Schottky Resonators for CR

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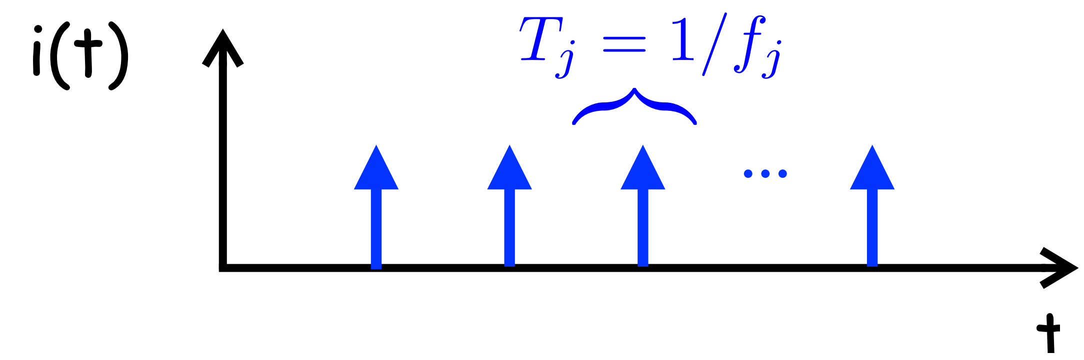
GSI Helmholtzzentrum für Schwerionenforschung

BINP Workshop
2014-12-02, Darmstadt

Overview

- Short introduction about Schottky diagnostics
- The ESR Resonator as a prototype for CR
- Introduce some pilot designs for CR
- New approaches for transversal sensitivity
- Conclusion

Schottky signals

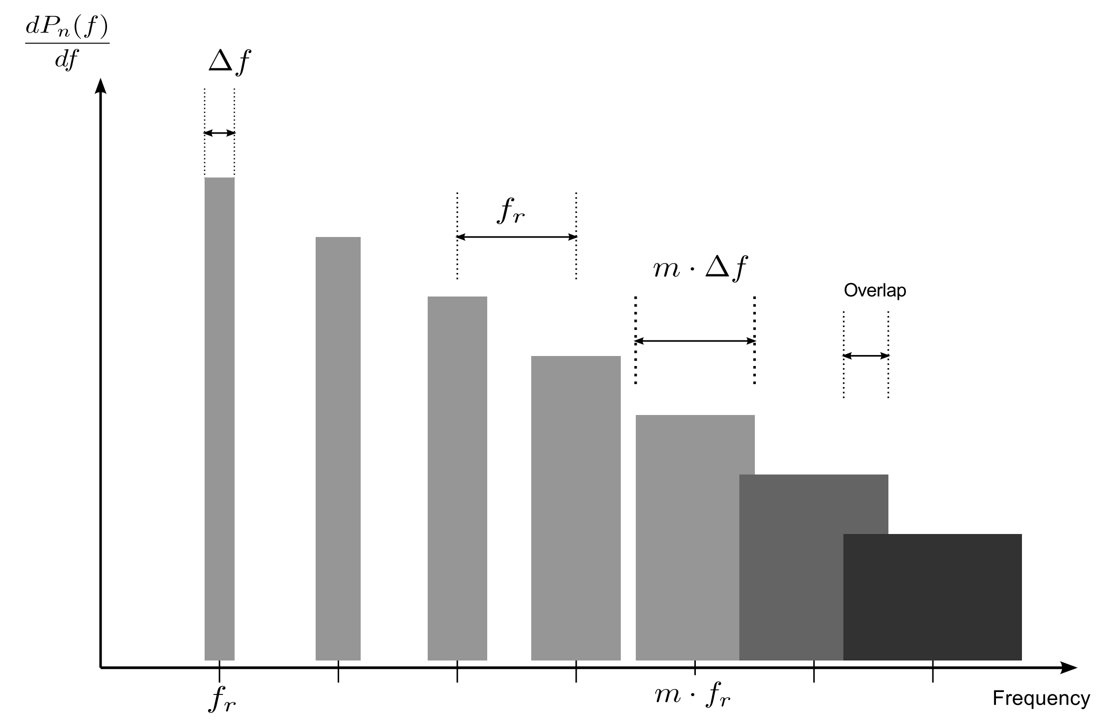


- 2nd order moment function (power)

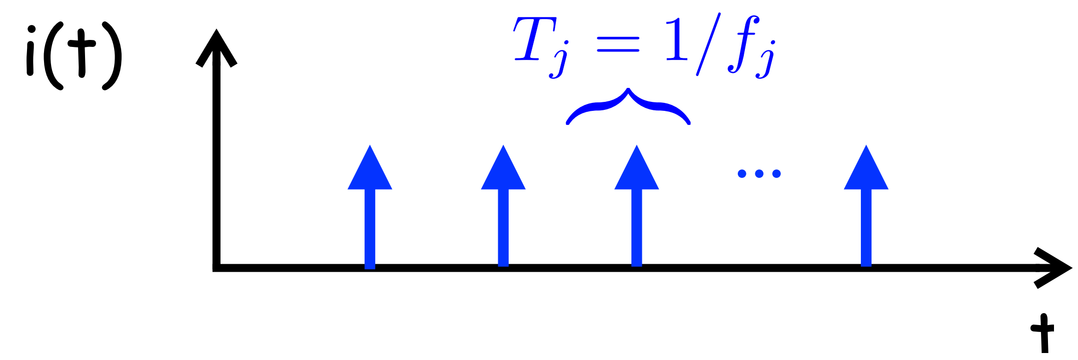
$$r_{ii}(t+\tau,t) = \cdots$$

$$= (Ze)^2 f_r^2 N^2 + 2(Ze)^2 f_r^2 \sum_{j=1}^{N} \sum_{m=1}^{\infty} \cos(m\omega_j \tau)$$

- Perform Fourier transformation
- Schottky "bands" on integer harmonics of f_r
- Total power in each band is equal



Schottky signals



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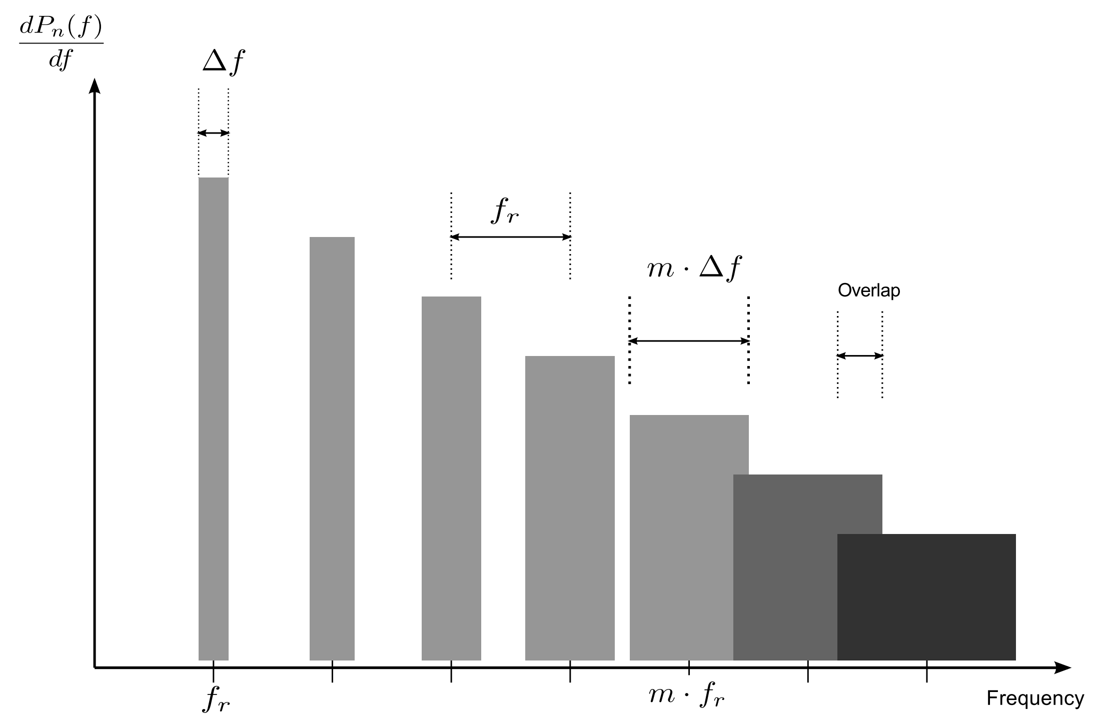


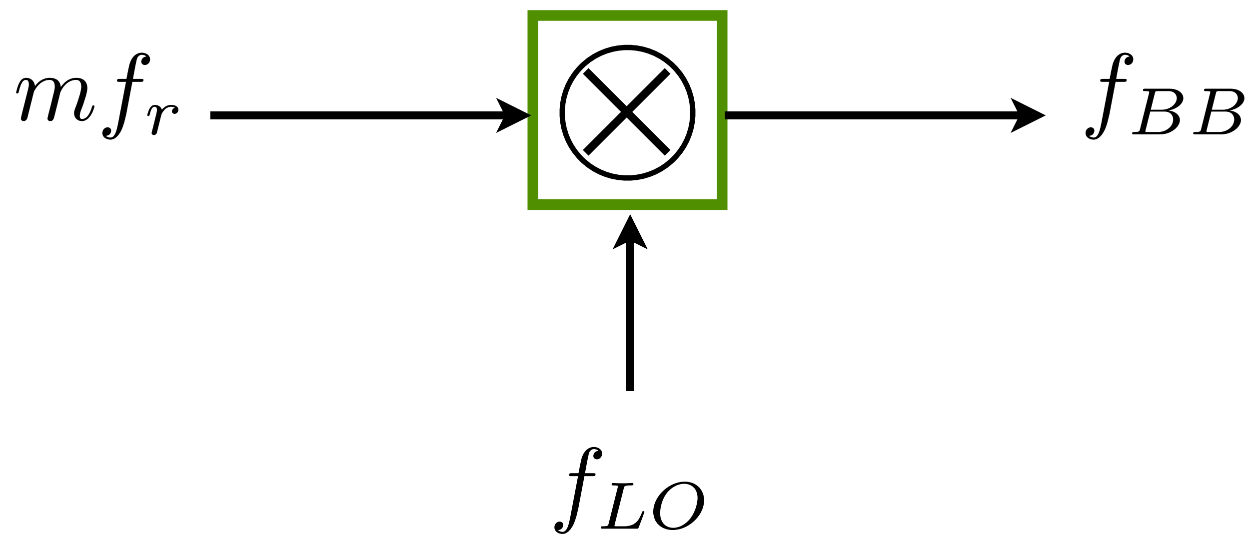
$$\langle \delta i_{||}^2 \rangle = 2(Ze)^2 f_r^2 N = 2Zef_r I_{beam}$$

Can be used for beam intensity measurements

- Same information exists in every band

- At higher harmonics:
  - For a given Δf or Δ(m/q)
    - Shorter recording time
  - For a given Δt
    - Higher frequency (or m/q) resolution

- Mixing into base band needed:



$$\frac{\Delta f}{f_r} = \frac{m\Delta f}{mf_r} < \frac{m\Delta f}{f_{BB}}$$

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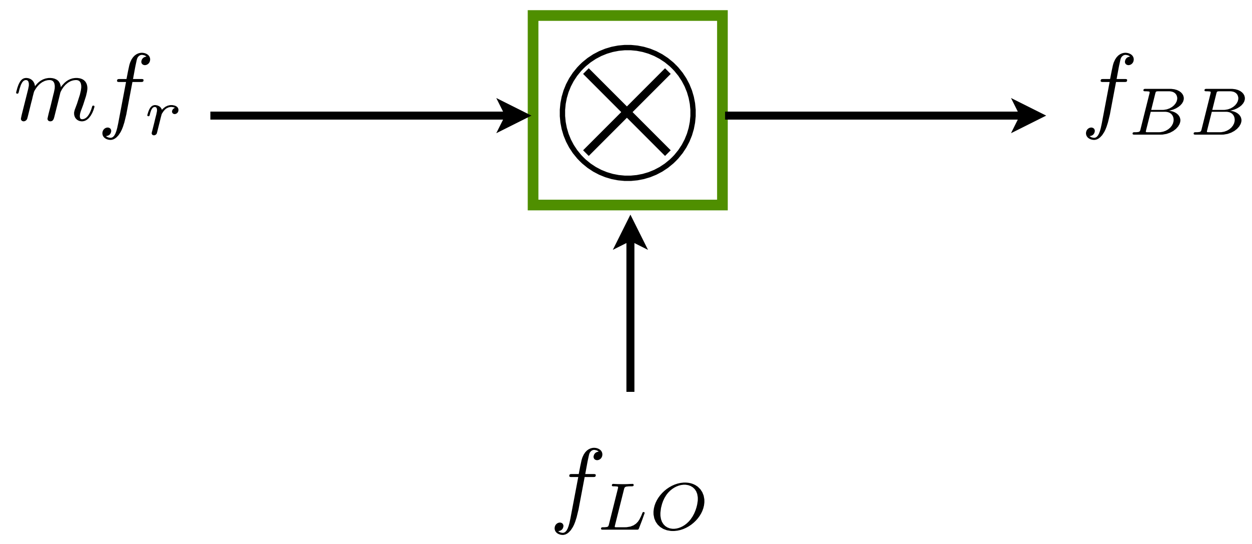
Mass and lifetime measurements!

- Mixing into base band needed:



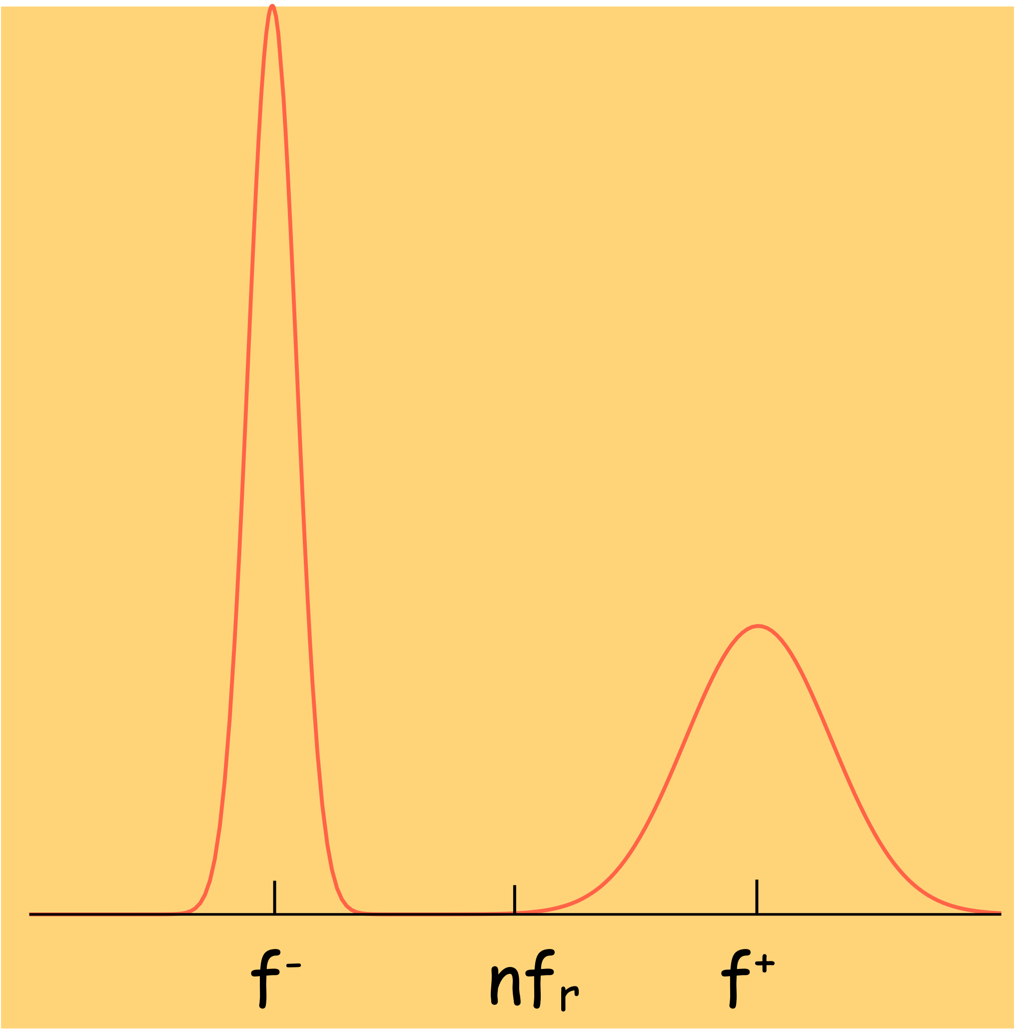
$$\frac{\Delta f}{f_r} = \frac{m\Delta f}{mf_r} < \frac{m\Delta f}{f_{BB}}$$

Transversal signals

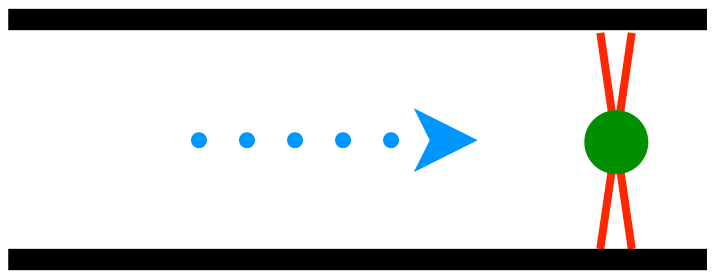
- Similar to long. case
  - Additionally modulated by the betatron motion

$$x_j(t) = a_j \cos(Q\omega_j t + \phi_j^0)$$

- Upper and lower Schottky sidebands
- Info on: Tune, Chromaticity, transverse beam size etc.



Resonant Pick-ups

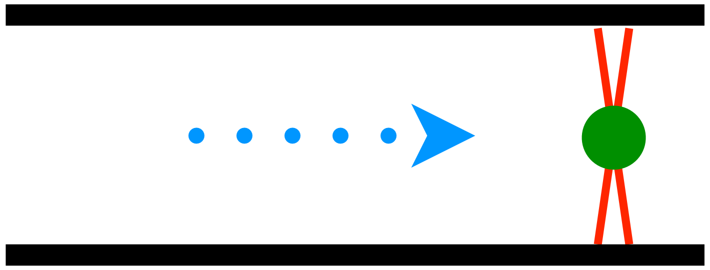


- 1st Approach: Parallel plates
  - Mirror charge density
  - Primary fields
  - Nearly flat frequency response

  - Example: ESR Pickup since 1990

Photo: A. Zschau

Resonant Pick-ups



- 1st Approach: Parallel plates
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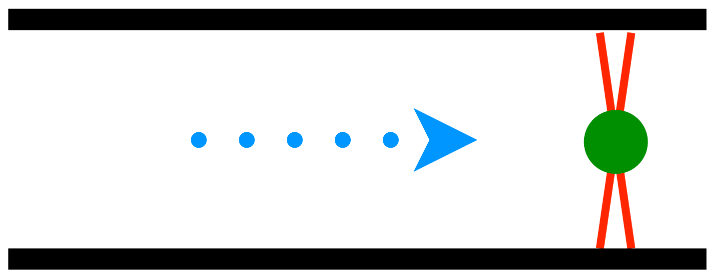
  - Example: ESR Pickup since 1990
- 2nd approach: From plates to cavity
  - Trapped fields (wake fields)
    - Damped oscillation

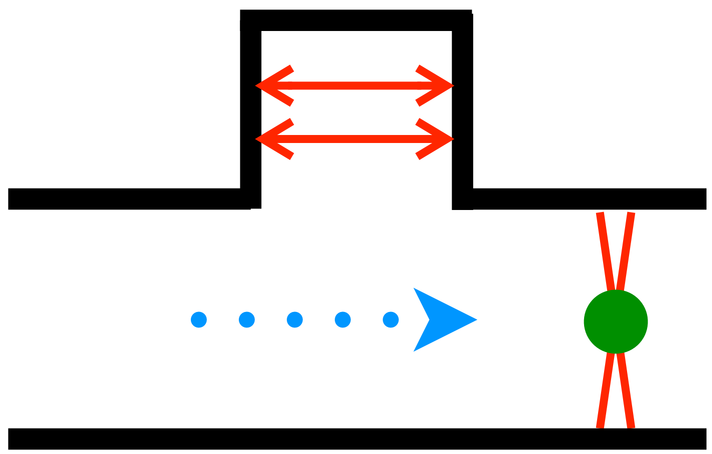
  - Constitute different:

    - Resonant modes
    - Frequencies
    - Patterns
    - Surface currents

Photo: A. Zschau

Resonant Pick-ups





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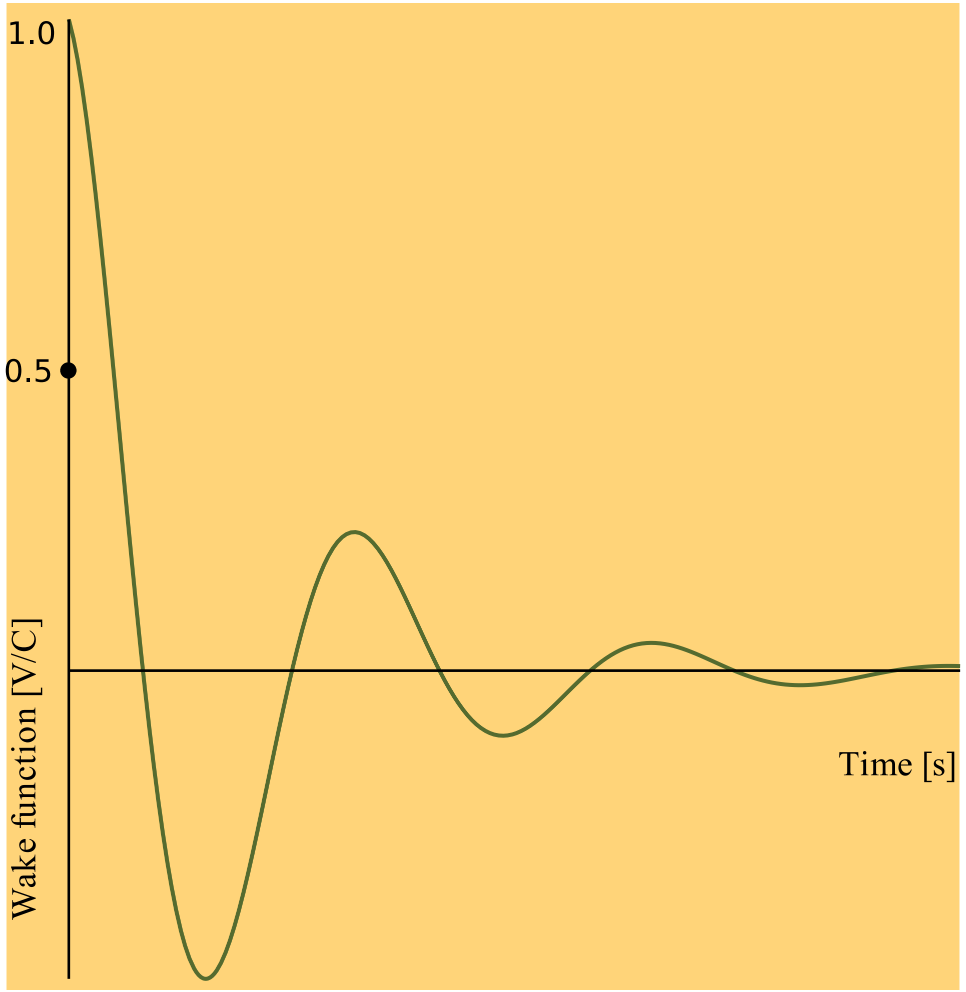
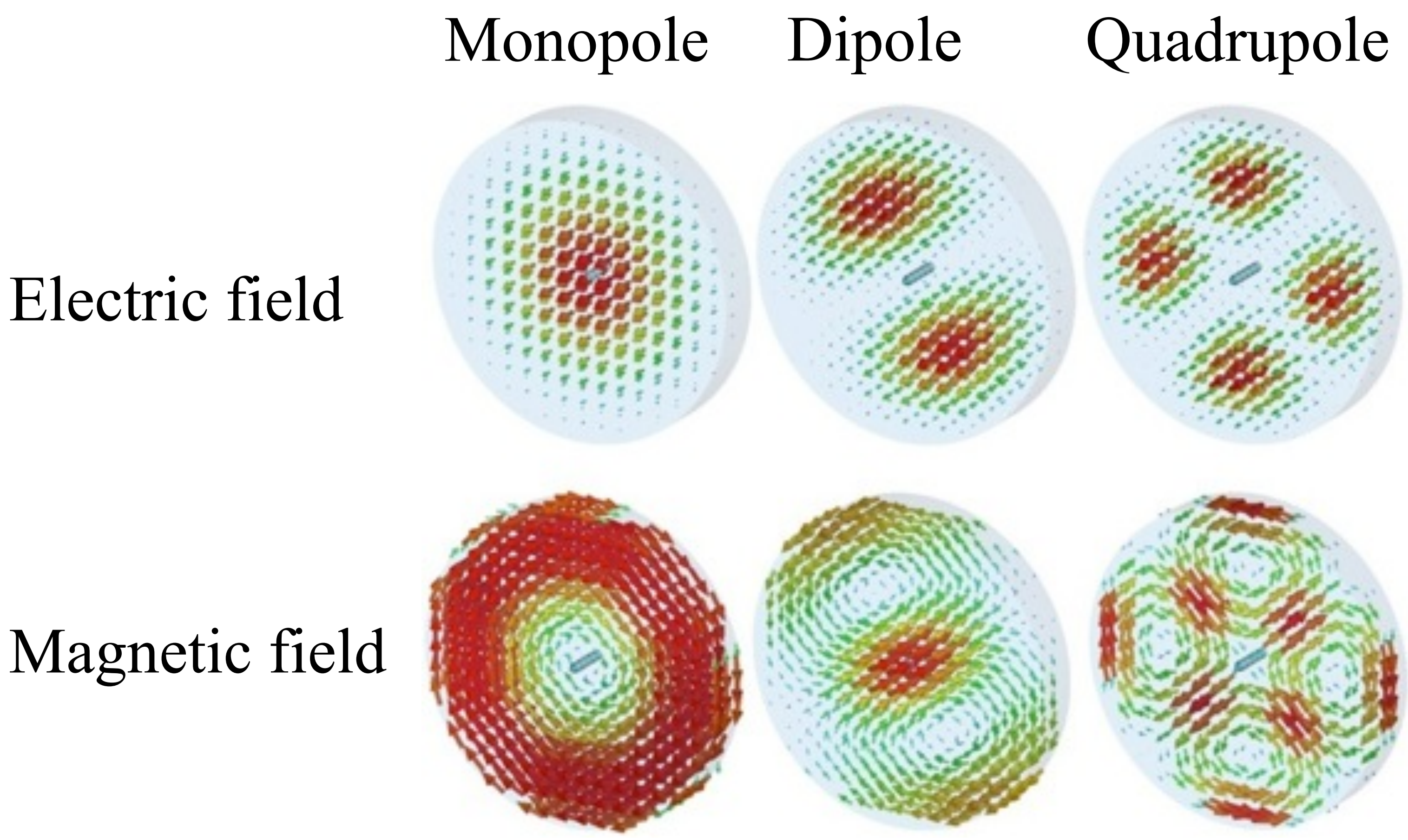
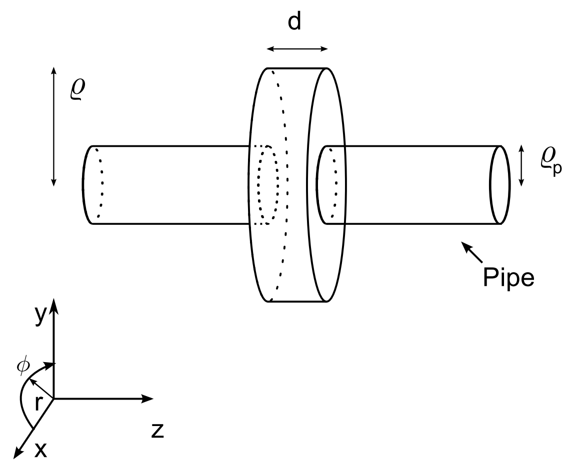
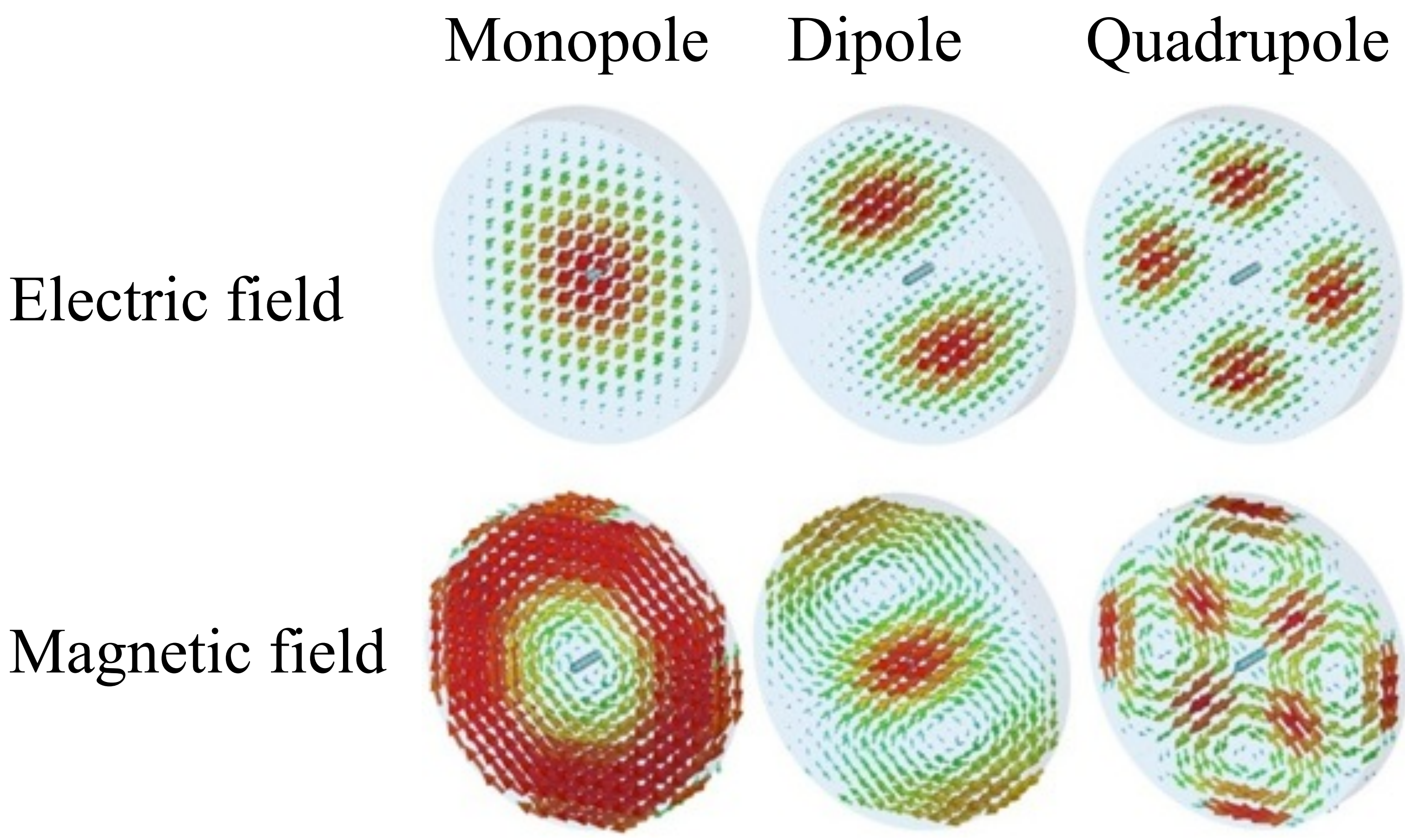


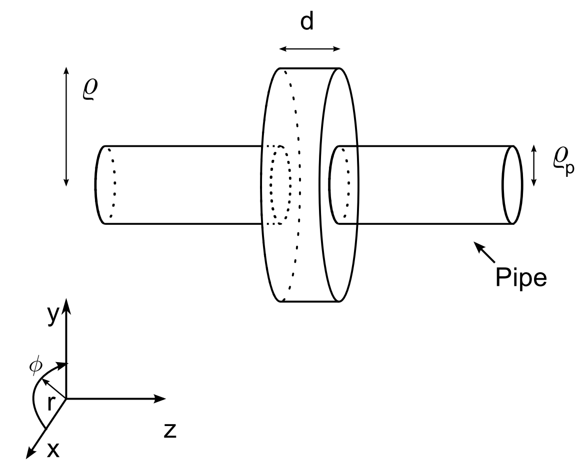
First modes of a pillbox cavity





- First modes of a pillbox cavity



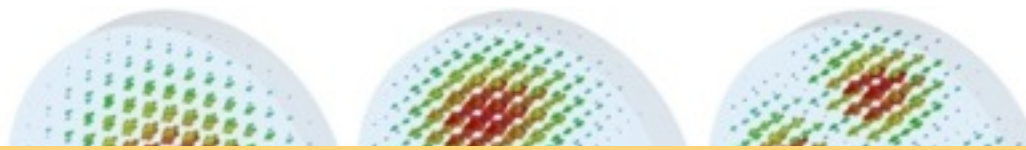


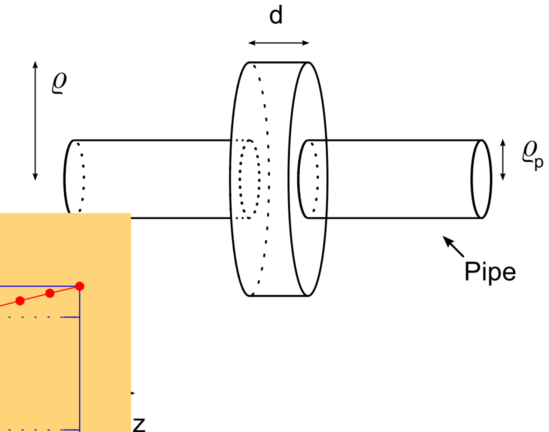
$$\left(\frac{R_{sh}}{Q}\right)_\nu = \widehat{\left(\frac{R_{sh}}{Q}\right)_\nu} \Lambda_\nu(\beta)^2$$

$$\langle P_{out}\rangle|_{mf_r} = \langle P_{diss}\rangle|_{mf_r} = (Ze)^2 f_r^2 \widehat{R_{sh,\nu}} \Lambda(\beta)^2$$

First modes of a pillbox cavity

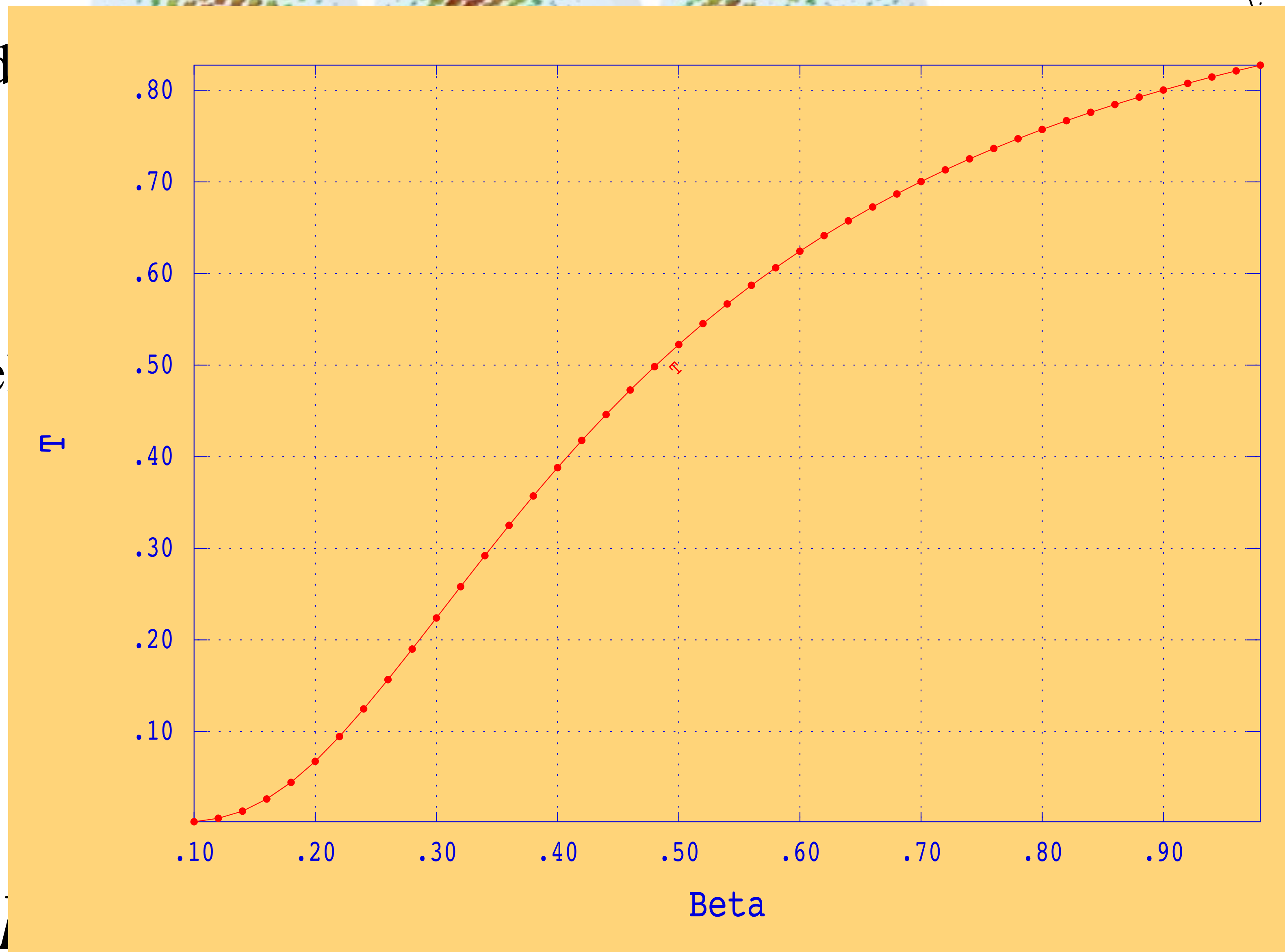
Monopole Dipole Quadrupole





Electric field

Magnetic fie



$$\nu = \widehat{\left(\frac{R_{sh}}{Q}\right)}_{\nu} \Lambda_{\nu}(\beta)^2$$

$$\langle \ldots {}_{,\nu}\ \Lambda(\beta)^2$$

The ESR Resonator

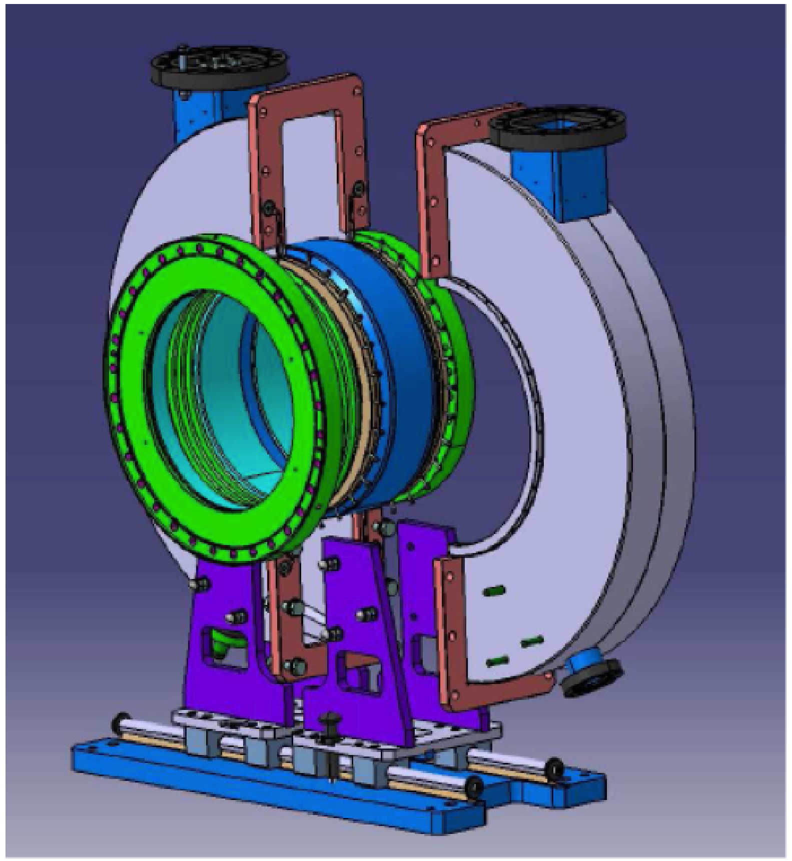


Photo: I. Schurig

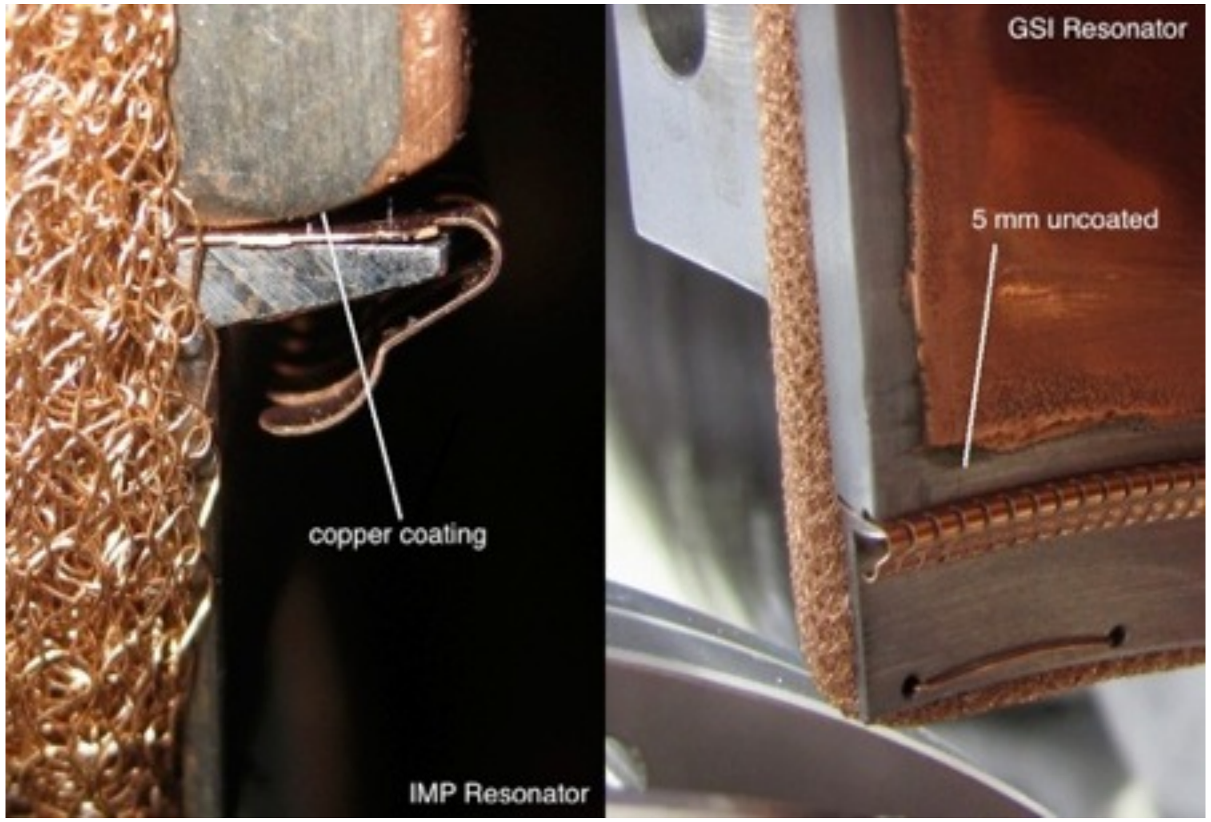
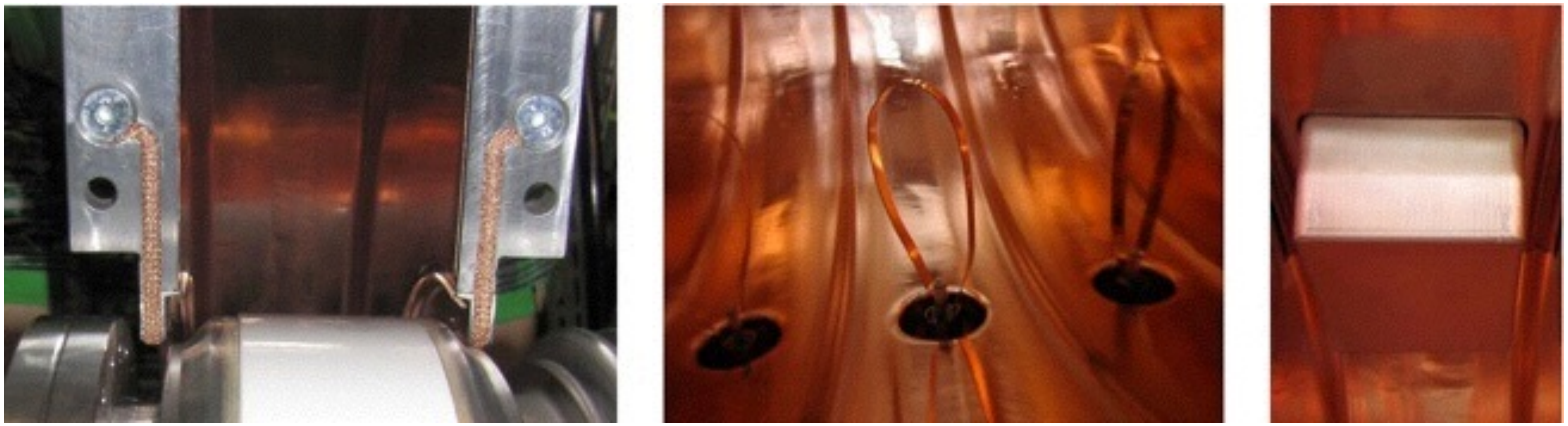


Photo: P. Petri 2009



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The ESR Resonator

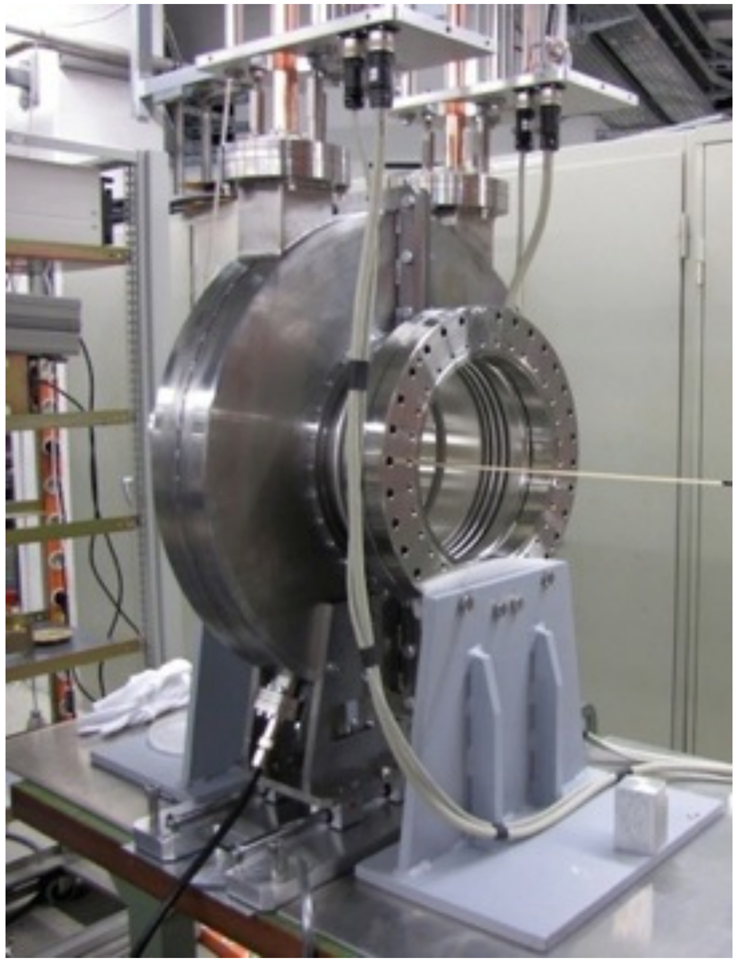
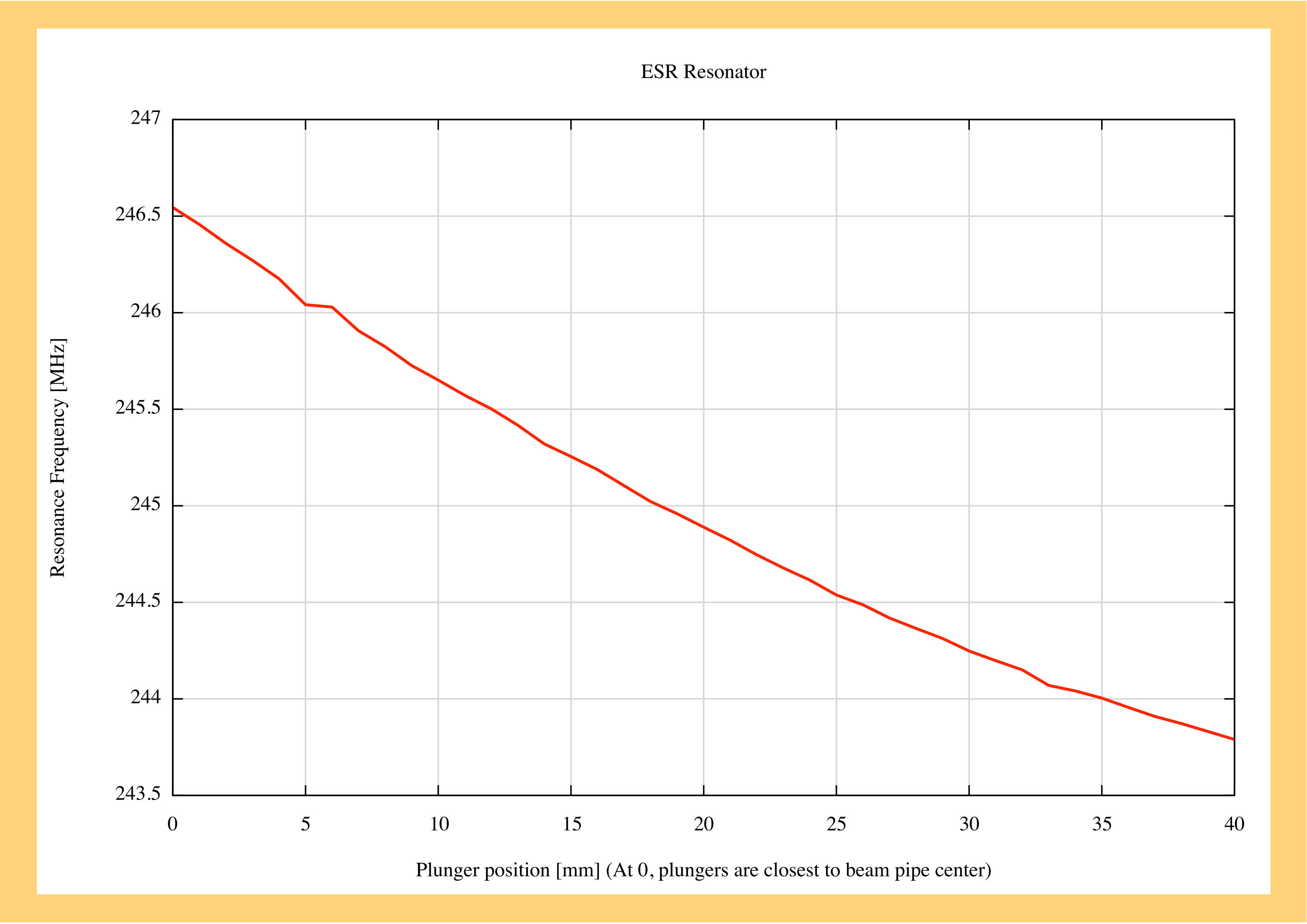
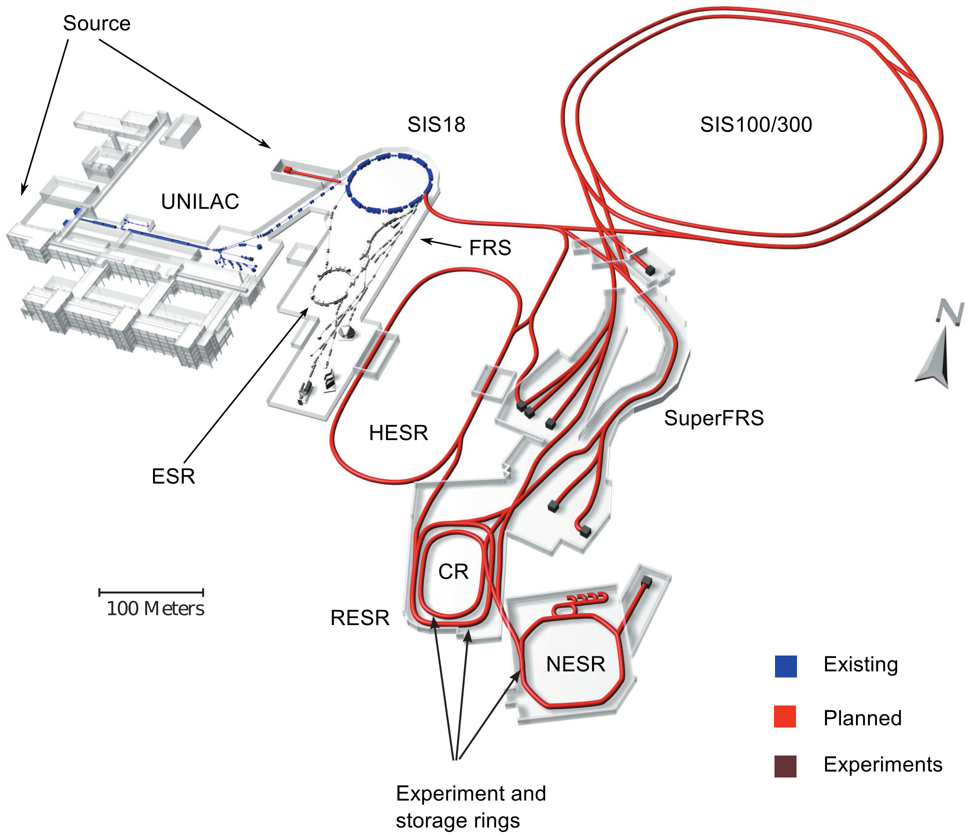


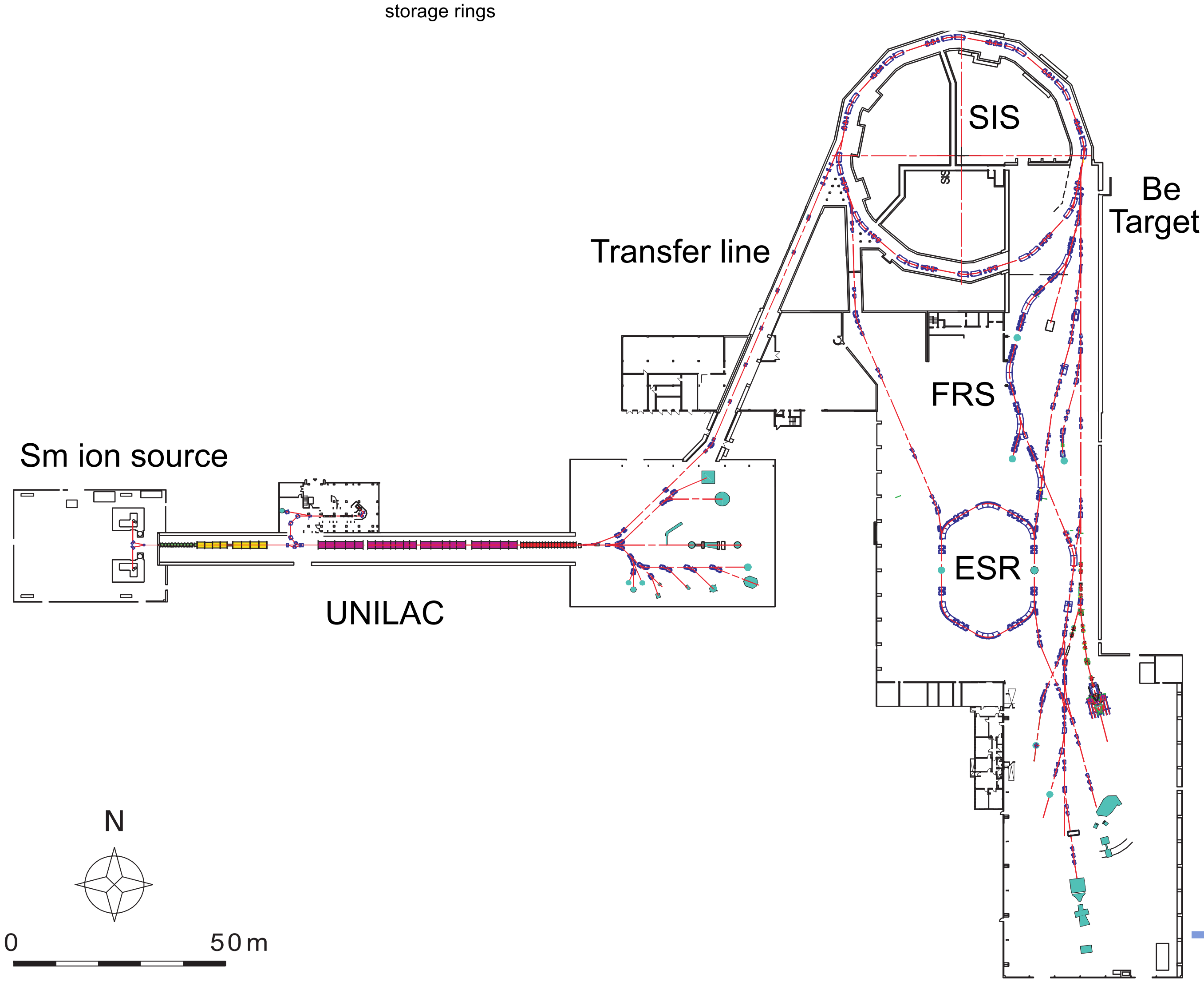
Photo: P. Petri 2009

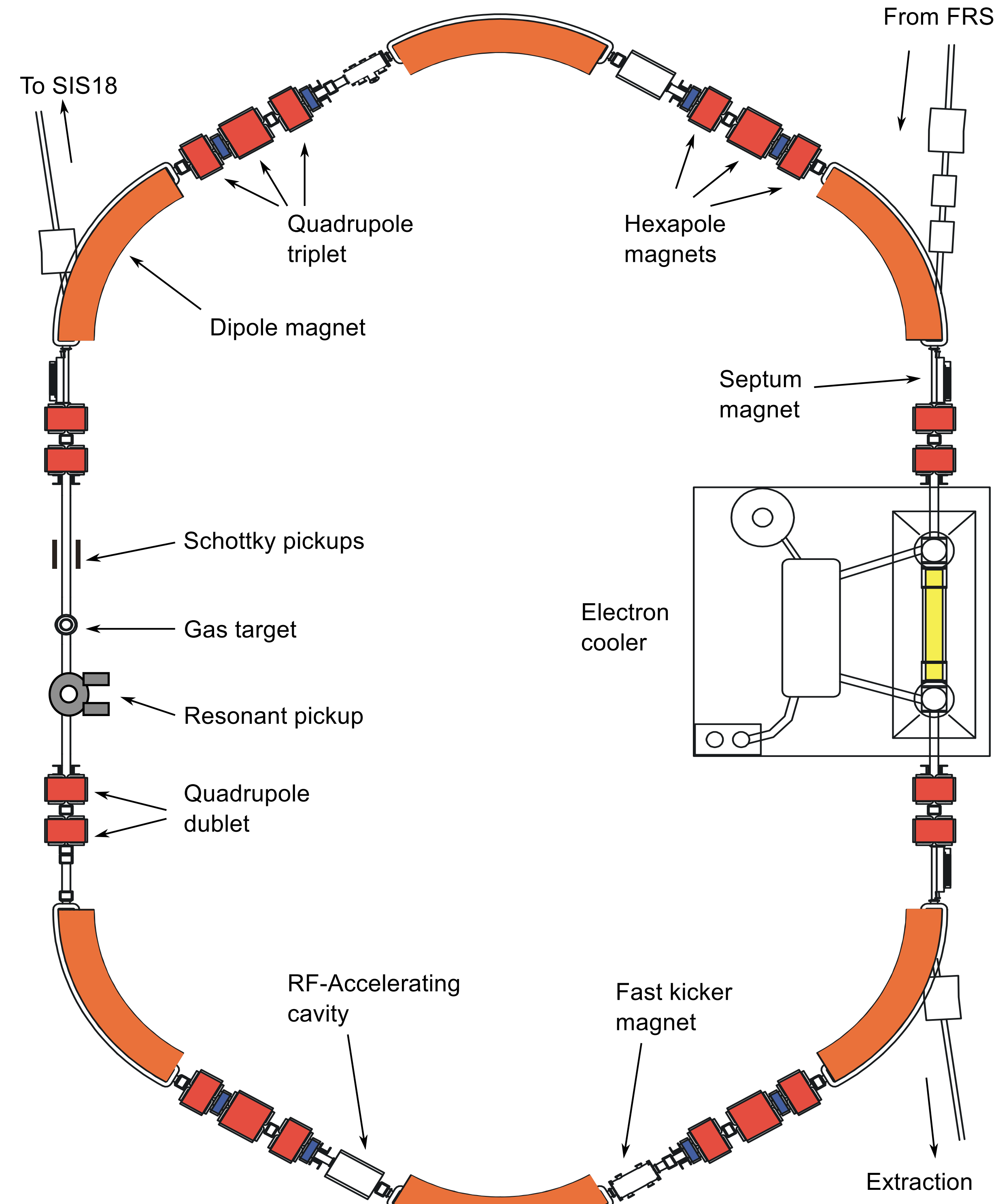
- Characteristics
  - f_0 = 245 MHz
  - Q_{loaded} ~ 510
  - R/Q ~ 42 Ω
  - Critical coupling
  - BW ~ 700 kHz

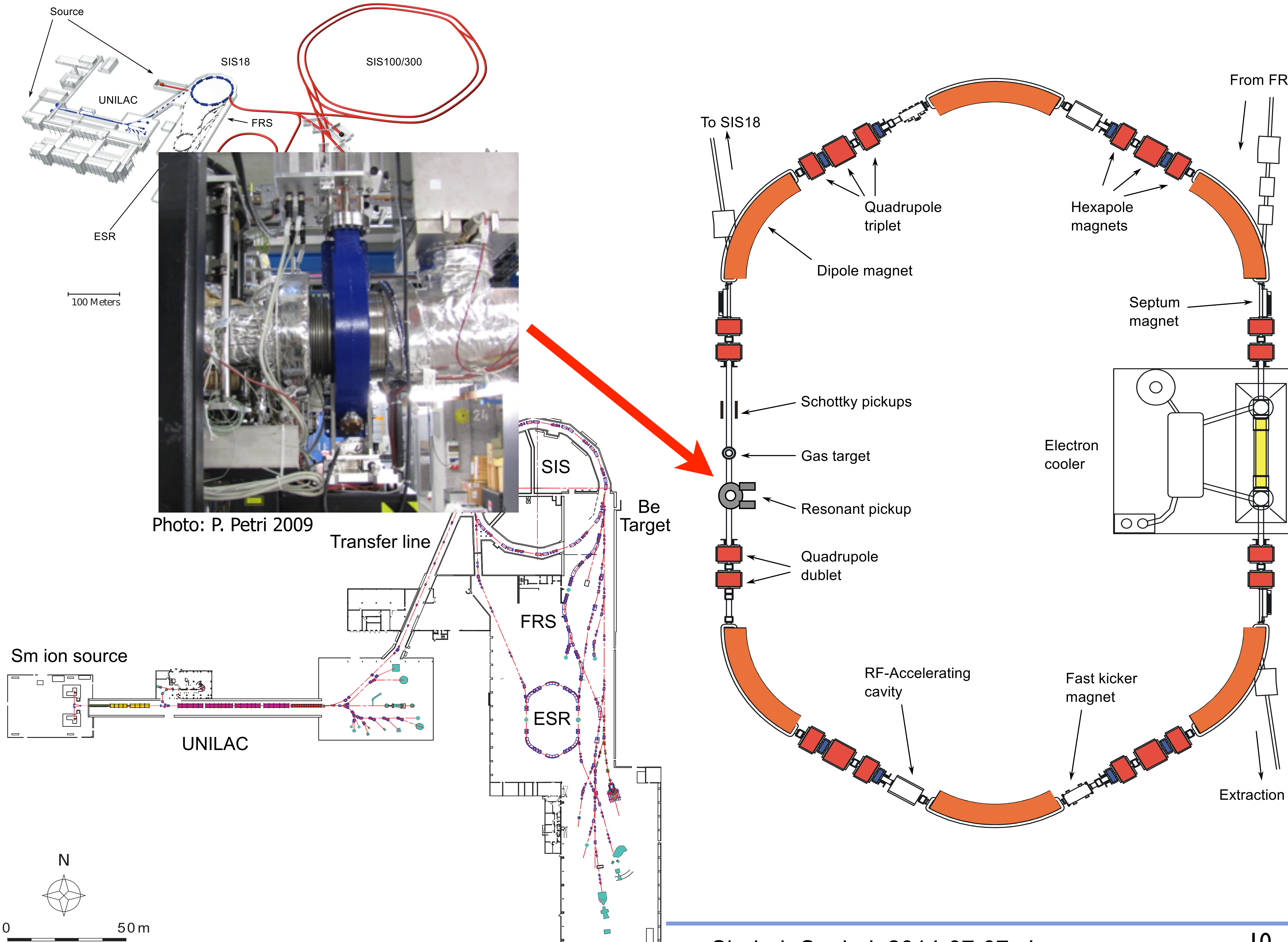


Freq. vs. Plunger


Source
SIS18
SIS100/300
UNILAC
FRS
ESR
HESR
SuperFRS
CR
RESR
NESR
100 Meters
Experiment and storage rings
Existing
Planned
Experiments
N


SIS
Be Target
Transfer line
FRS
Sm ion source
UNILAC
ESR
N
0
50 m


To SIS18
From FRS
Quadrupole triplet
Hexapole magnets
Dipole magnet
Septum magnet
Schottky pickups
Gas target
Resonant pickup
Electron cooler
Quadrupole dublet
RF-Accelerating cavity
Fast kicker magnet
Extraction


Source
SIS18
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Transfer line
SIS
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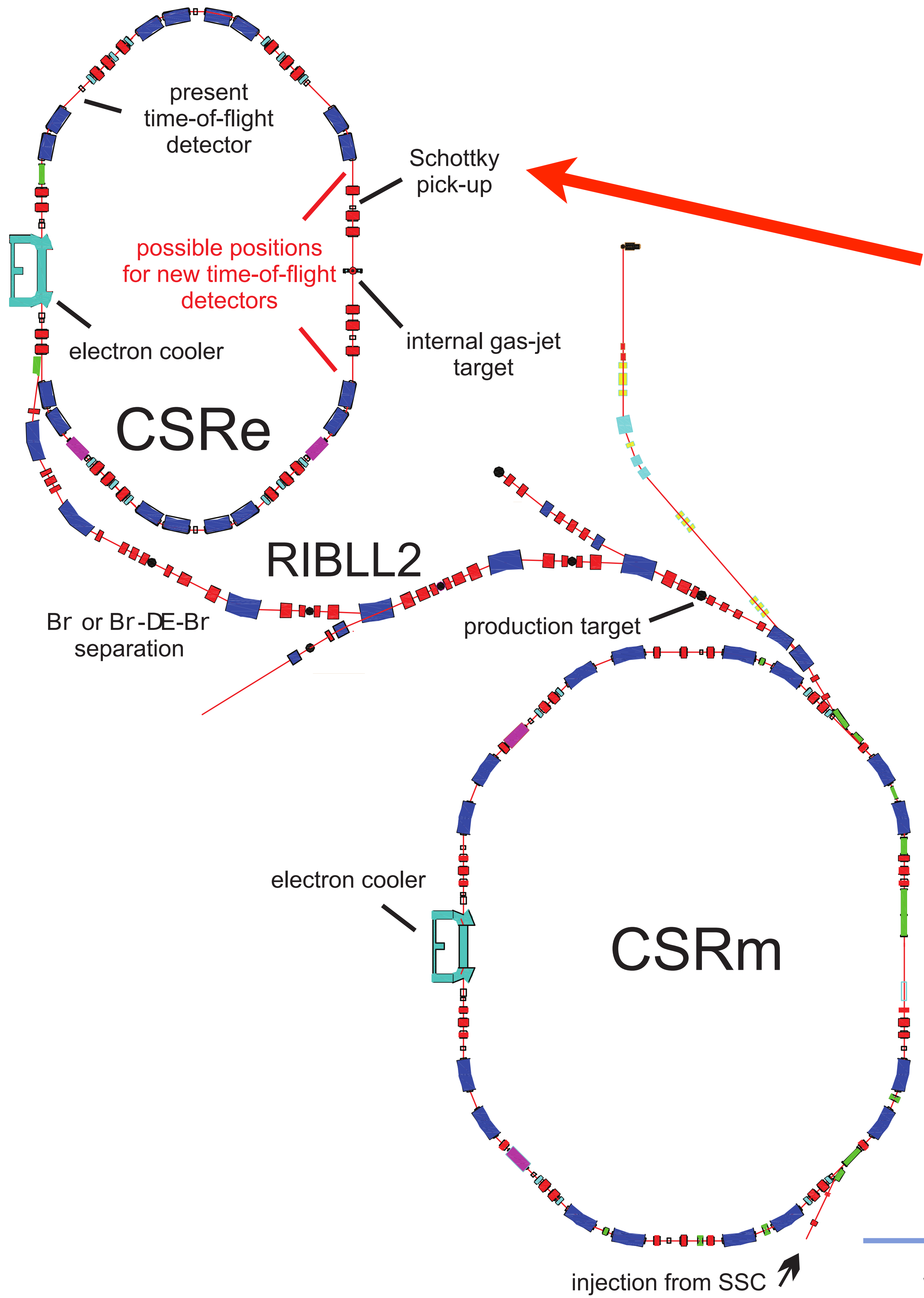
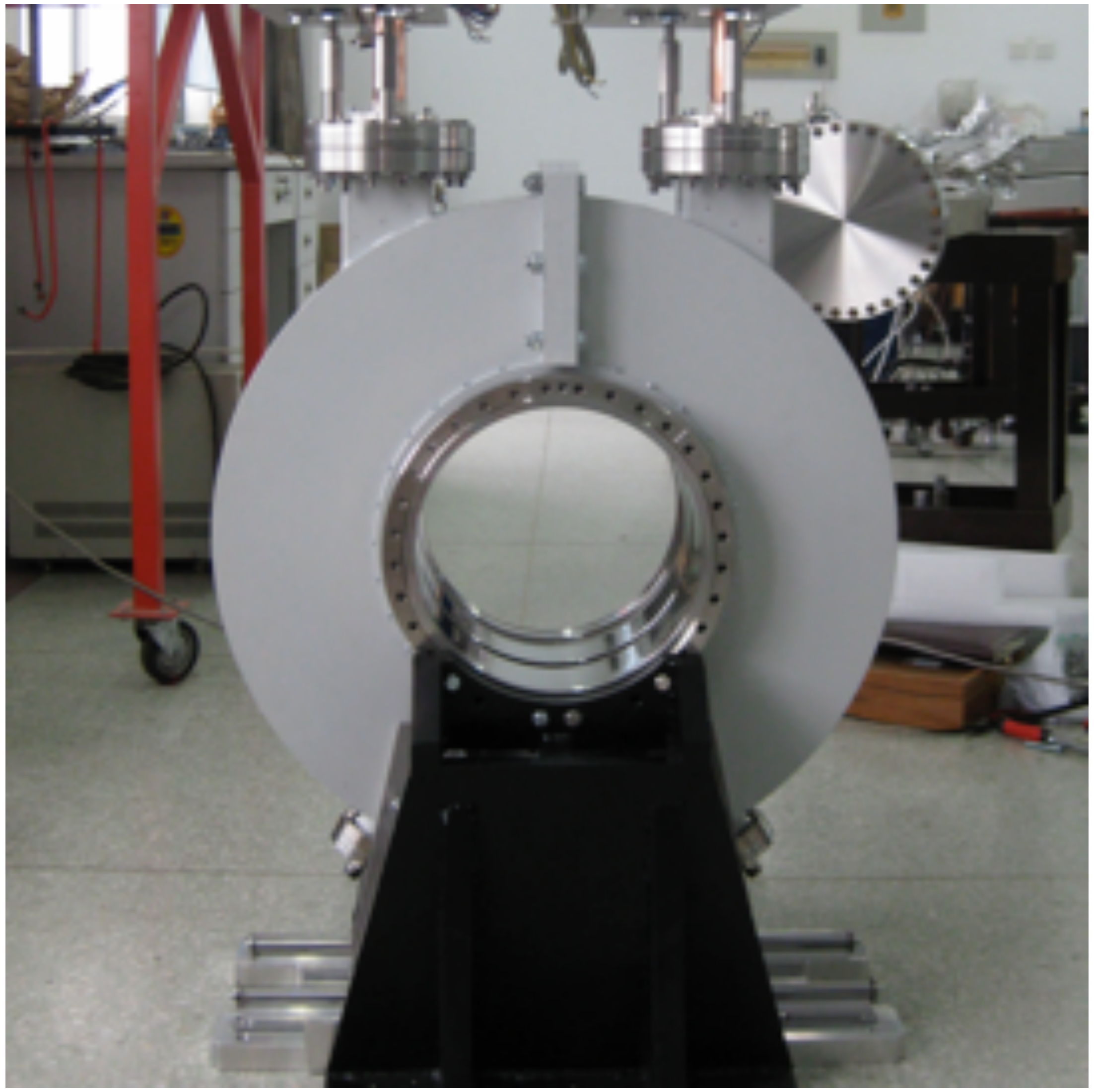
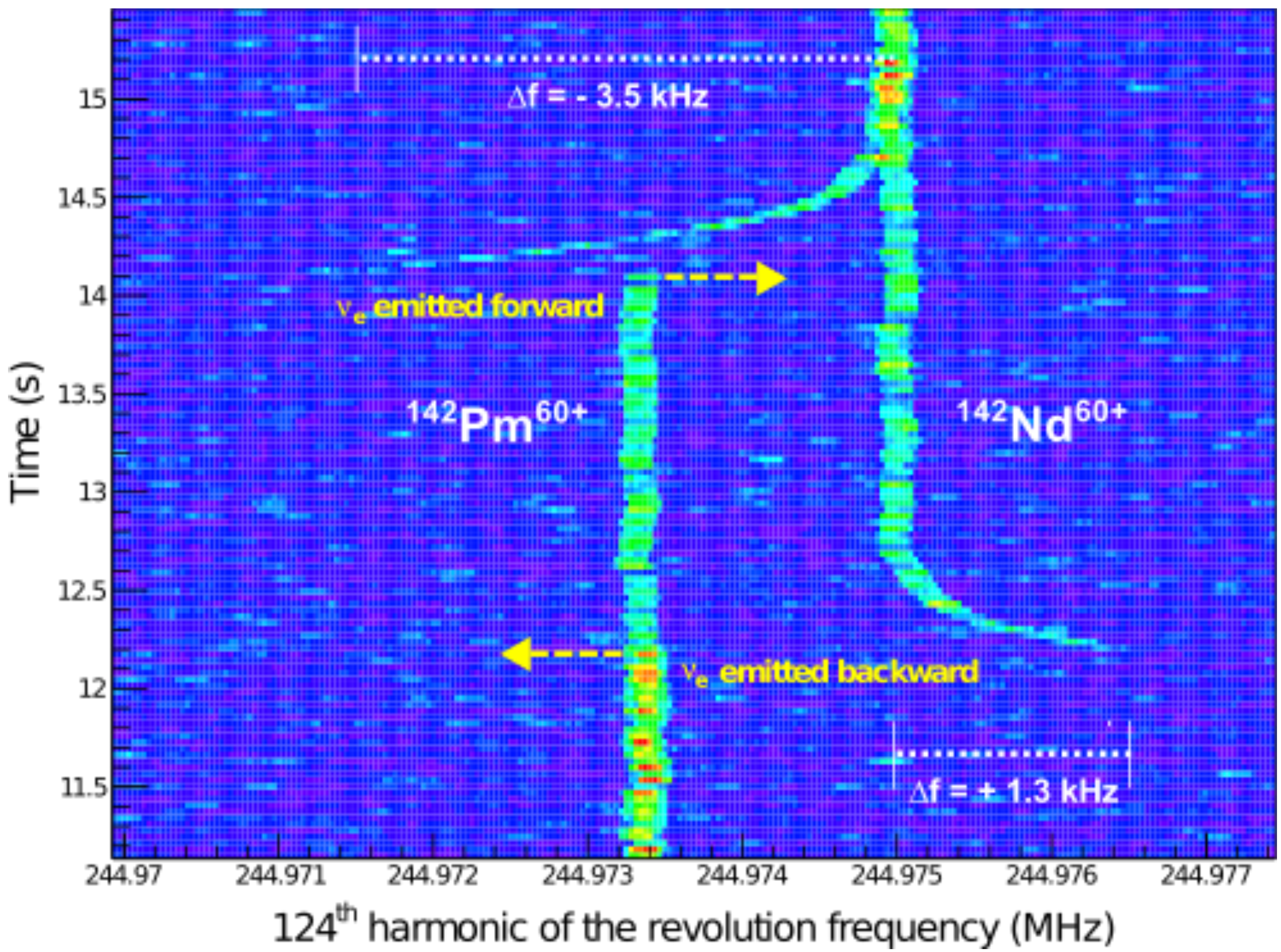
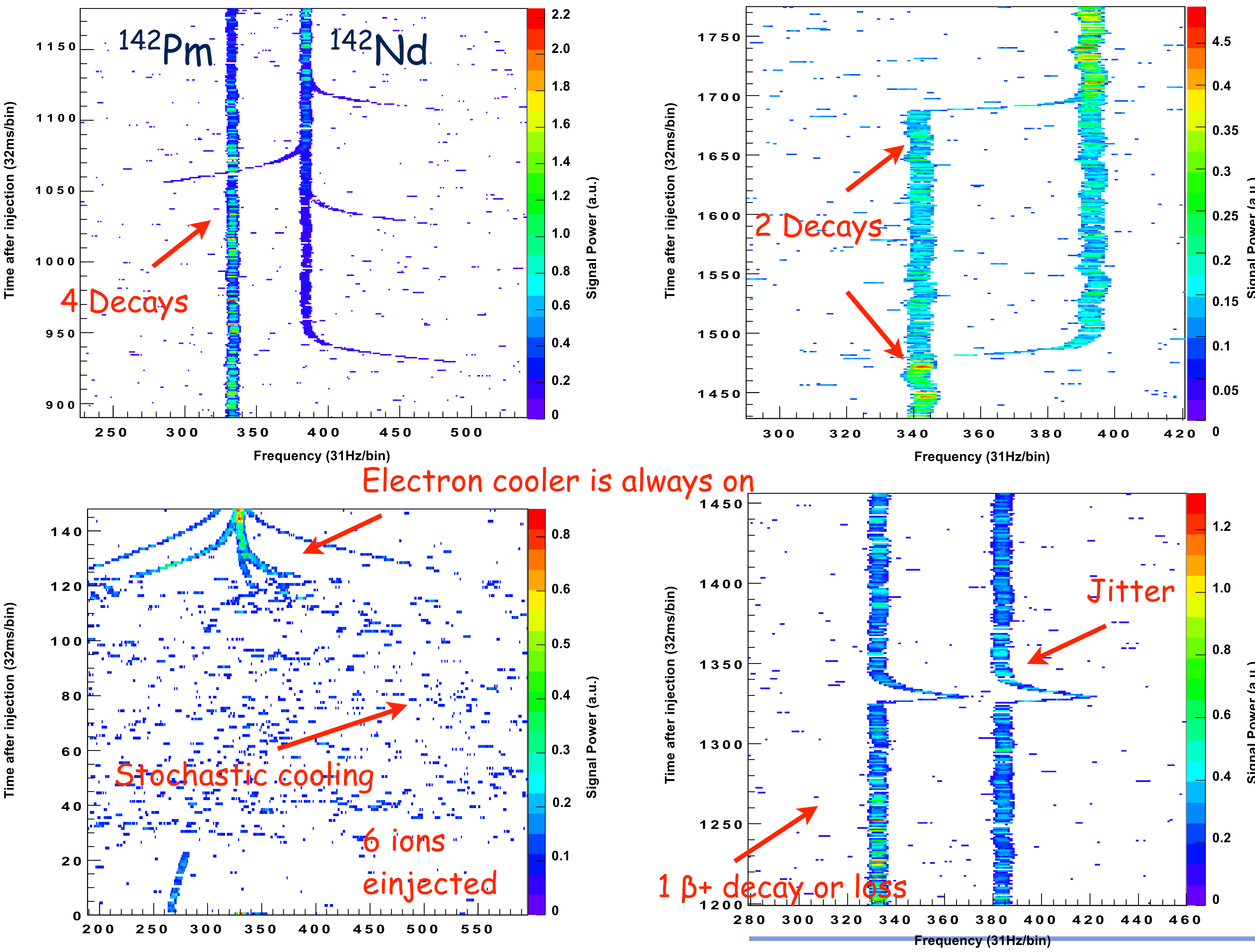

present
time-of-flight
detector
Schottky
pick-up
possible positions
for new time-of-flight
detectors
electron cooler
internal gas-jet
target
CSRe
RIBLL2
Br or Br-DE-Br
separation
production target
electron cooler
CSRm
injection from SSC



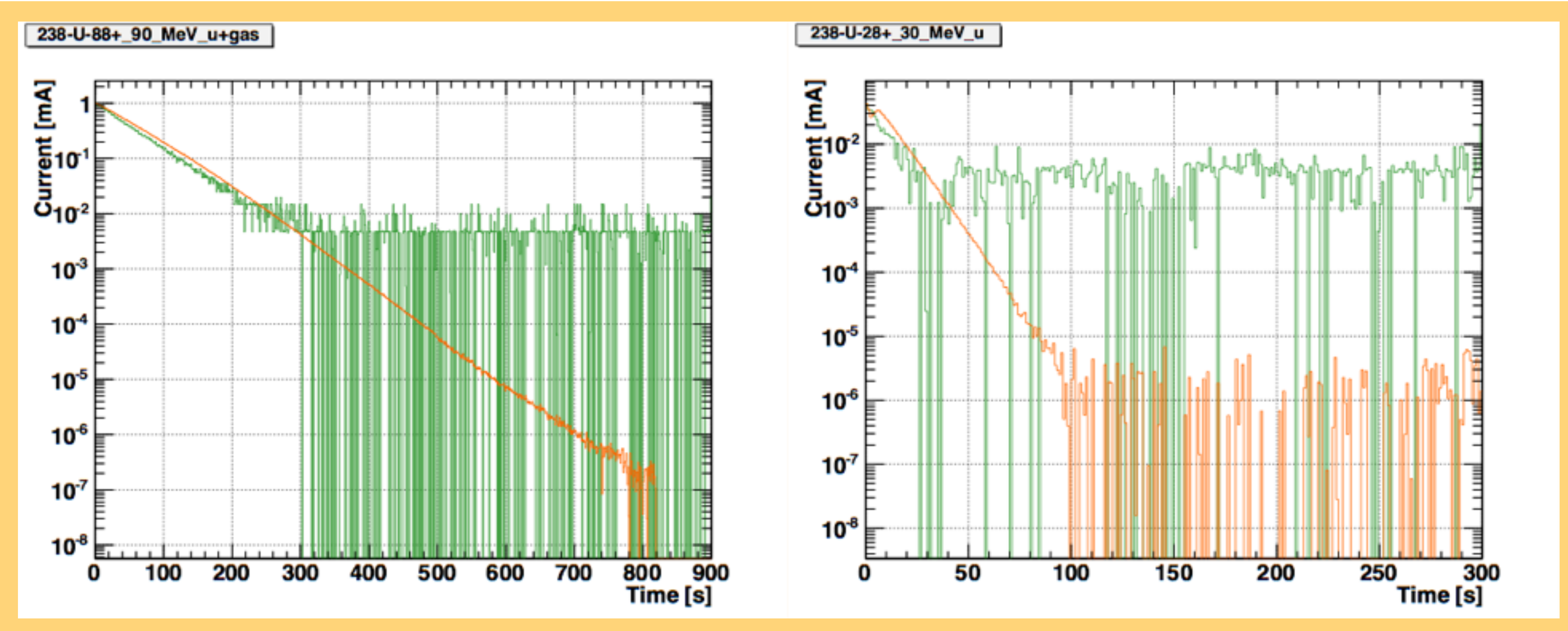


Source: Kienle, F. Bosch et. al., Phys. Lett. B 726 (2013) 4–5, p.638

Collage of different EC spectra ($^{142}Pm \rightarrow {}^{142}Nd + \nu_e$)



Beam intensity

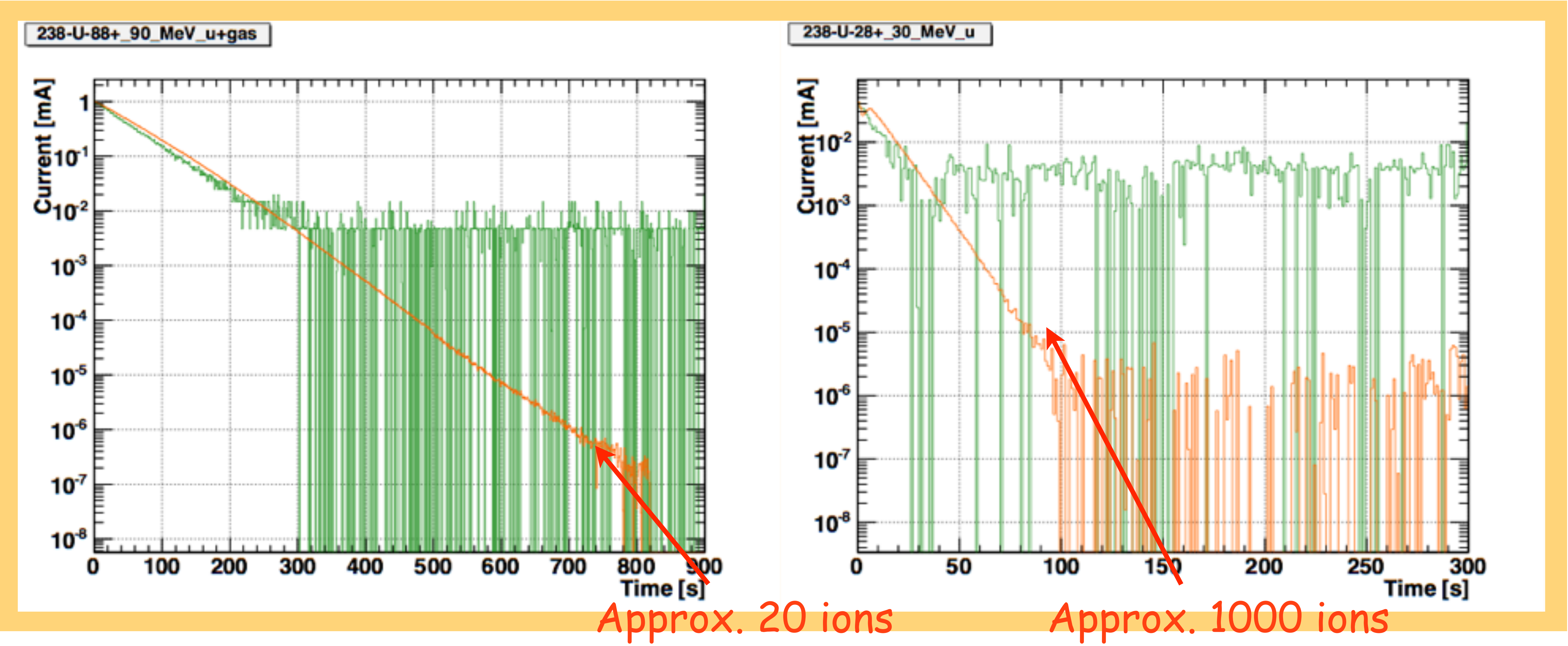


- Calibrate the integral Schottky power
  - using e.g. a DCCT

- Limited by DCCT error (±1μA)

- Test beams
  - Left: $^{238}U^{88+}$ with 90 MeV/u with N_2 Target
  - Right: $^{238}U^{28+}$ with 30 MeV/u

Beam intensity



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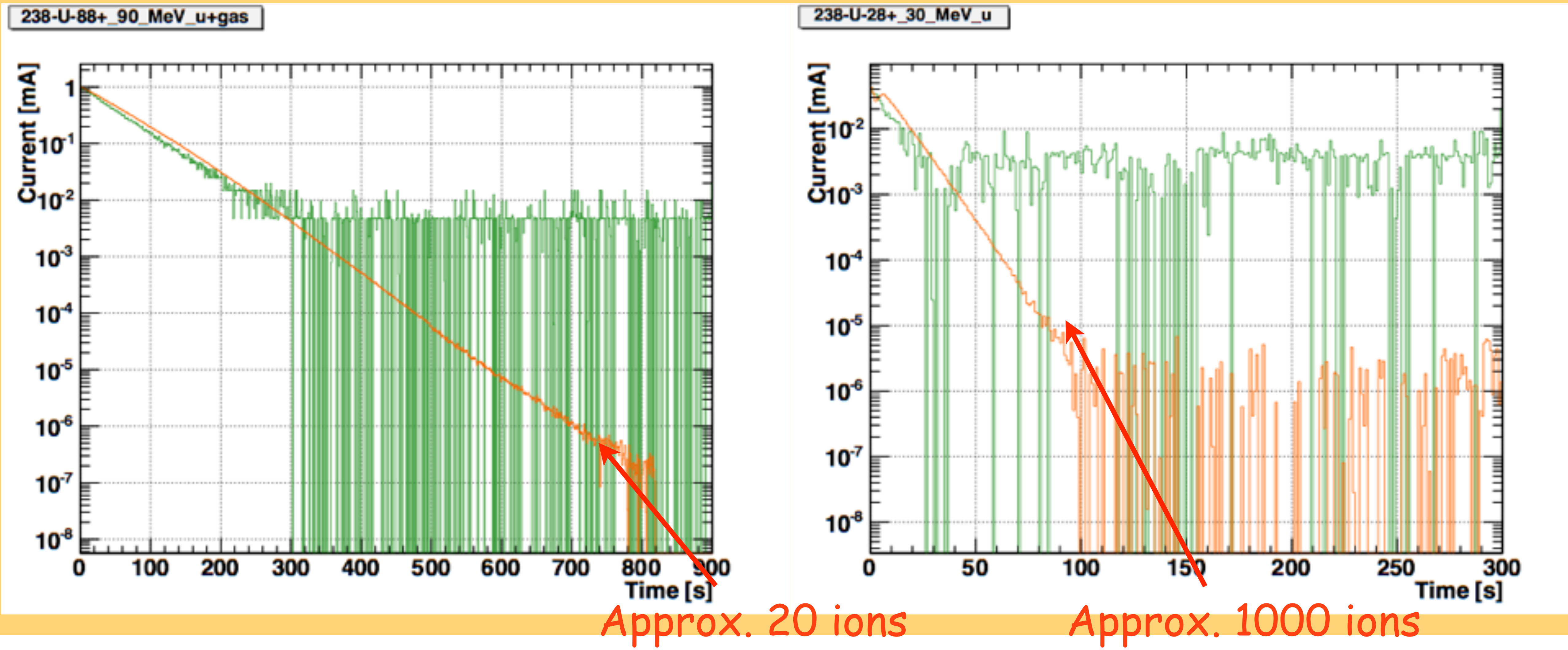

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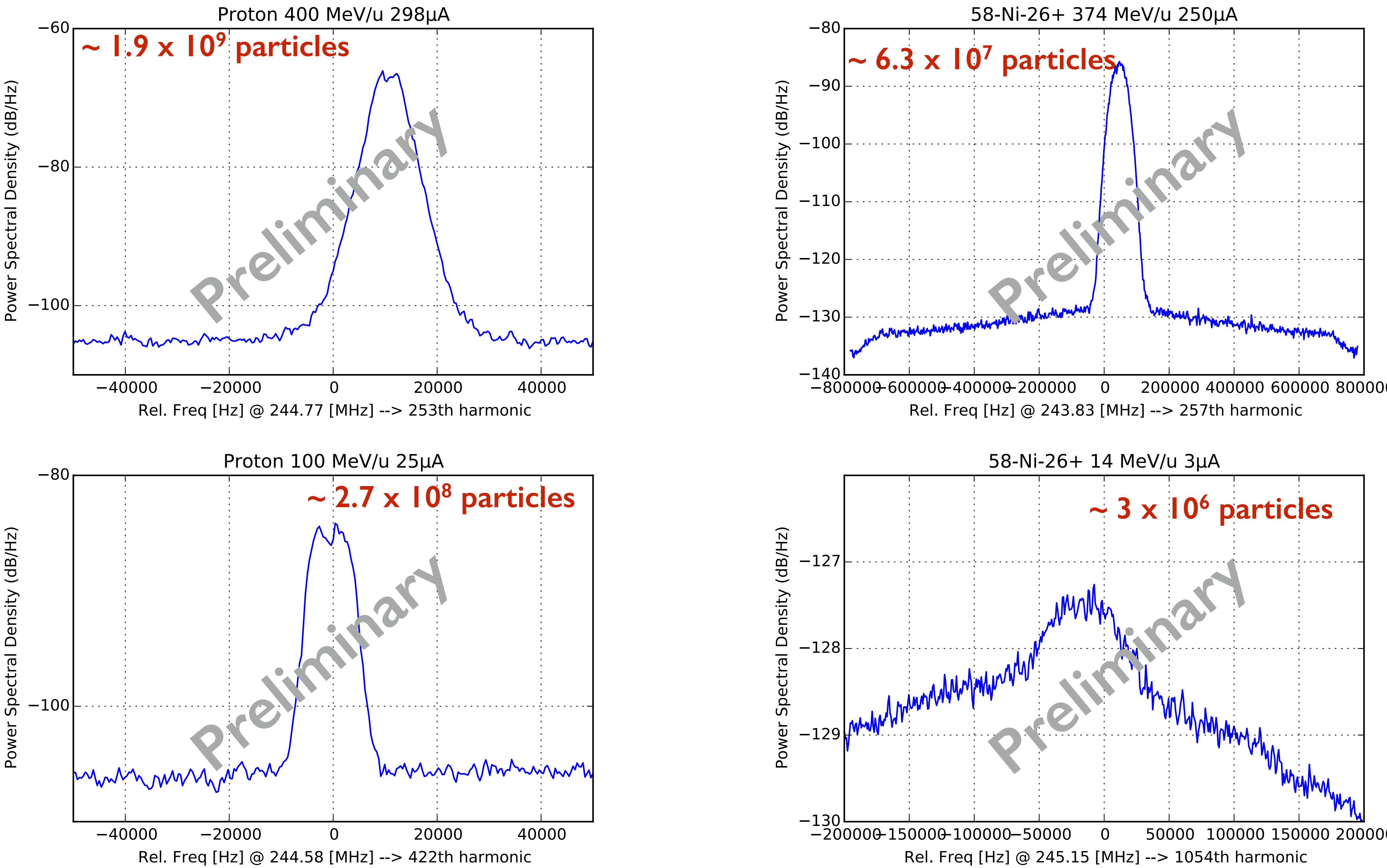
CCC needed!

Recent measurements

- Measurements in ESR
  - During summer beam time 2014

To be published in Nuclear Instruments and Methods



Schottky in CR

Schottky for beam diagnostics

CR Beam Diagnostics

↓

Original Plan

↓

Long. + Trans.

Schottky as an experimental "detector"

ILIMA @CR

↙ ↓

Similar to ESR → Long.

New Concept → Transv.

Schottky in CR

Schottky for beam diagnostics

CR Beam Diagnostics

↓

Original Plan

↓

Long. + Trans.

Schottky as an experimental "detector"

Was postponed for later (until recently plans changed)

ILIMA @CR

Similar to ESR

↓

Long.

New Concept

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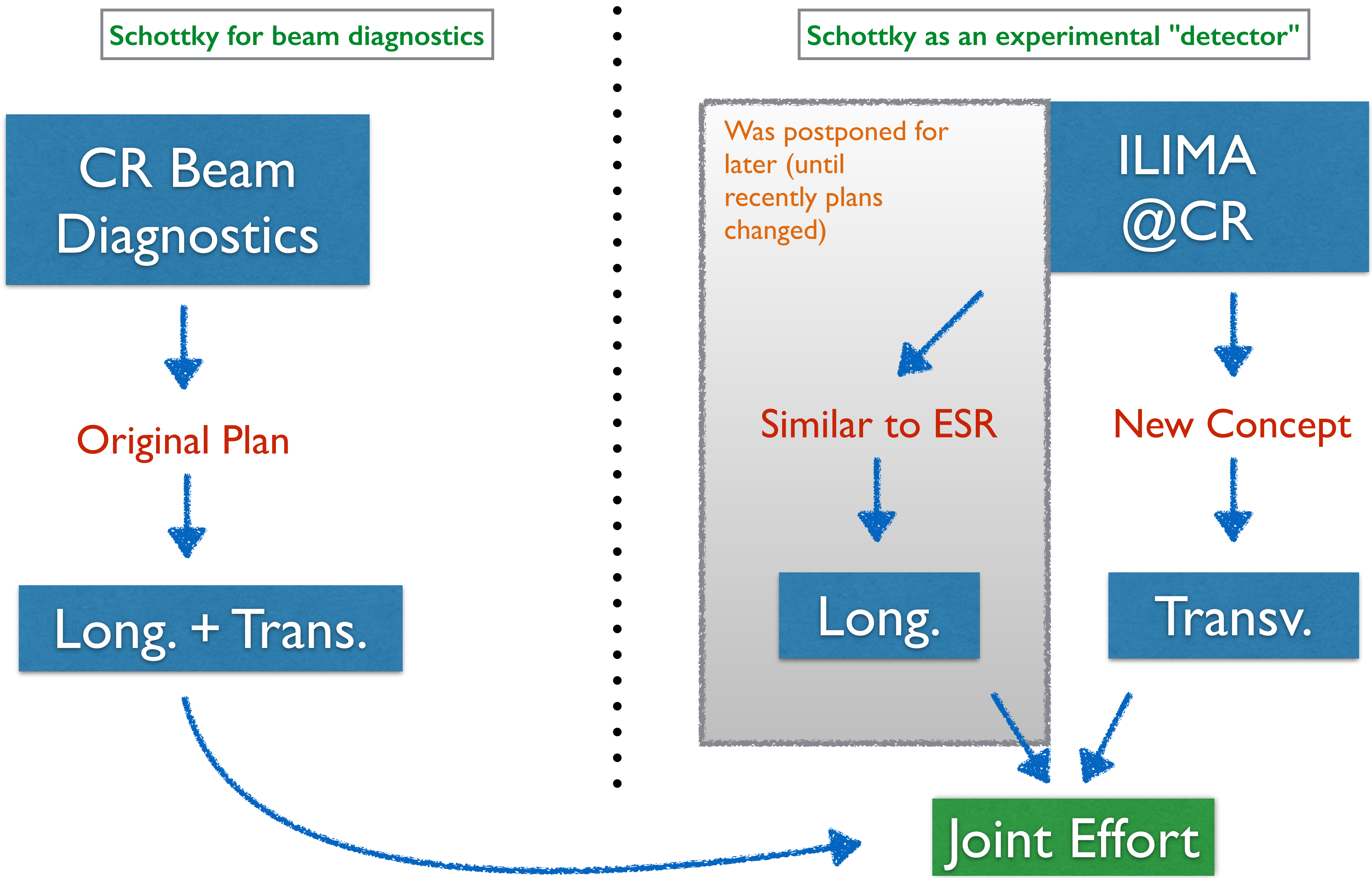
Schottky in CR



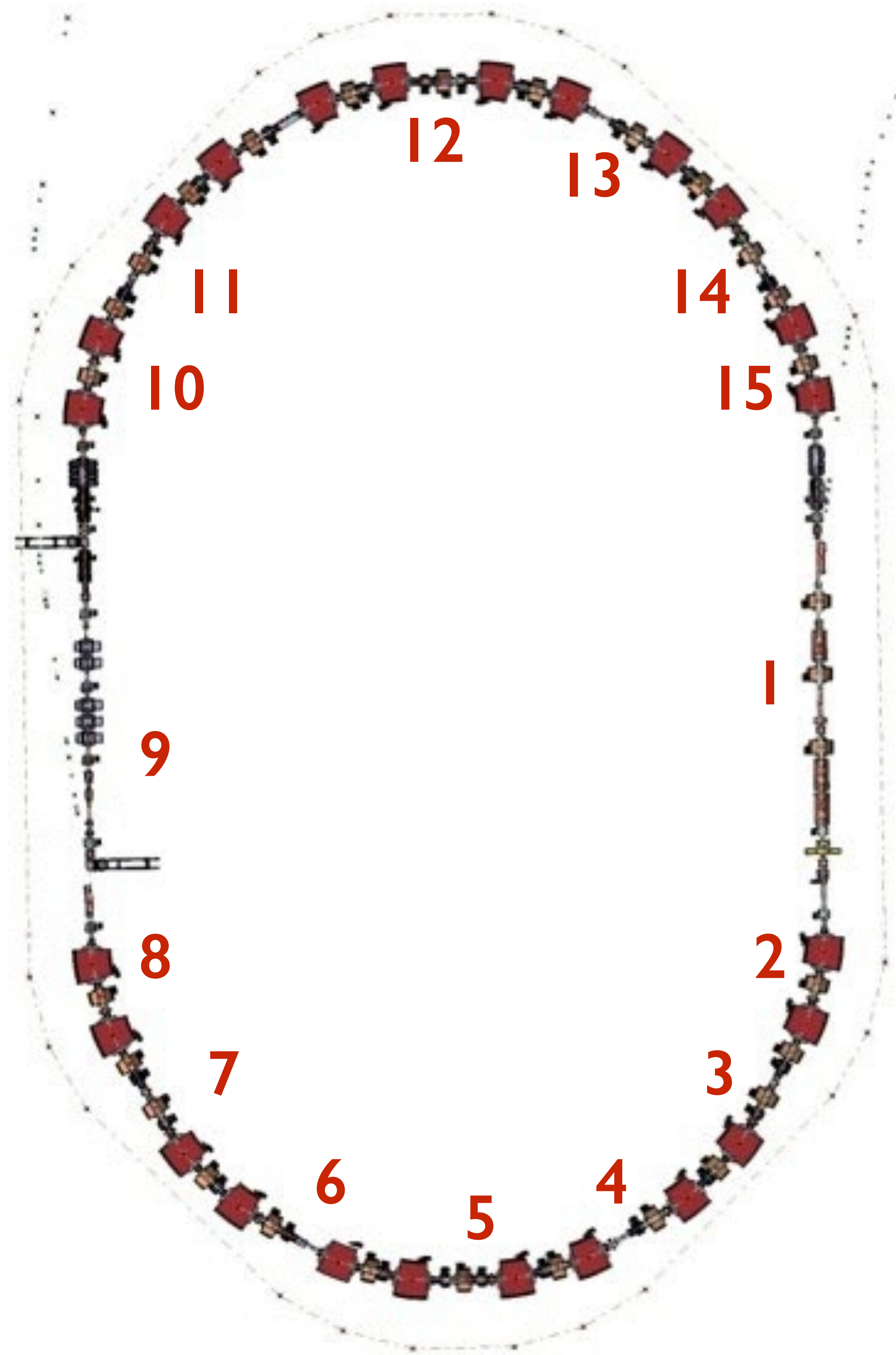
Schottky in CR

- Needed Schottky diagnostics
  - Longitudinal vs transversally sensitive

	Energy [MeV/u]	Δp/p [+- %]	long.	trans.
pbar	3000	3	yes	no
ILIMA RIB	740	1.5	yes	no
ILIMA ISO	400, 625, 790	0.22, 0.46, 0.62	yes	yes
General Beam Diagnostic			yes	of advantage

Schottky in CR

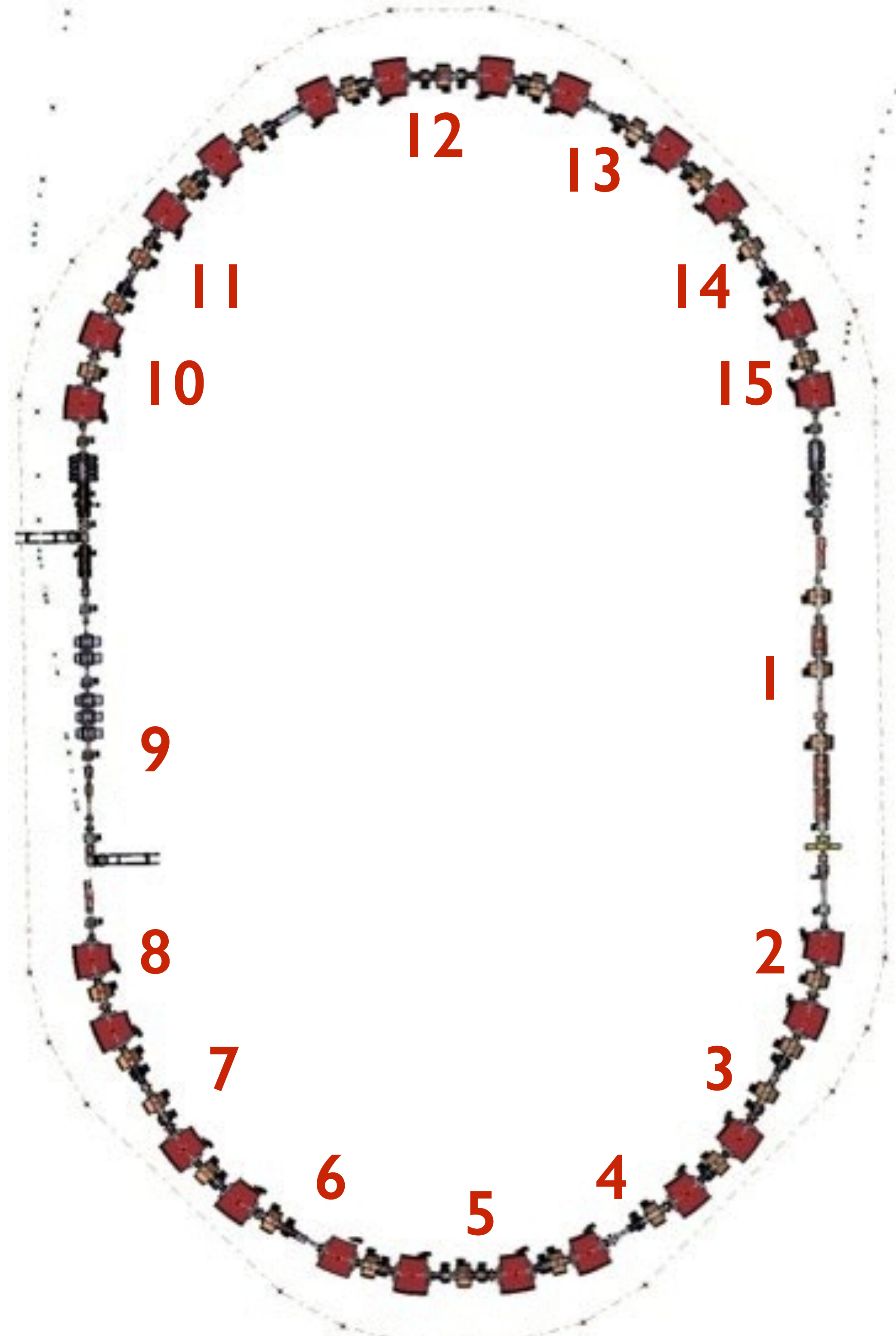
- Reserved places
  - 15 in total
  - Straight and arc sections
  - All places have "nomenclature"



Schottky in CR

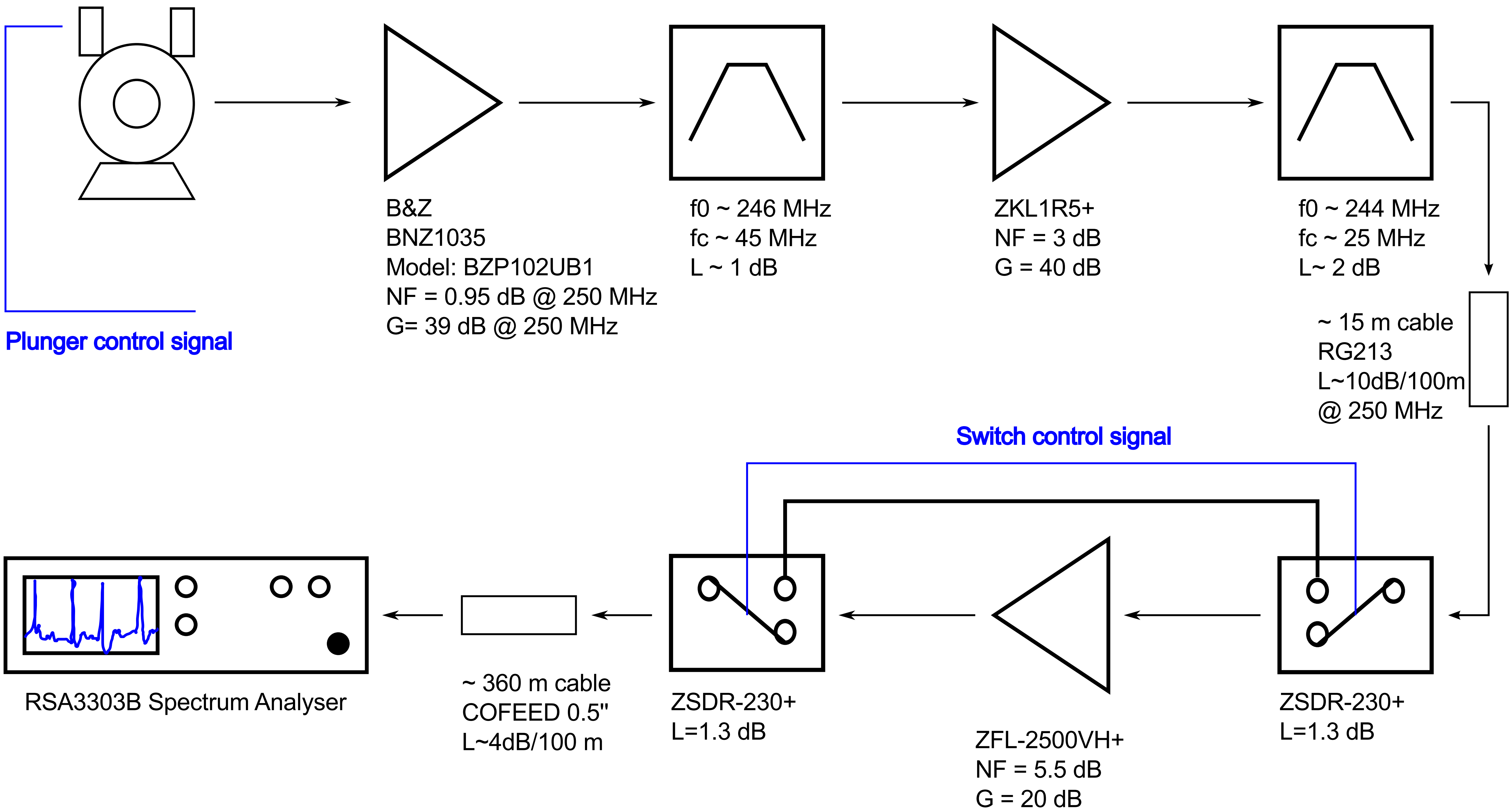
- Reserved places
  - 15 in total
  - Straight and arc sections
  - All places have "nomenclature"

- Application of many detectors
  - Tune on several frequencies
    - Continuous broad band
    - Broad band with gap
      - Special physics case
  - All on the same frequency
    - Signal phase correlation
    - Dedicated research (ongoing)



Racks, Power Supply and Cables

- Signal chain and control signals

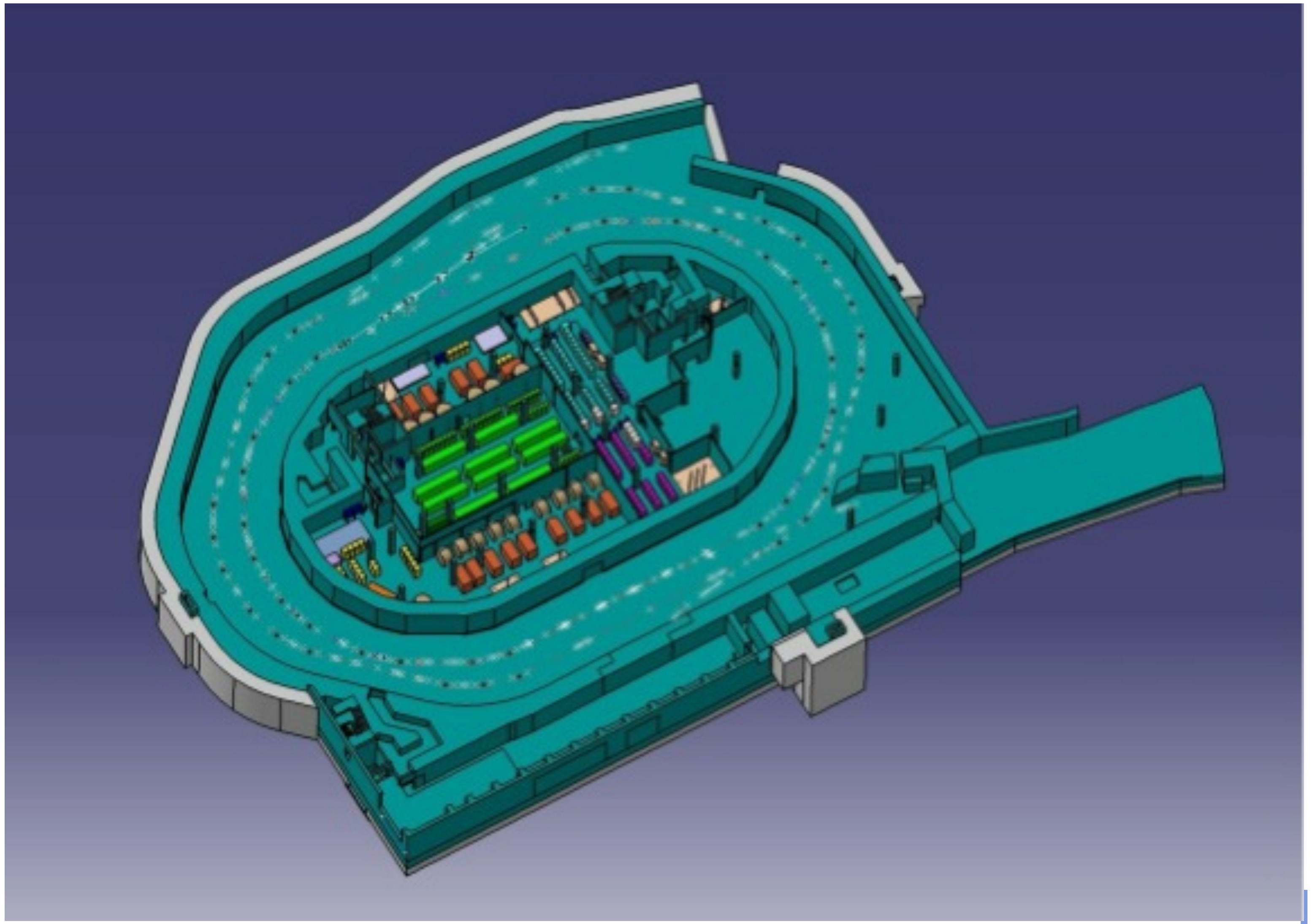


- Offline Schottky noise estimation (spectral estimation)

Racks, Power Supply and Cables

- 9 Racks
  - Near Beam Diagnostics Section
  - 2 UPS
  - 7 CPS
  - 1 Beam line supply

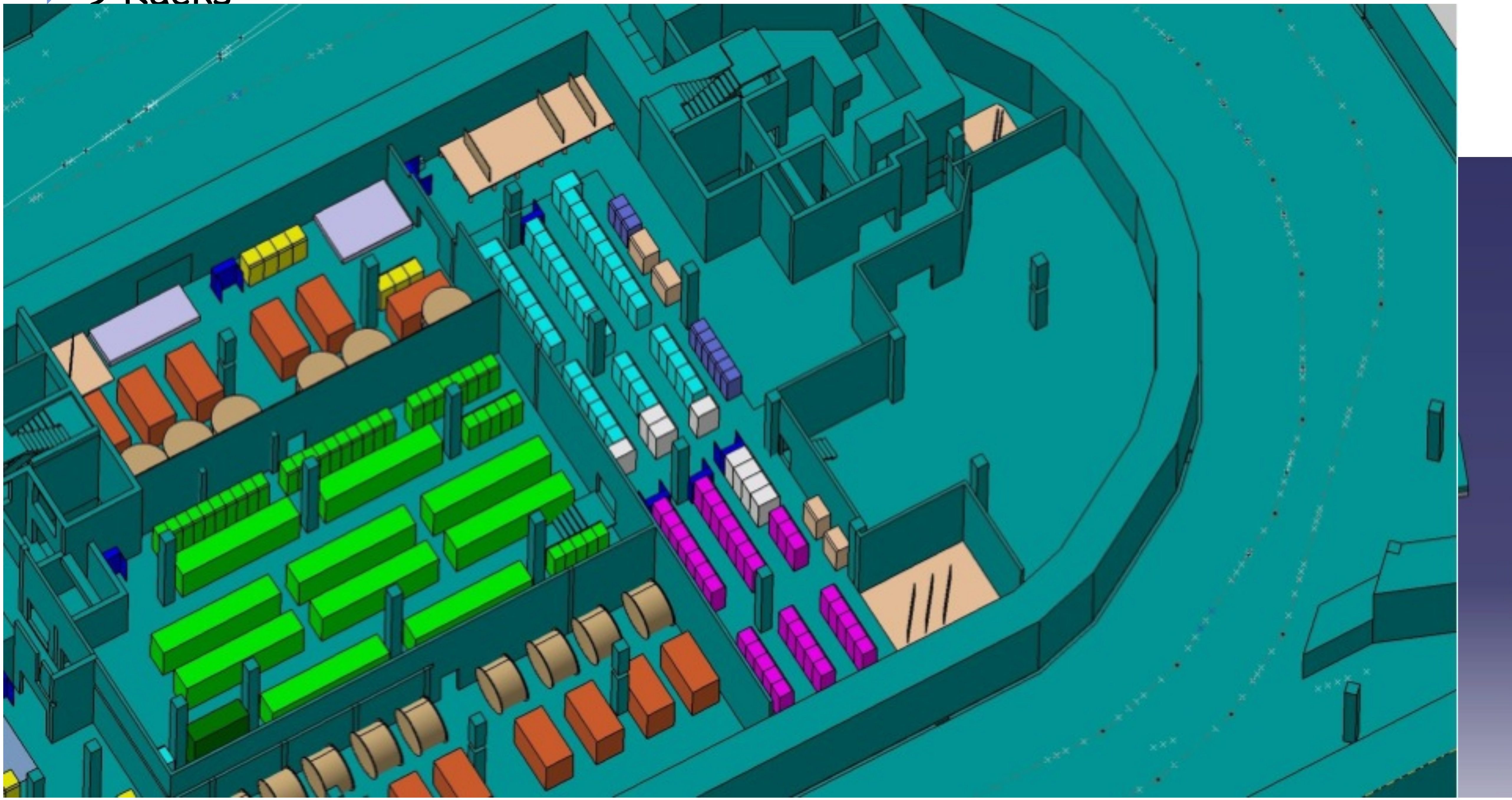
- Cable Planing on going
  - together with BD
  - Cable types:
    - Supplies
    - Control
    - RF



Source: I. Schurig

Racks, Power Supply and Cables

- 9 Racks



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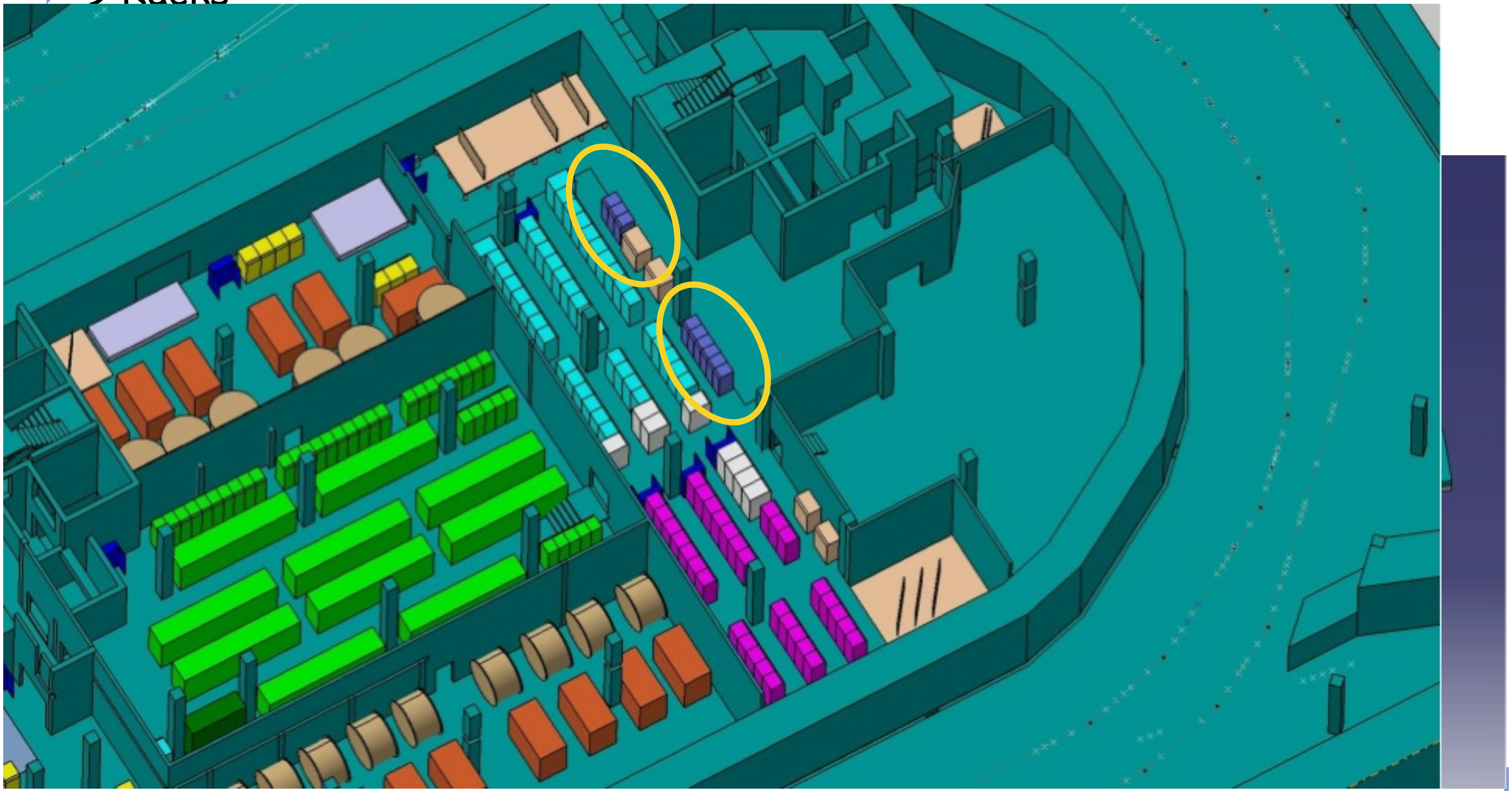


Source: I. Schurig

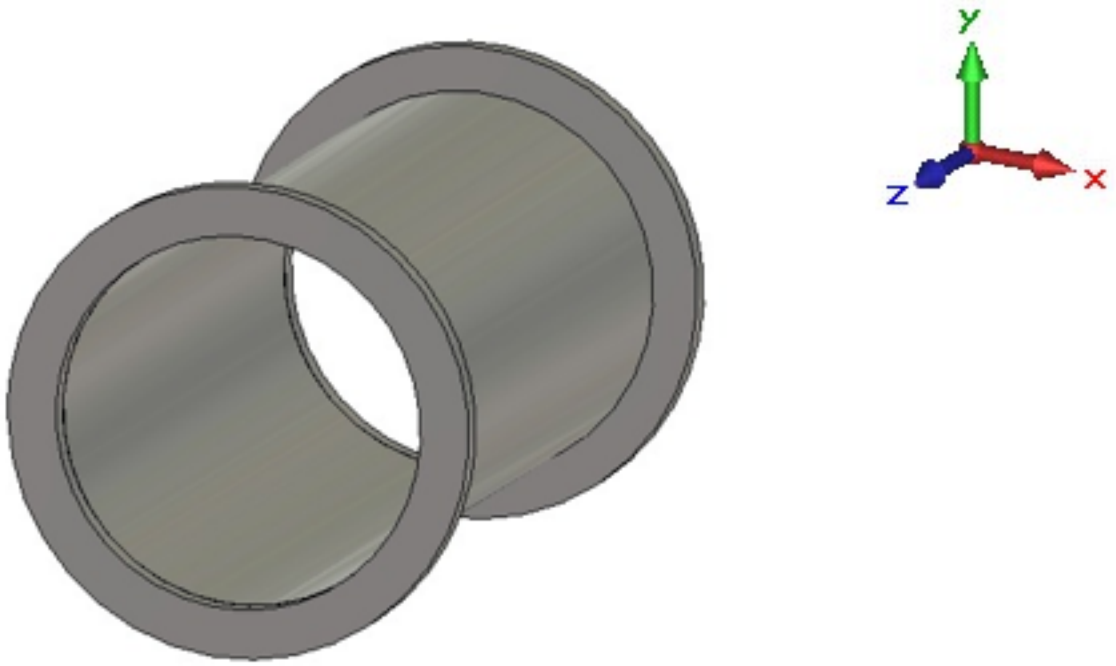
Data Acquisition

- Data Acquisition is based on Beam diagnostics (Talk of O. Chorniy)
  - Discussion ongoing
  - Software interface

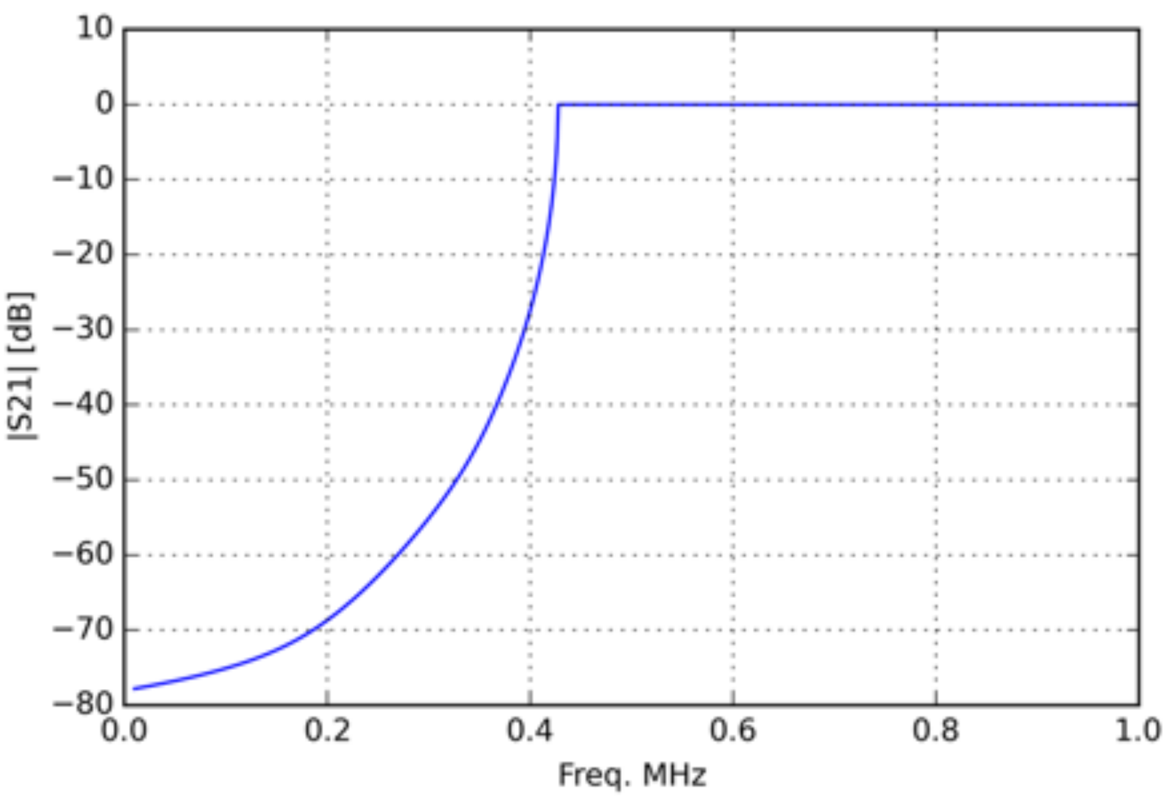
- Other possibilities
  - Usage of NTCAP system (Ch. Trageser, PhD thesis)
    - Based on NI Hardware
    - Successful commissioning in october 2014 in ESR + Resonator Data
  - Unified data Acquisition based on Software Defined Radio (J. Piotrowski, MSc Student)

CR Beam Pipes

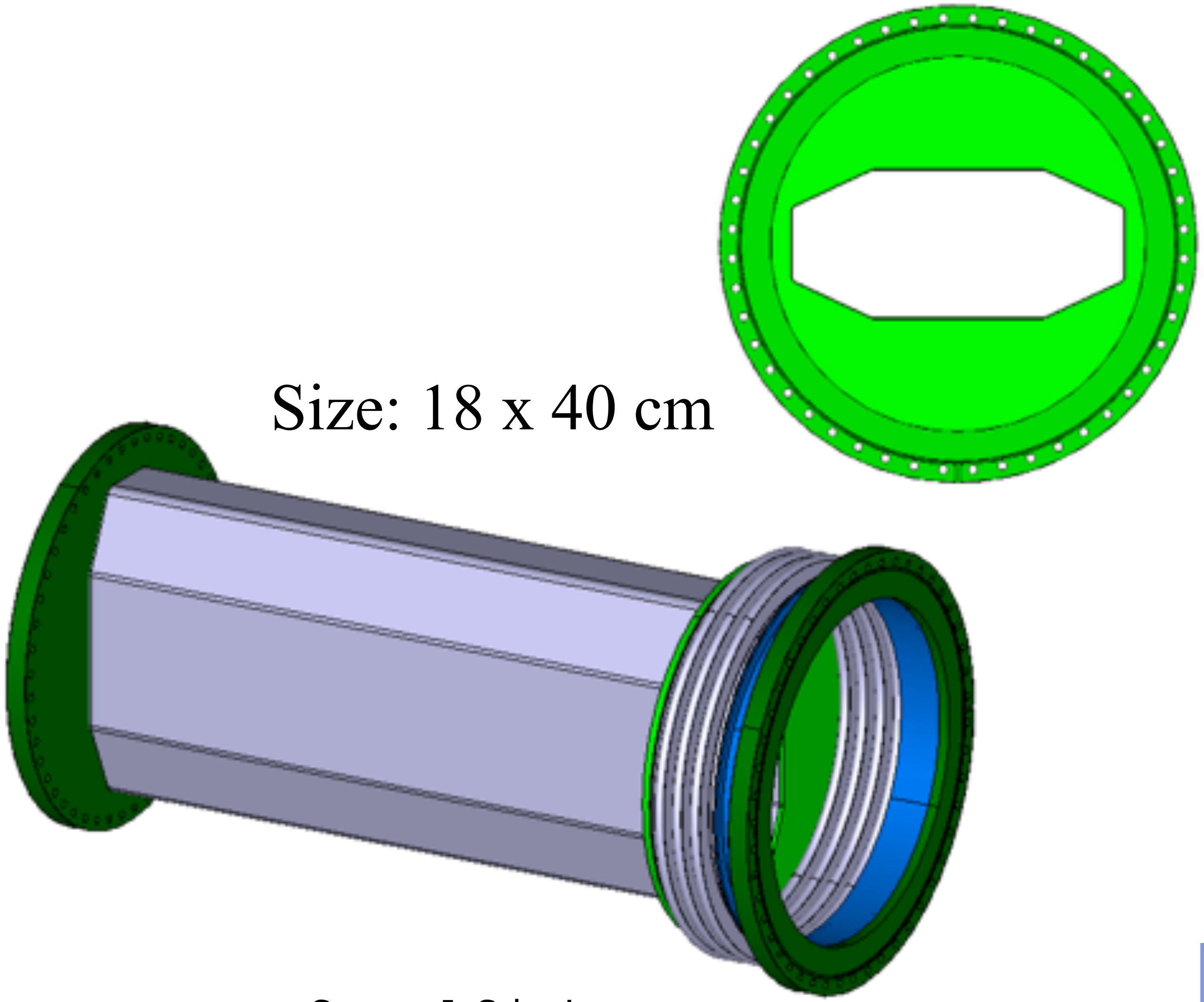
- Straight section pipes
  - DN200 (radius = 10 cm)
  - Cut-off freq. ~ 879 MHz



- Arc section pipes:
  - CATIA Model imported into Microwave Studio
  - Cut-off frequency ~ 428 MHz



Size: 18 x 40 cm

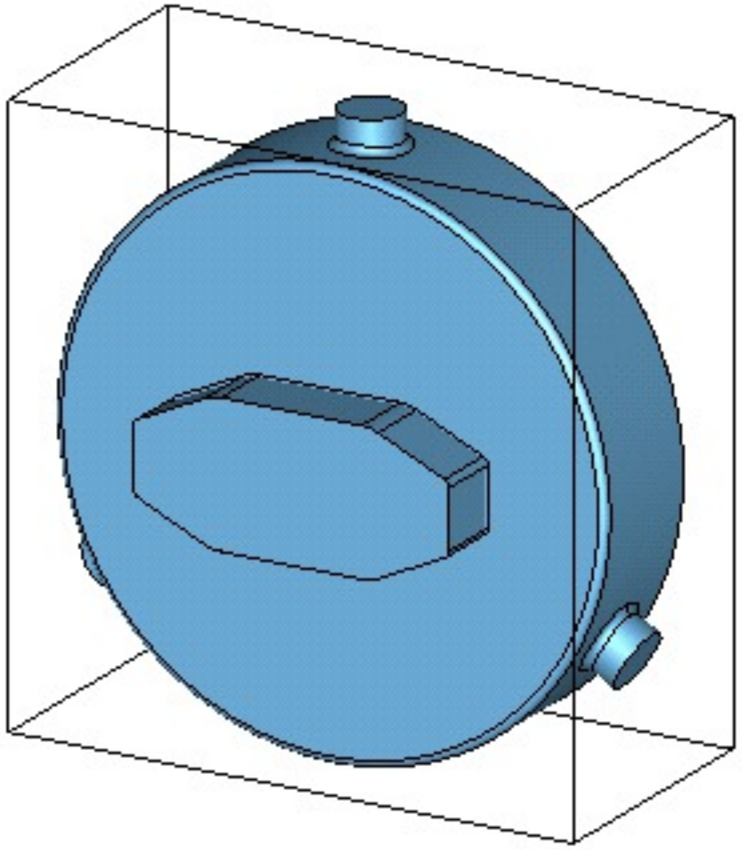


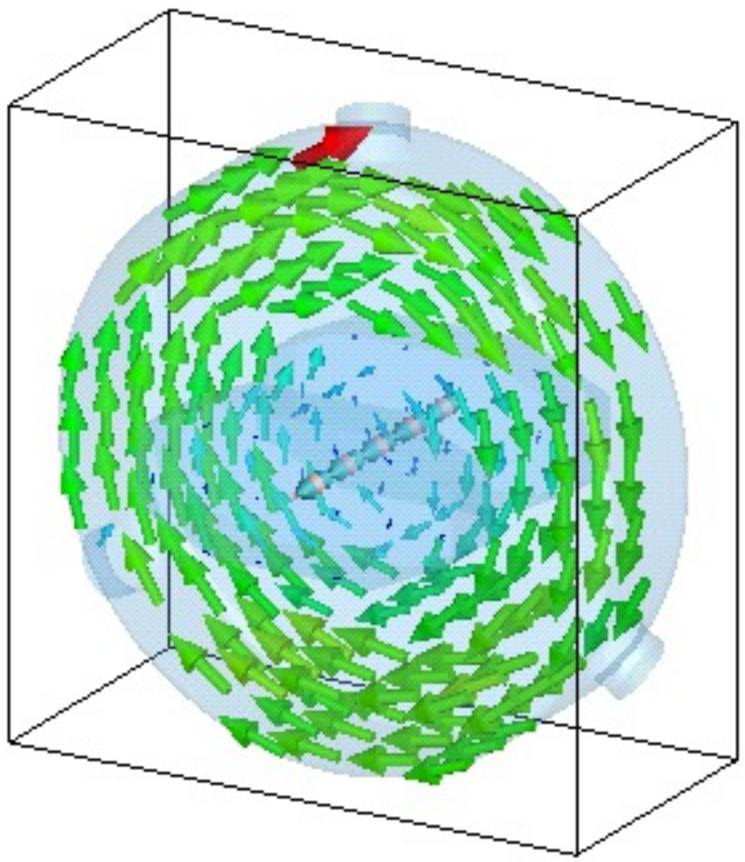
Source: I. Schurig

CR Longitudinal Resonators

- Pilot design for arc sections
  - Coupler at top
  - Symmetrical Plungers at bottom
  - No ceramic gap
  - Stainless steel no coating
  - radius 35 cm
  - depth 10 cm

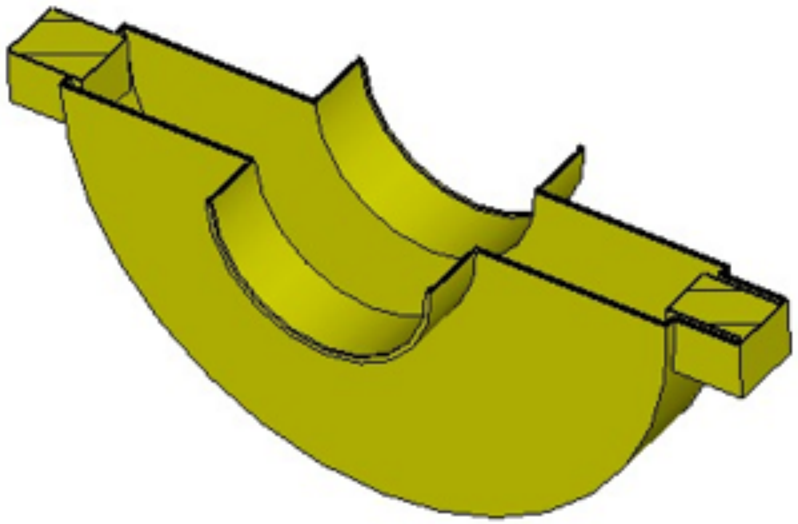
Mode	Freq. [MHz]	Q	R/Q [ohm]
1	344	33787	82
2	477	41034	~ 0





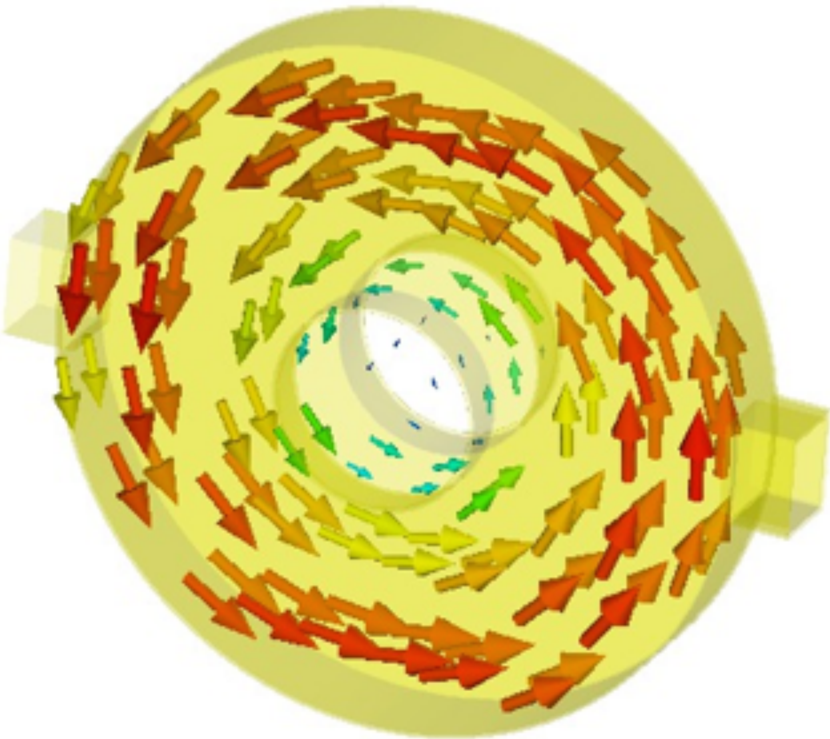
CR Longitudinal Resonators

- Pilot design for straight section
  - plungers 180°
  - radius 35 cm
  - depth = 10 cm



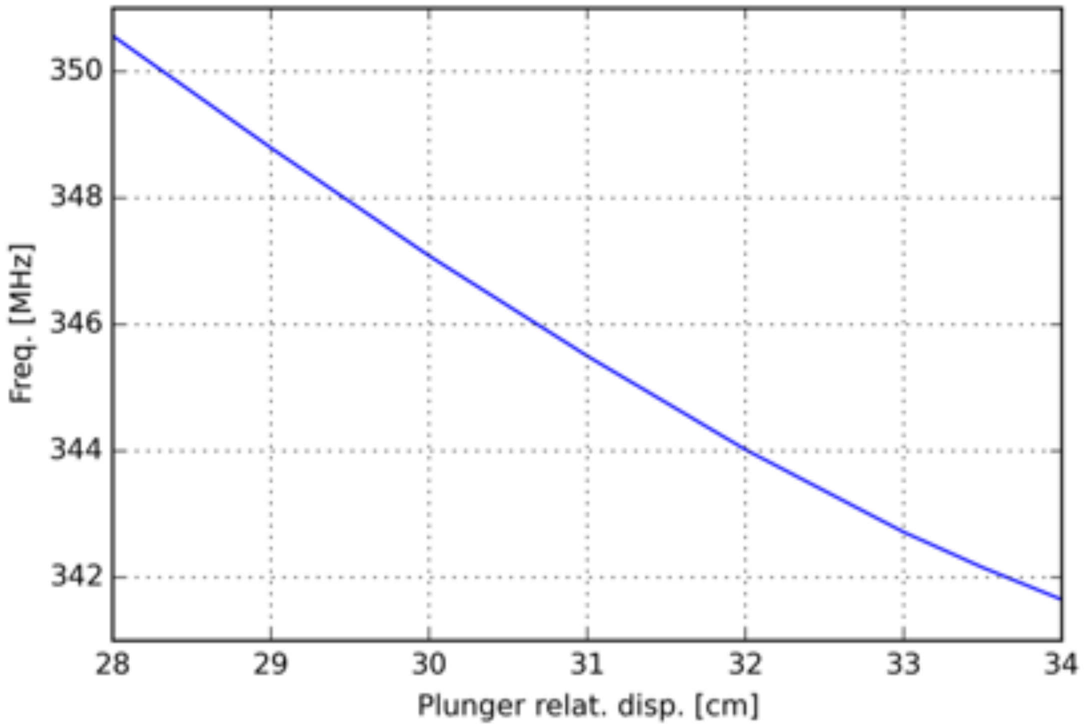
- Plunger tuning

Mode	Freq. [MHz]	Q	R/Q [ohm]
1	340	21512	108
2	504	28521	~ 0



CR Longitudinal Resonators

- pbar at 3GeV/u
  - $\beta = 0.97$
  - $\gamma = 4.19$
  - $f_r = 1.314$ MHz
  - $m = 261$
- Tuning $m f_r = f_0$
  - $\Delta f \sim 114$ kHz

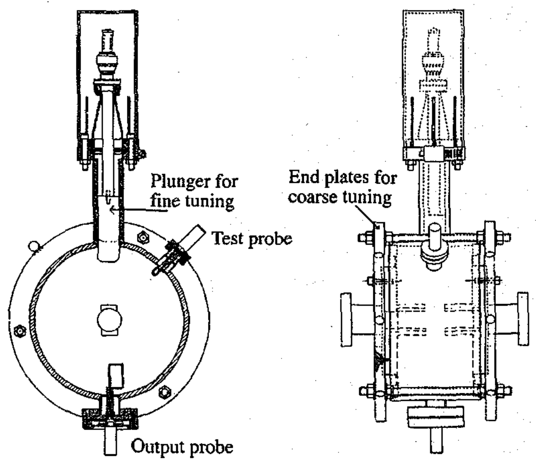


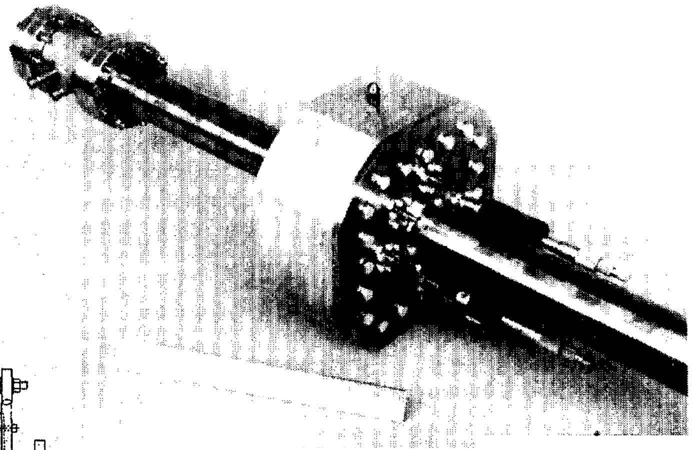
Freq. vs. Plunger

- Max. Q_{loaded} for $2 \times \Delta f$ is approx. 1500

- Reduction of Q
  - Mechanical shorting (electric, or manual)
  - "heavily loading"
  - non-critical coupling
  - Vacuum tight permanent lossy material

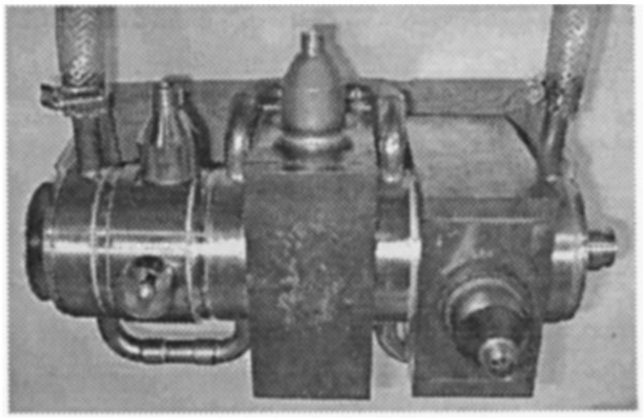
Transversal approaches

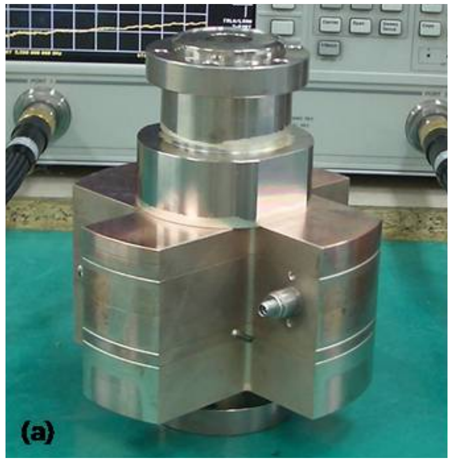




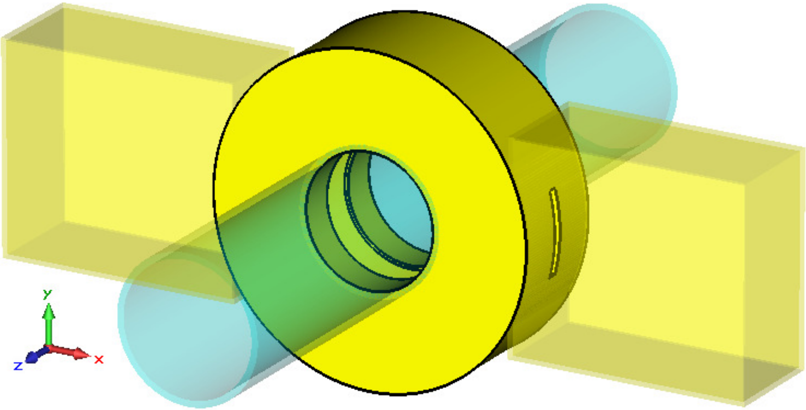
- Cavity based designs:
  - Small designs for small aperture machines: SLAC, SwissFEL, etc…

1962 Bergere et. al., Saclay
1963 Neal, SLAC
1964 Brunet et. al. SLAC
1967 Farinholt et. al. SLAC
1987 Goldberg et. al. LBNL
1997 Ursic et. al. SLAC
1998 Slaton et. al. SLAC
2004 Kim et. al. SLAC
and more!





- Suggestions of P. Hülsmann (GSI):
  - TM110/TM010 pickup for CR beam diagnostics
  - (PhD Thesis: M. Hansli, TU-Darmstadt)



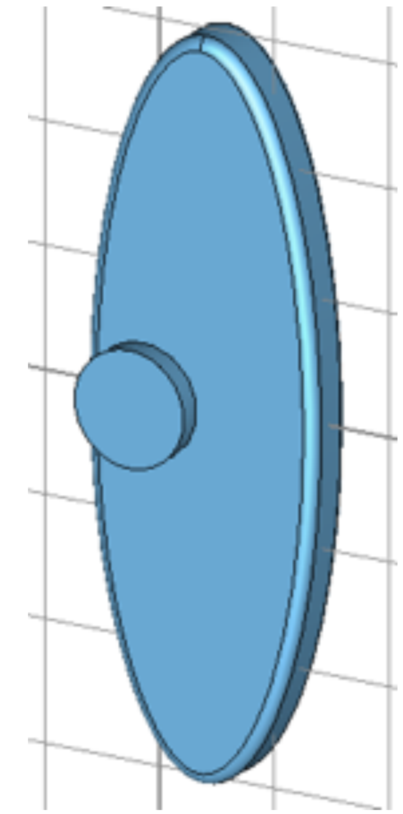
Source: M. Hansli et. al, Proceedings of BIW2012, Newport News, VA

Present Design Approach

- All previous designs based on Dipole mode
- Current design:
  - Based on elliptical geometry
  - Place of high dispersion
  - Not yet fully adapted for CR
- Advantages over Dipole resonators
  - Cope with large Beam pipe apertures
  - Information the strong monopole mode
  - Position information of coasting beam

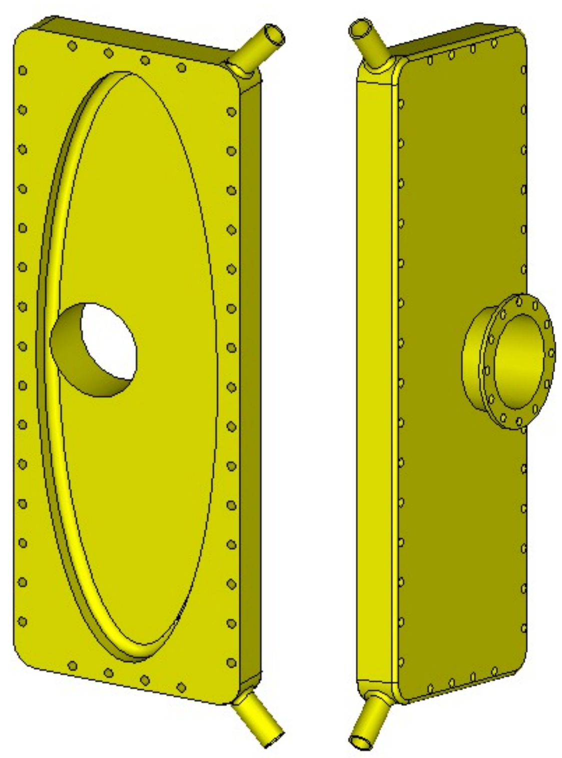
Mode	Freq. [MHz]	Q	R/Q [ohm]
1	422	23381	pos. dep.
2	509	25580	~ 0

Diameters:
40 x 120 cm
pipe: 17 cm
Depth: 10



Source: Phys. Scr. Special Issue 2014

Possible CAD Model:



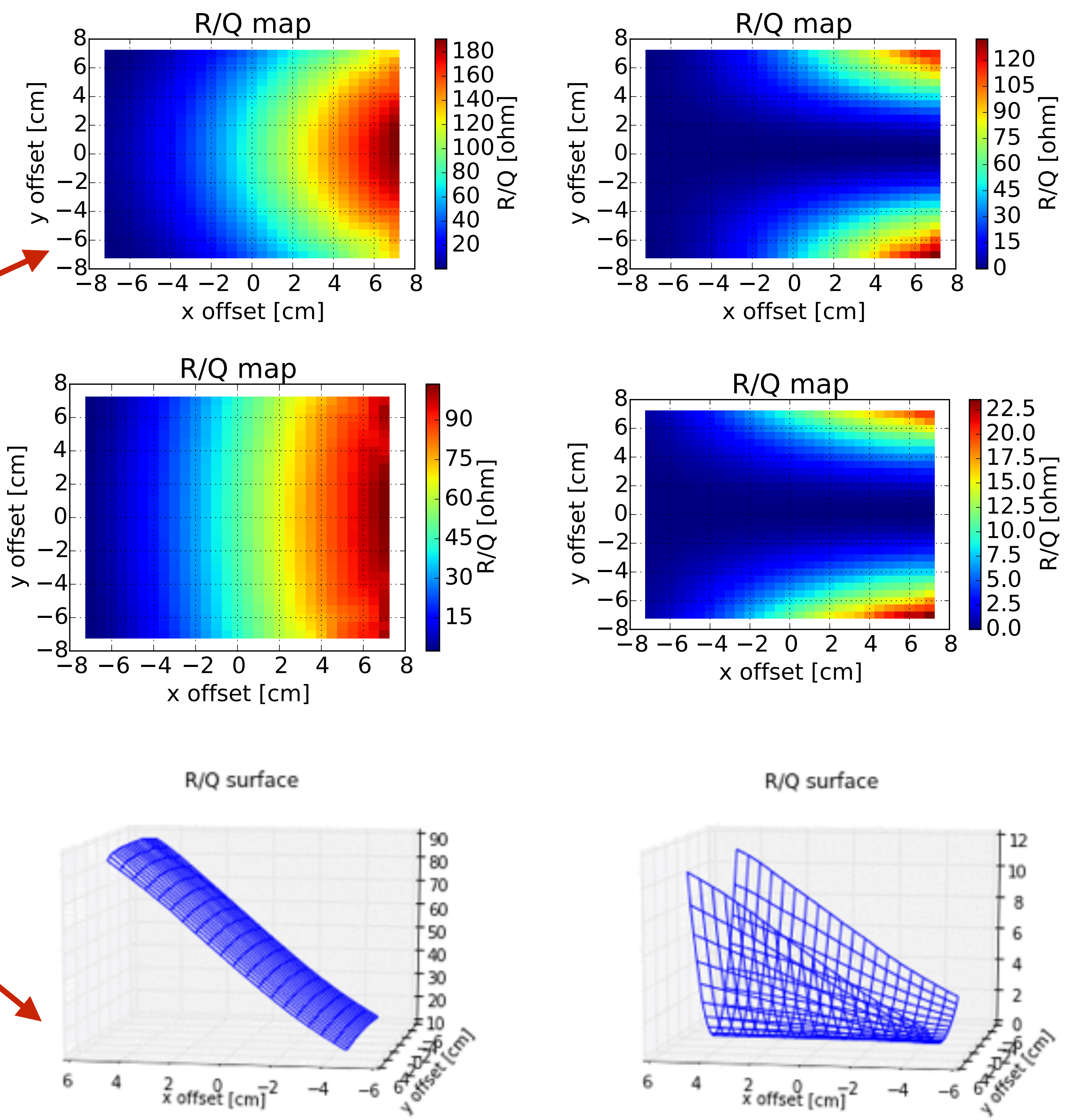
Present Design Approach

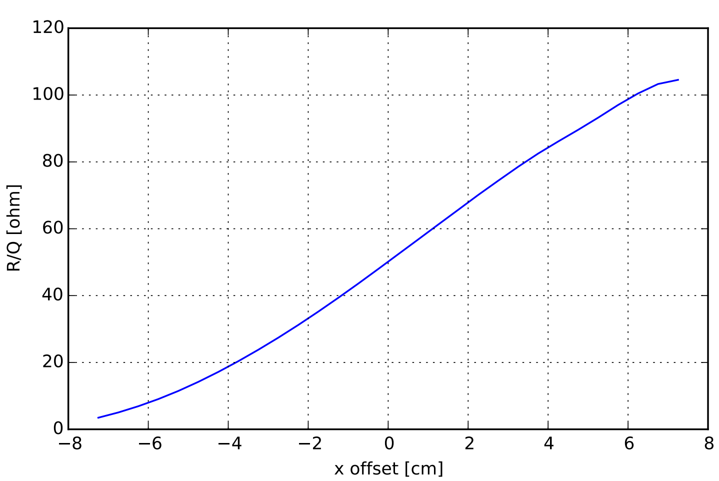
Source: Phys. Scr. Special Issue 2014

- Impedance
  - Circular vs Elliptical

Circular

Elliptical





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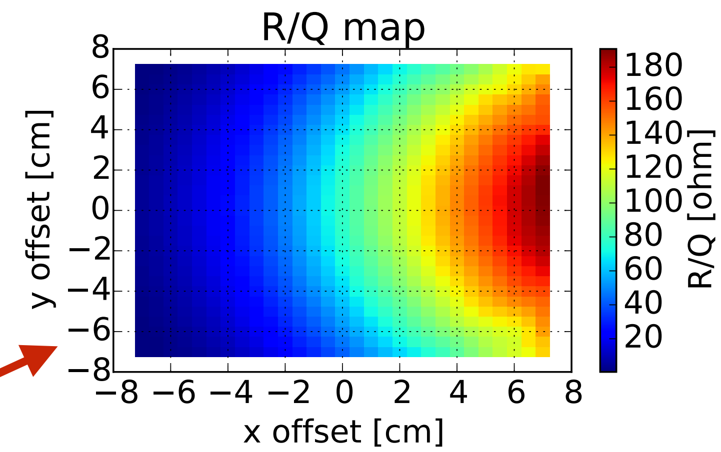
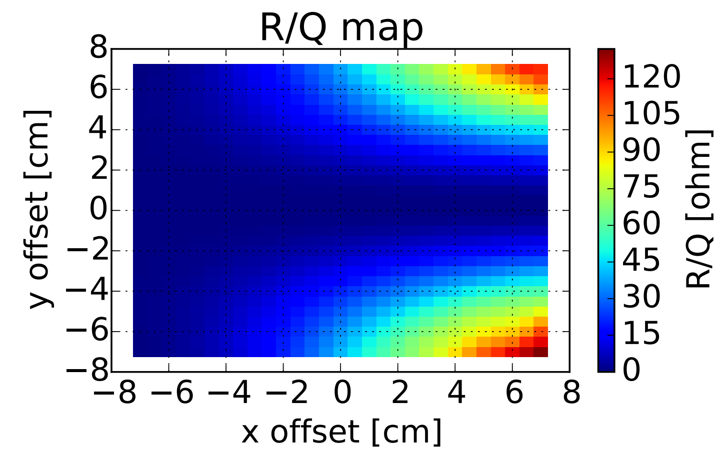
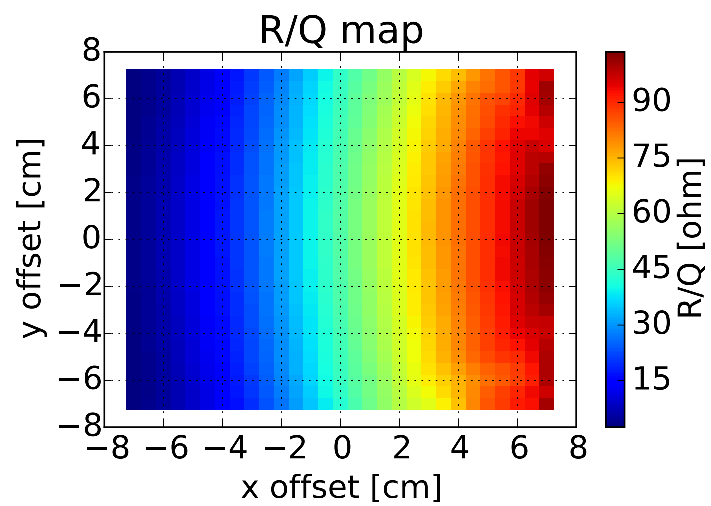
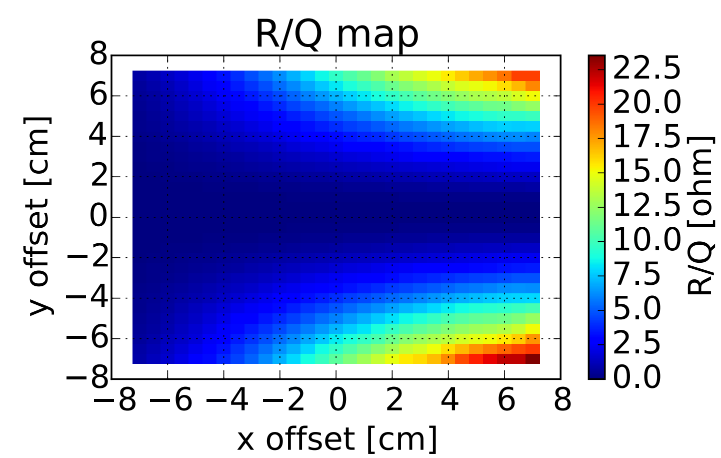
Circular

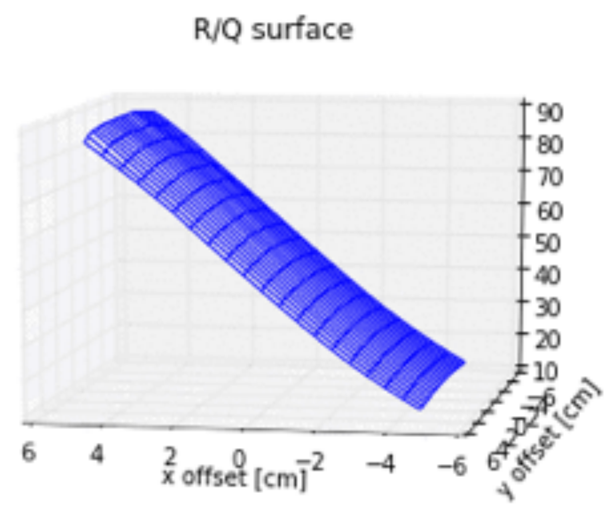


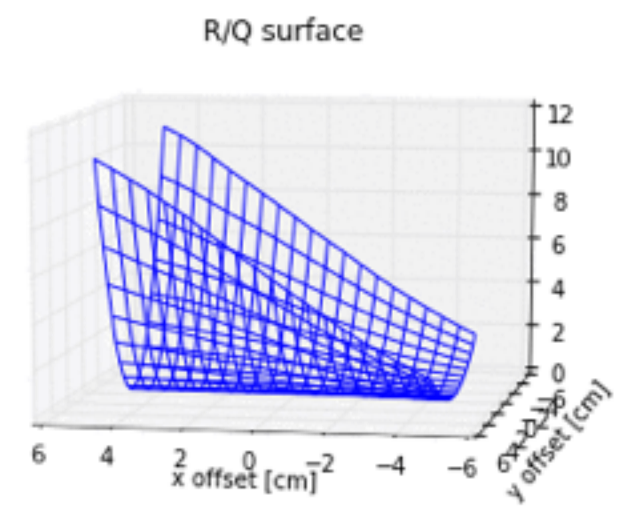


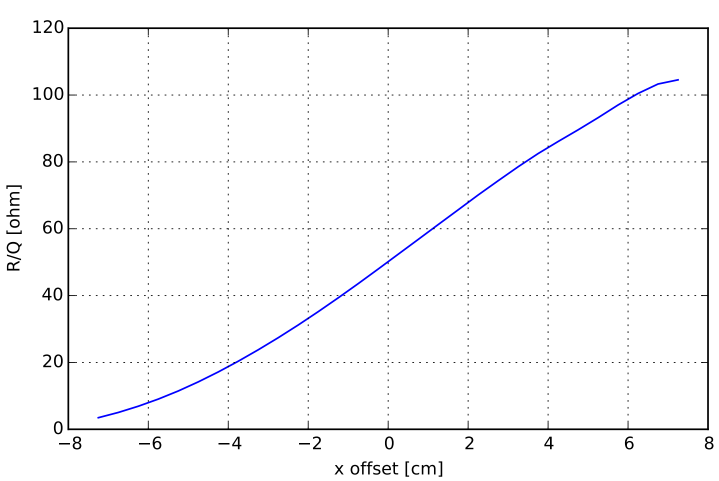
Elliptical











Bench top Model

- Circular bench top model
  - Automated test bench
  - Effects are measurable
  - Elliptical Model under development

Source: X. Chen et. al. Phys. Scr. Special Issue 2014

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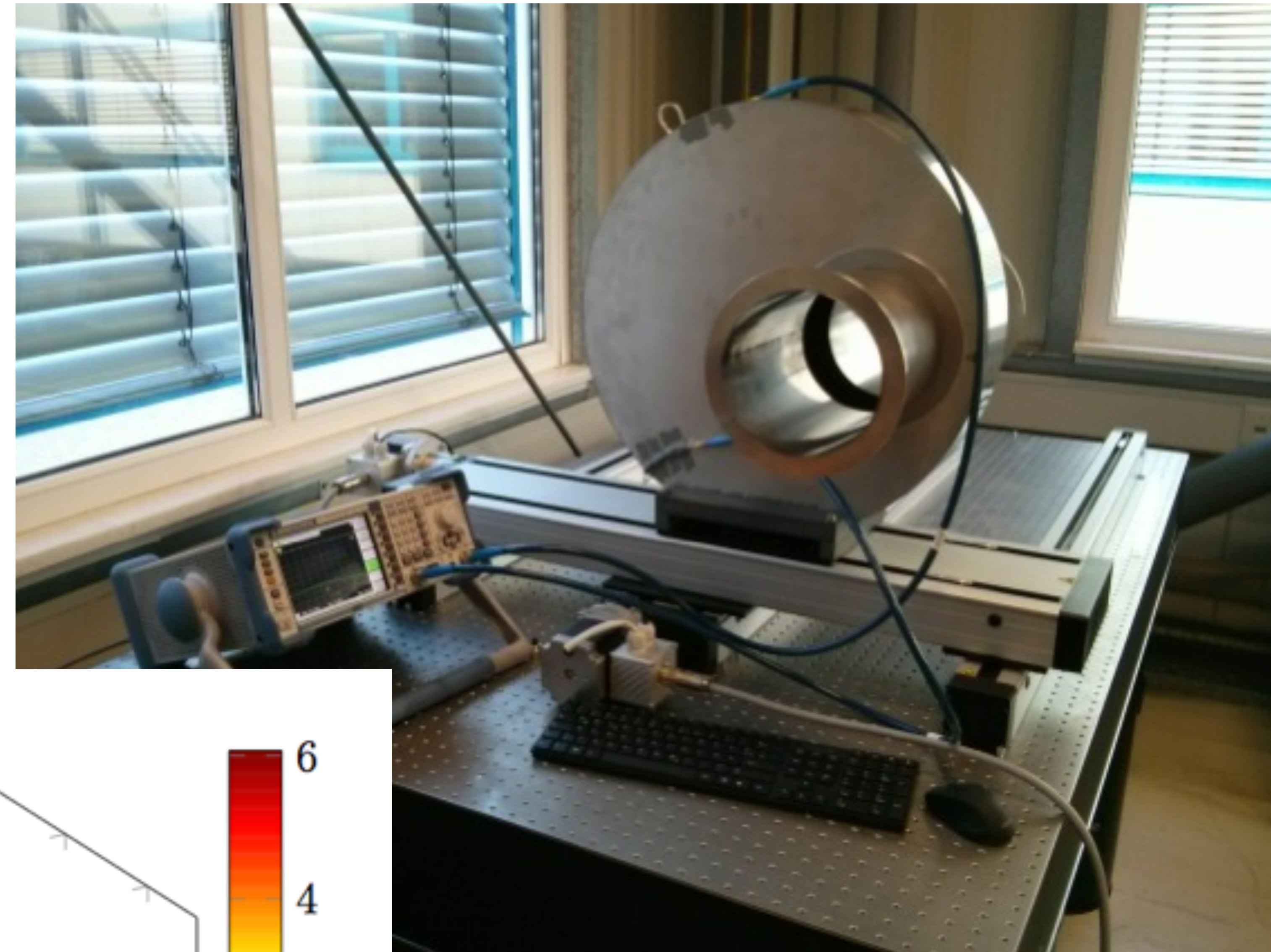

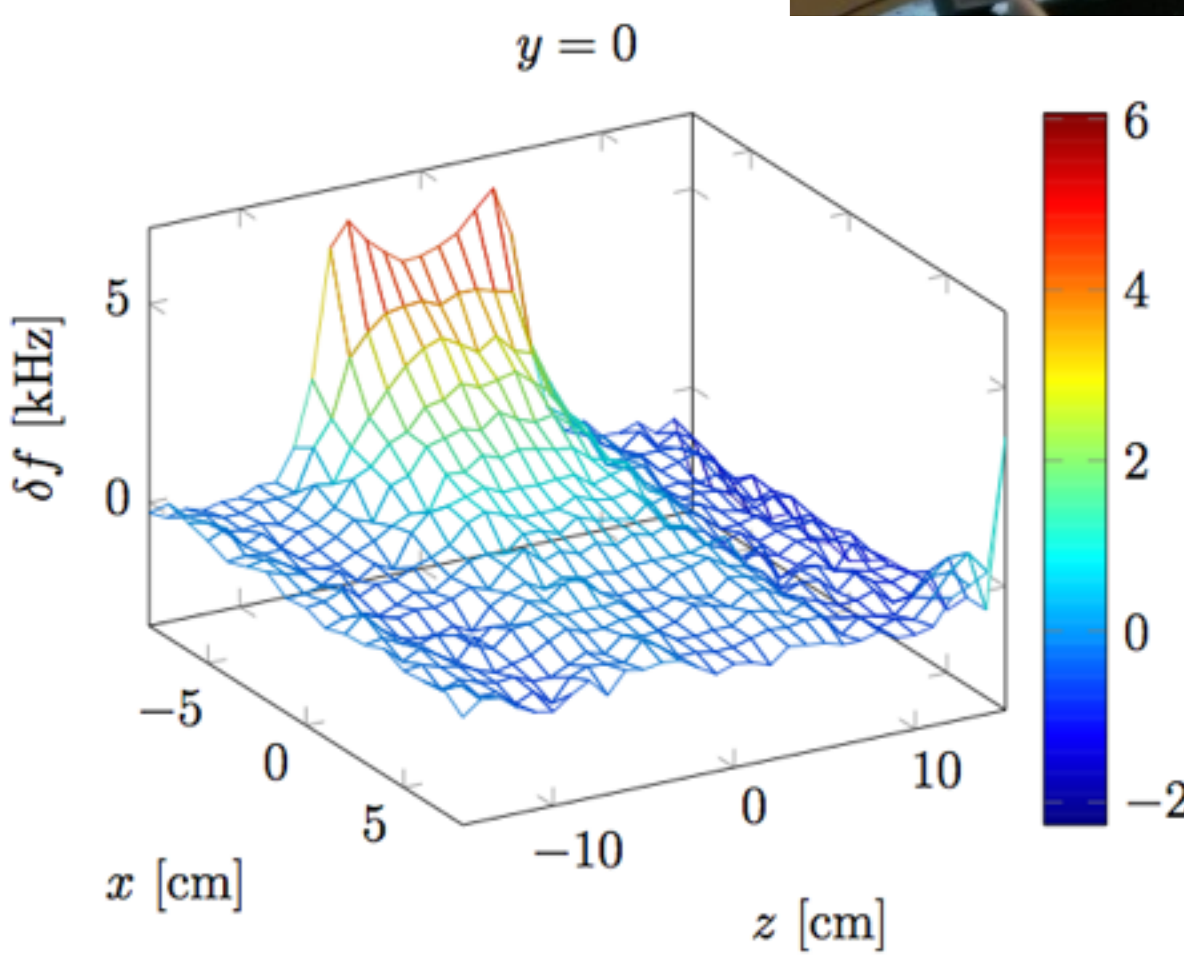

Source: X. Chen et. al. Phys. Scr. Special Issue 2014

Outlook and Conclusions

- Plans for 2015
  - Continue work R&D on transversal geometry

  - Construction of a real life prototype of a longitudinal resonator

- Currently:
  - Places are fixed
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- What is needed:
  - Fixed optics (specially places with maximum dispersion)
  - Fixed size of vacuum chambers
  - Reserved places for Schottky don't change
    - with respect to vacuum components etc...
    - where are the bellows etc...

Outlook and Conclusions

- In conclusion:
  - we are very optimistic about the feasibility of longitudinal resonators in CR not only as an experimental device but also as a diagnostic device for CR commissioning.
  - Elliptical cavities are promising for transversal sensitivity
  - Of course more R&D is needed.

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Thank you!