15kW)
- Focusing effect present!
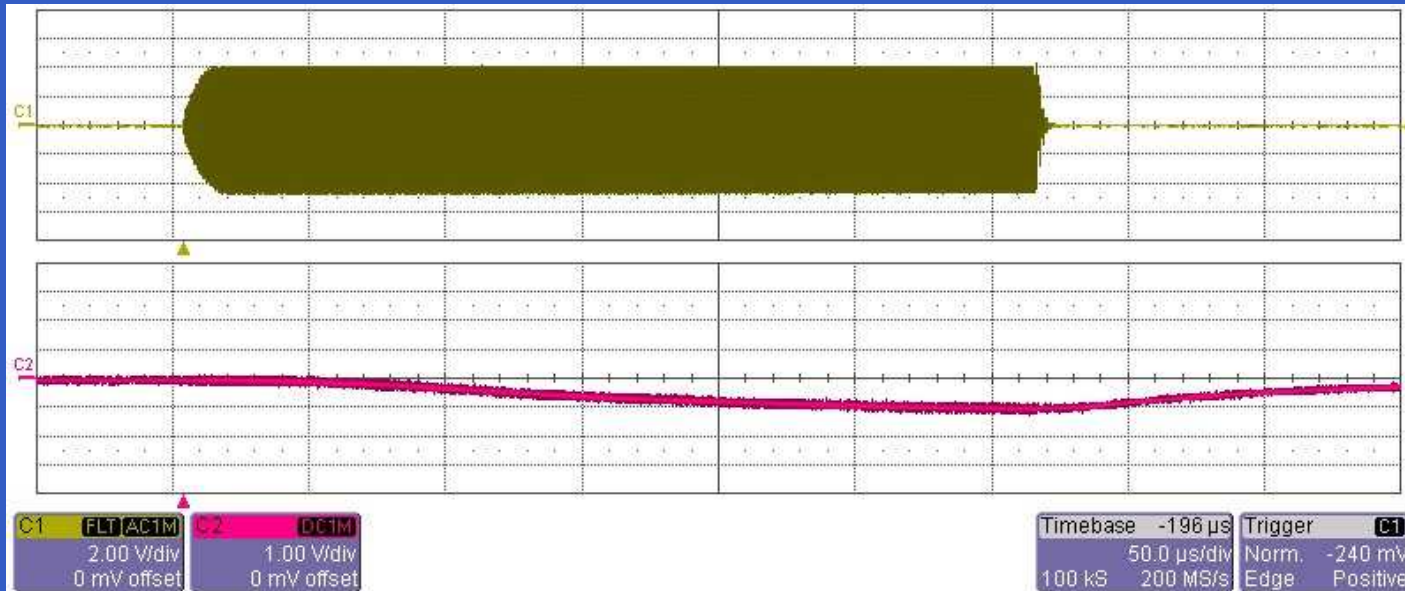
RF induced electrons

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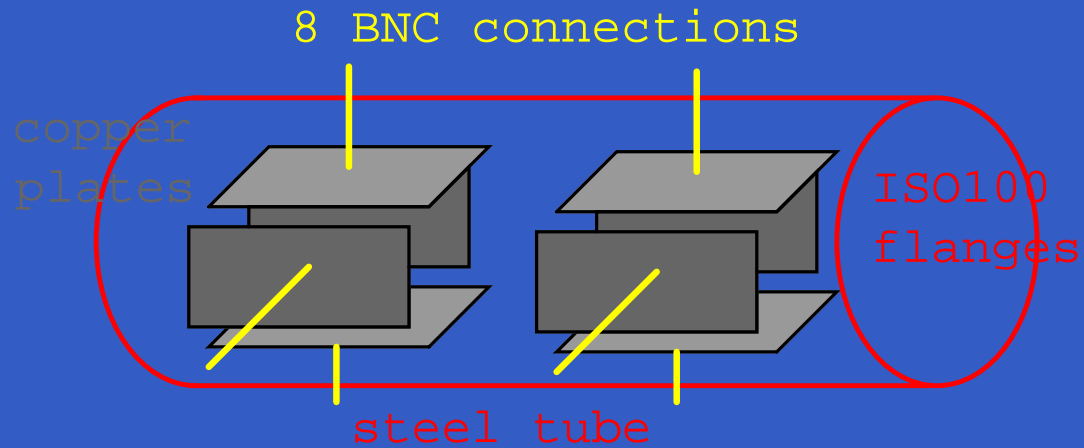- a dc shield (700V) before the cup reduces the effect

Conclusions and foreseen

- the CRFQ is a new type of circular accelerators

- a collaboration for the bending principle proof is going on

- about the linear sector:

  - a cold model has been built and tested

  - the hot model has been built and tested

  - the first beam tests has been done, more tests in the next months

- the first curved sector is going to be built in the next months

References

- A. Ruggiero, BNL-AP-65 note, 2001

- CRFQ02 workshop final relation, Benevento, Italy, October 2002

- L. Campajola, D. Davino, M.R. Masullo, A.G. Ruggiero, V.G. Vaccaro, RF excitation of linear and curved sections of the CRFQ project, EPAC2004 Conference (MOPLT055), Luzern.

- L. Campajola, D. Davino, M.R. Masullo, A.G. Ruggiero, V.G. Vaccaro, A practical demonstration of the CRFQ Storage Ring, EPAC2004 Conference (MOPLT071), Luzern.

Diagnostic box design
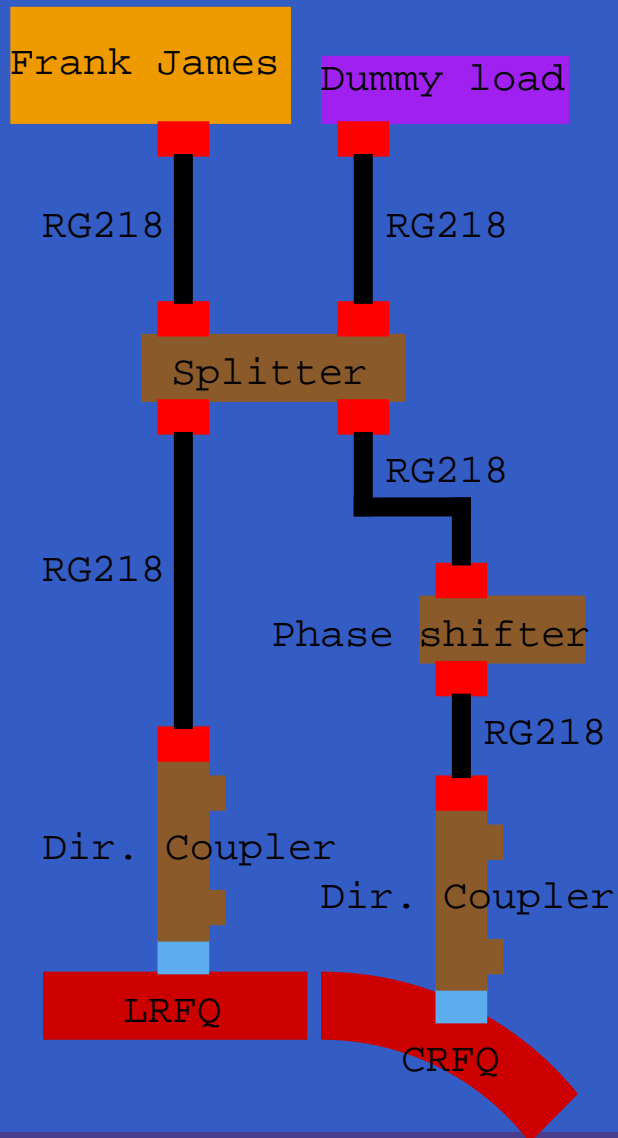
8 BNC connections

copper
plates

ISO100
flanges

steel tube

RF diagram

RF power source

- *Frank James* amplifier from CERN (M. Vretenar)
- Pulsed 50 kW (2 Hz max, 1 msec), f0=202.56MHz
- 3 racks (amplifier, high voltage, low level)

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