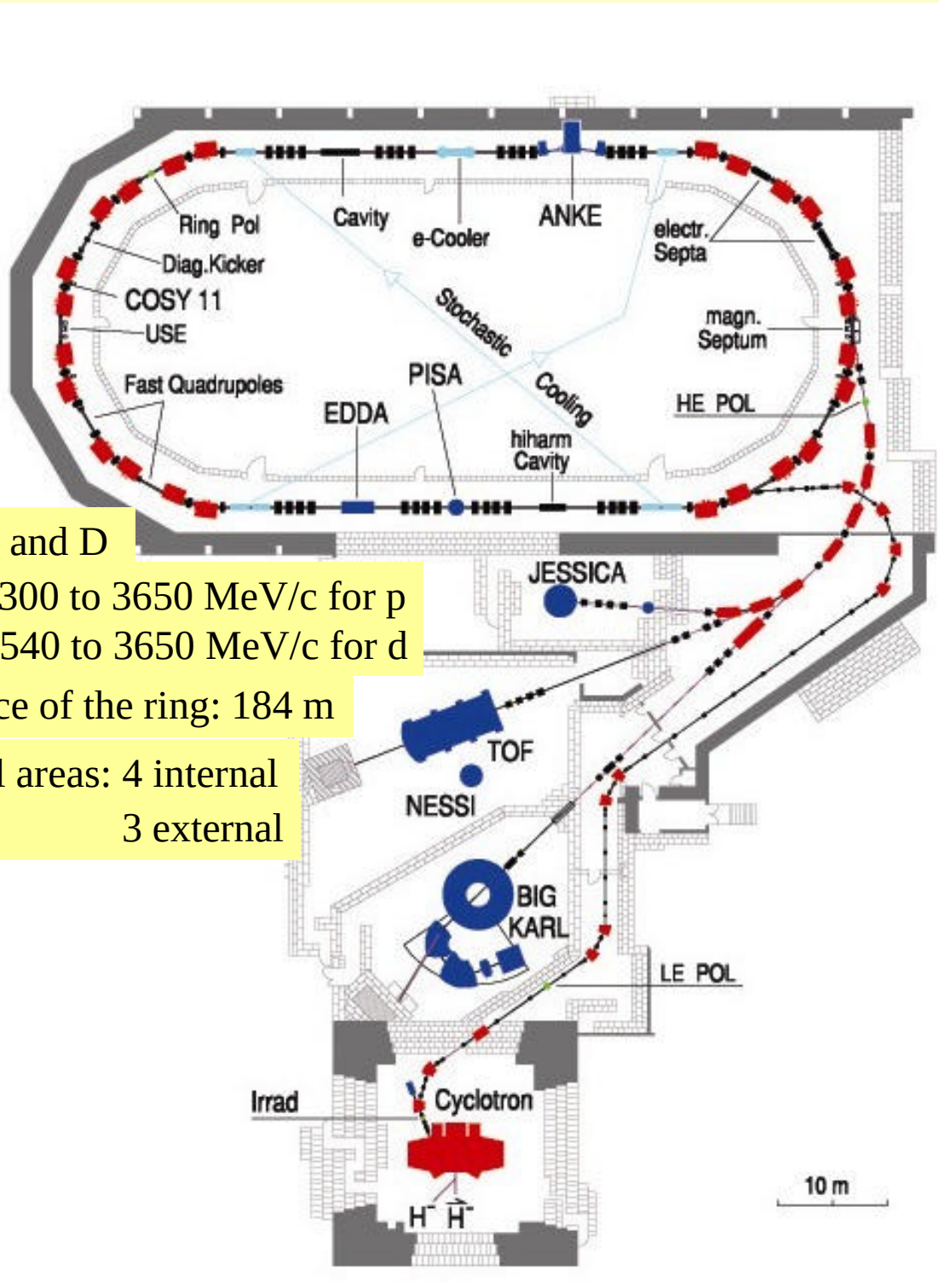
Slow and Fast Extraction at

- *The COSY Facility*
- *Experimental Areas*
- *Extraction at COSY*
  - *Pure resonance extraction*
  - *Stochastic extraction*
  - *Fast kicker extraction*
- *Summary*

Dieter Prasuhn

The **COSY** Facility



Ions: (pol.) P and D

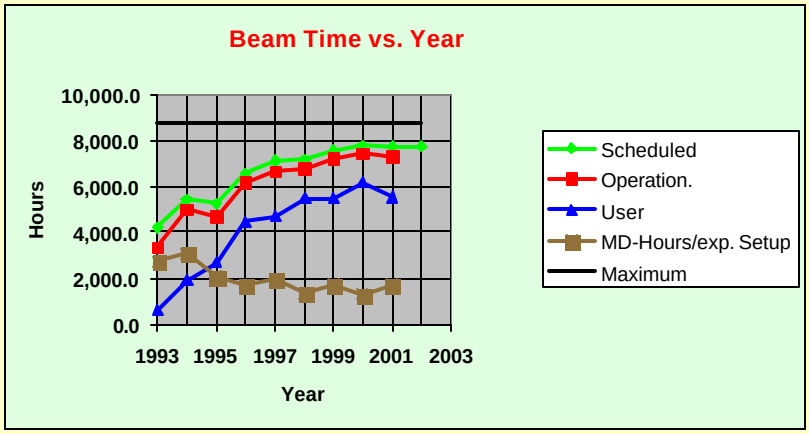
Momentum: 300 to 3650 MeV/c for p
540 to 3650 MeV/c for d

Circumference of the ring: 184 m

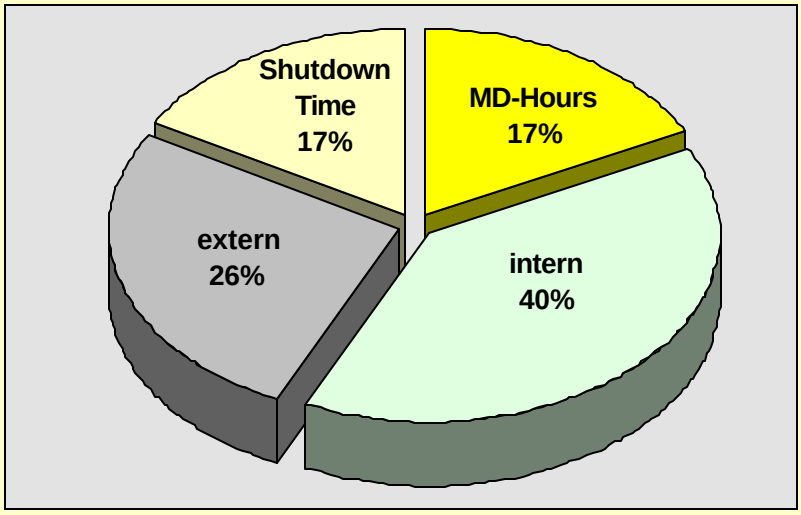
Experimental areas: 4 internal
3 external

View inside the COSY Hall

The Beam Time Distribution

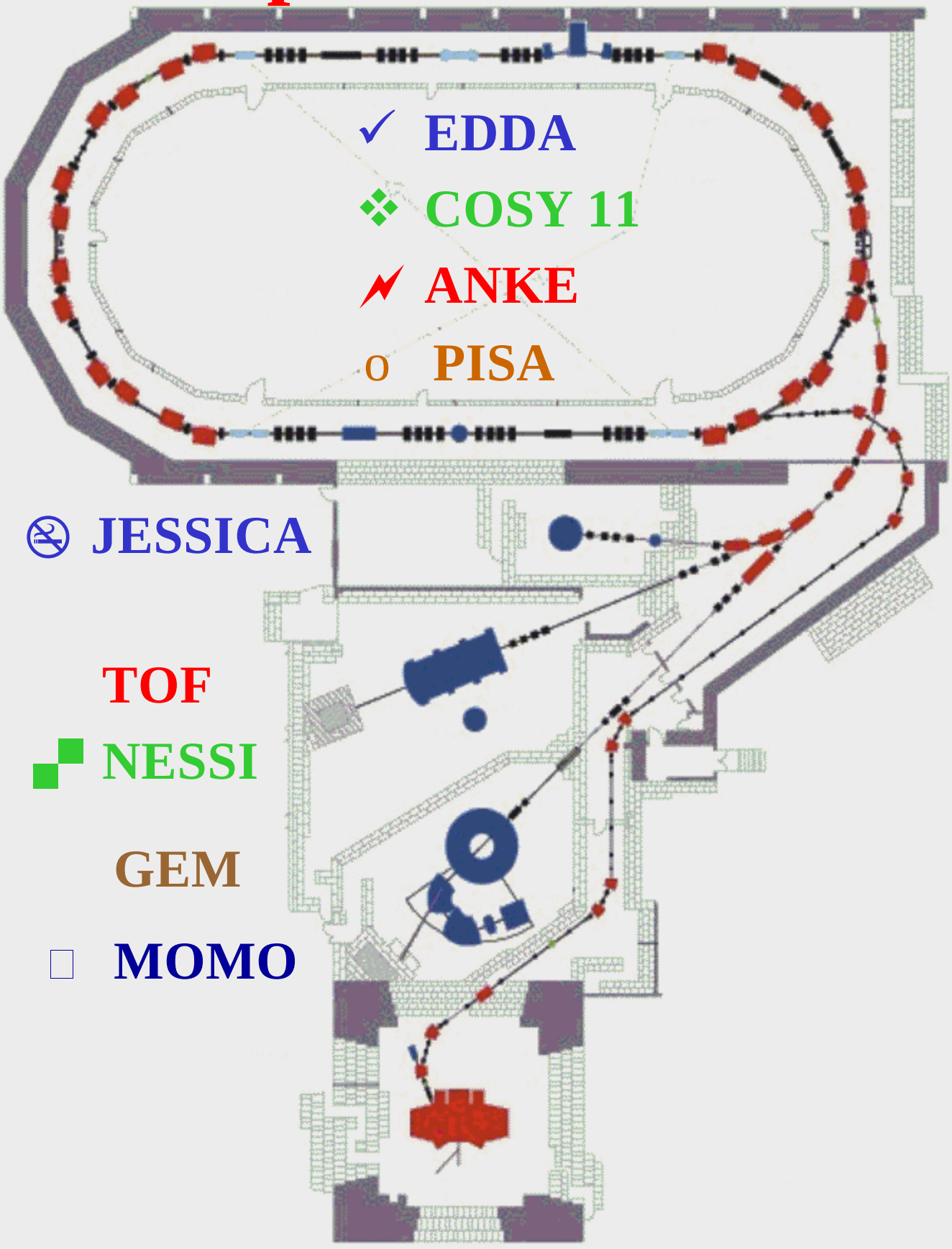


- More than 7.700 hours per year scheduled beam time
- reliability of more than 90%

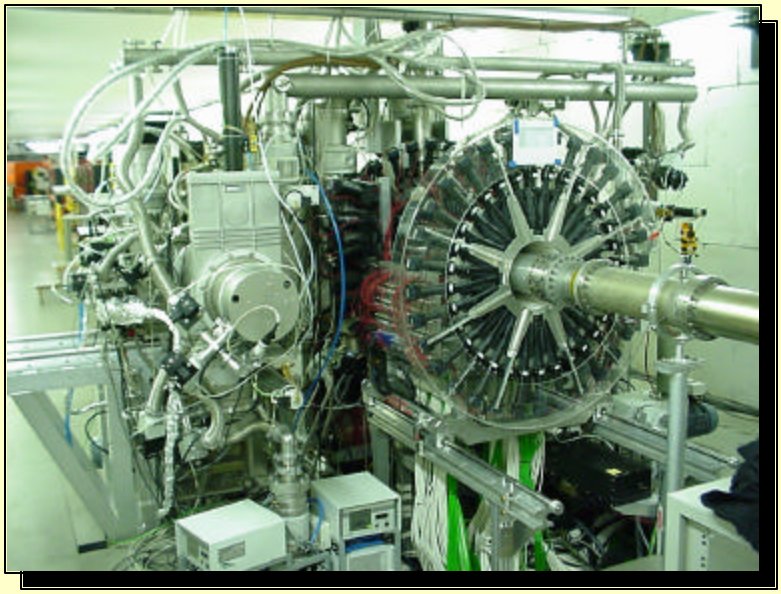


- External and internal experiments nearly equally distributed

The Experiments at COSY

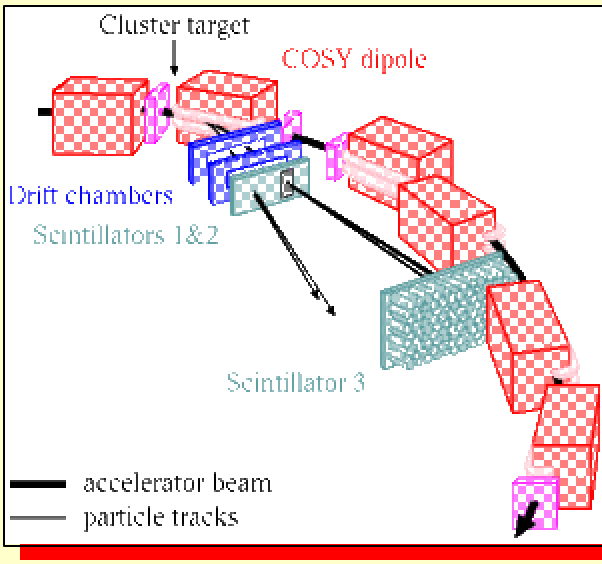


The Internal Experimental Areas



EDDA

($\vec{p}$ - $\vec{p}$ measuremen ts)



COSY-11

(Strangeness production)

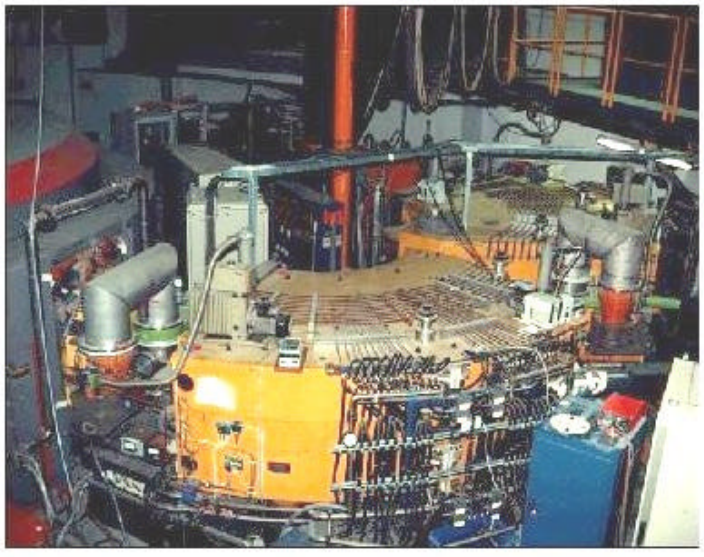
ANKE

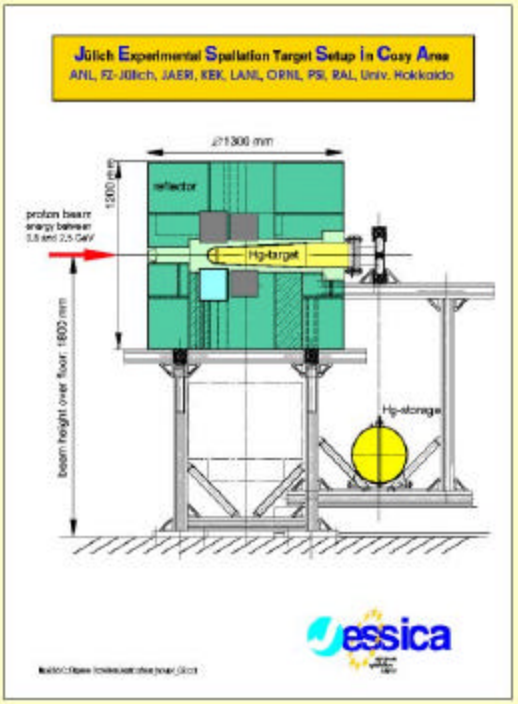
(Kaon production)

External Experimental Areas

***T*ime *o*f *F*light spectrometer**

Magnetic Spectrometer BIG KARL





JESSICA

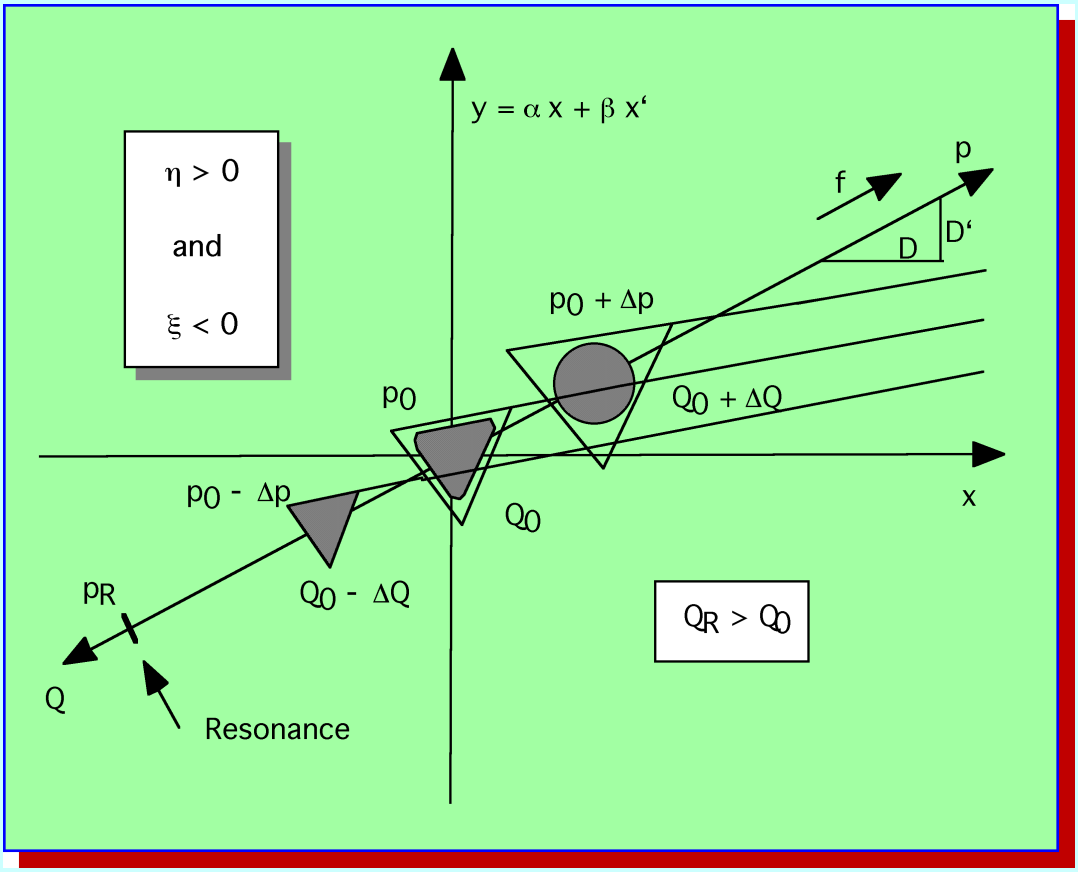
Horizontal Phase Space at the Extraction Septum

The area of separatrix is proportional to

- ***the distance to the resonance $dQ = Q_{Res} - Q$***

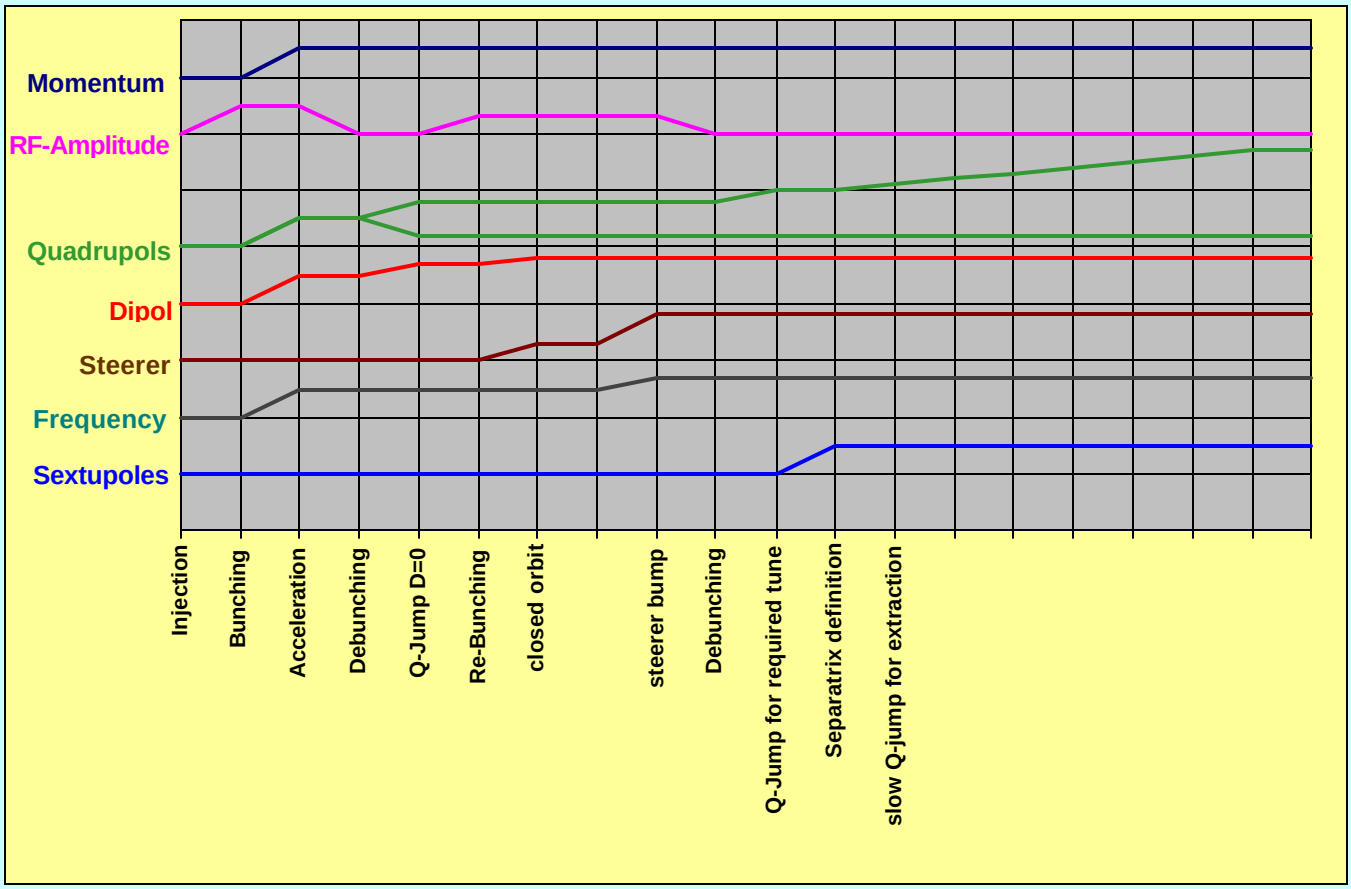
and

- ***the inverse of the sextupole strength***

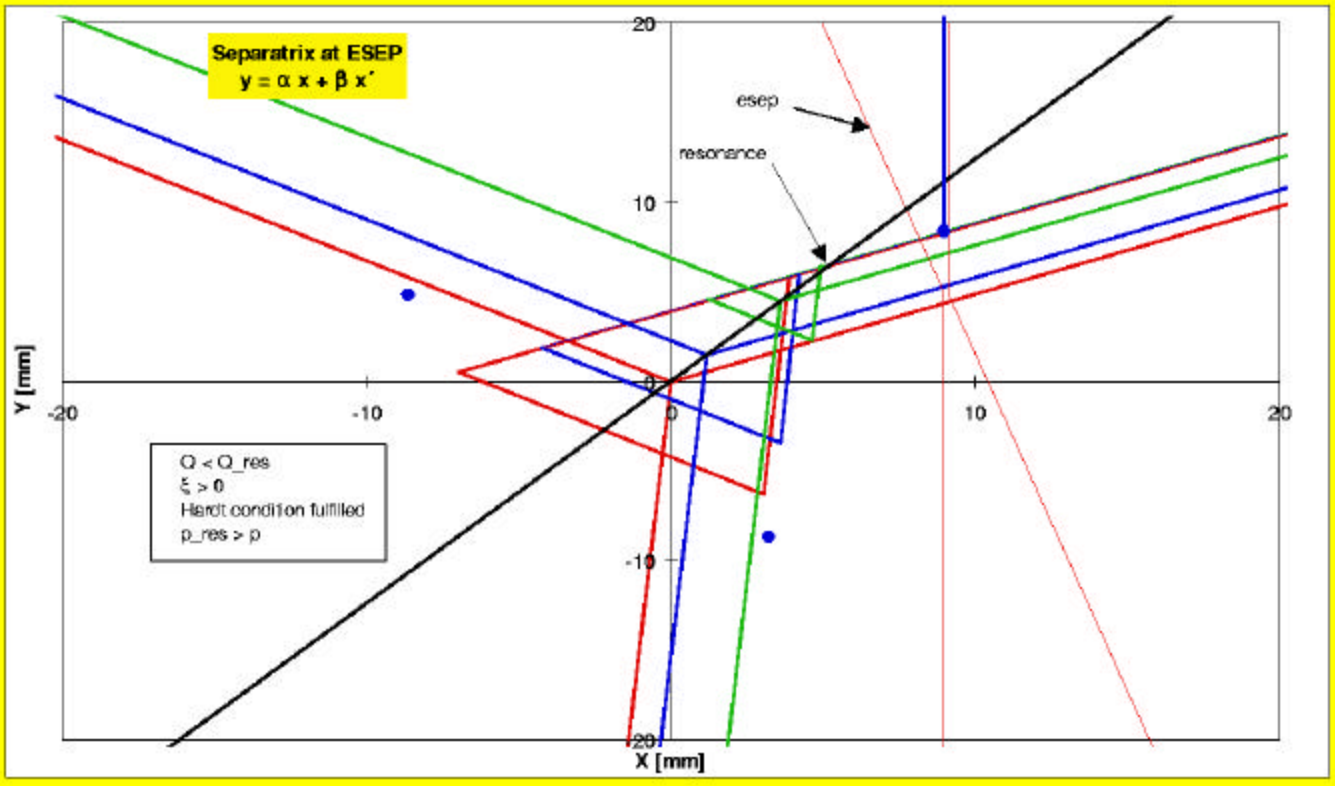


Extraction at COSY

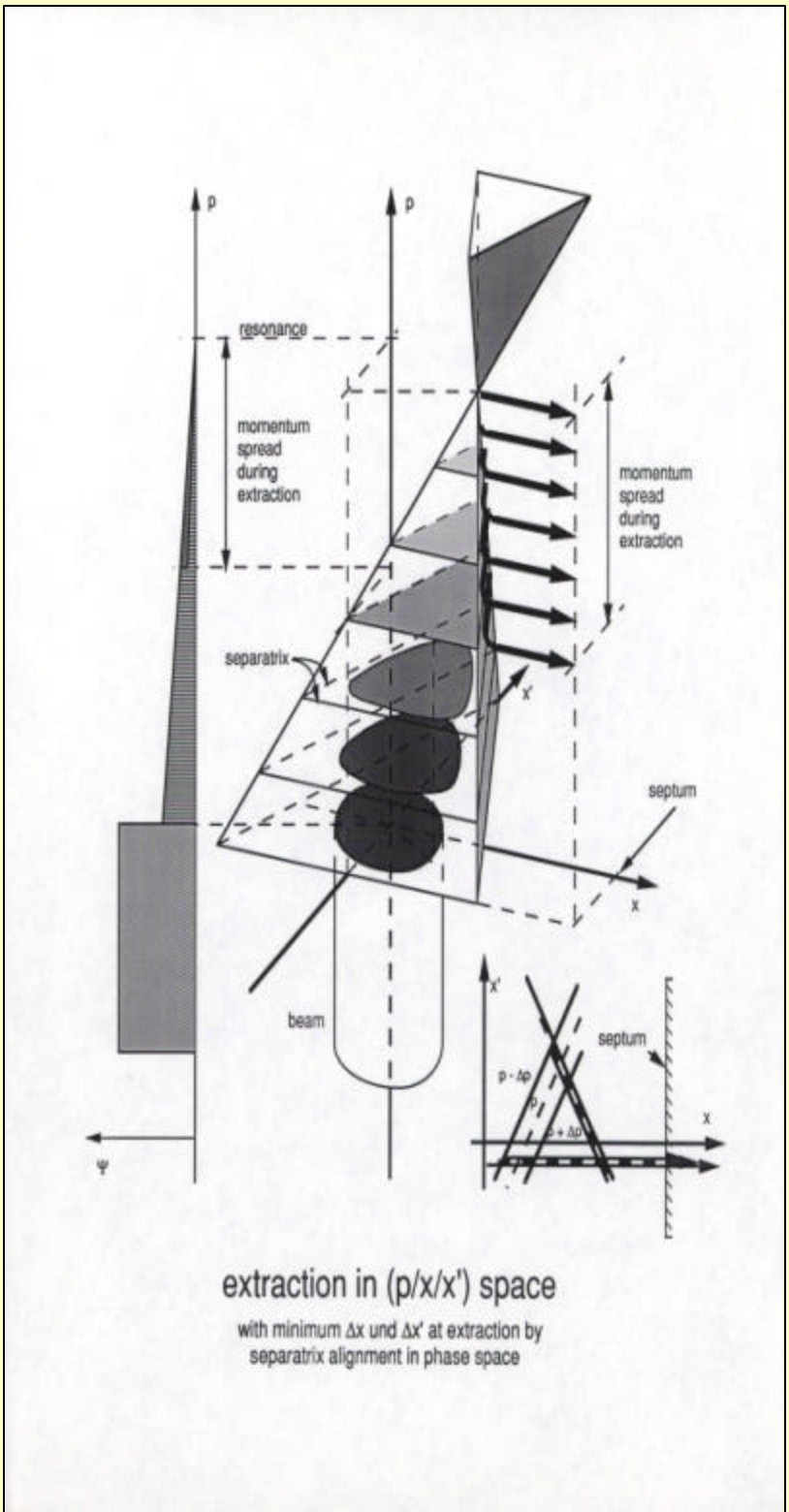
- The first extraction experiments were carried out with pure resonance extraction on the 11/3-resonance



The Separatrix



Pure Resonance Extraction



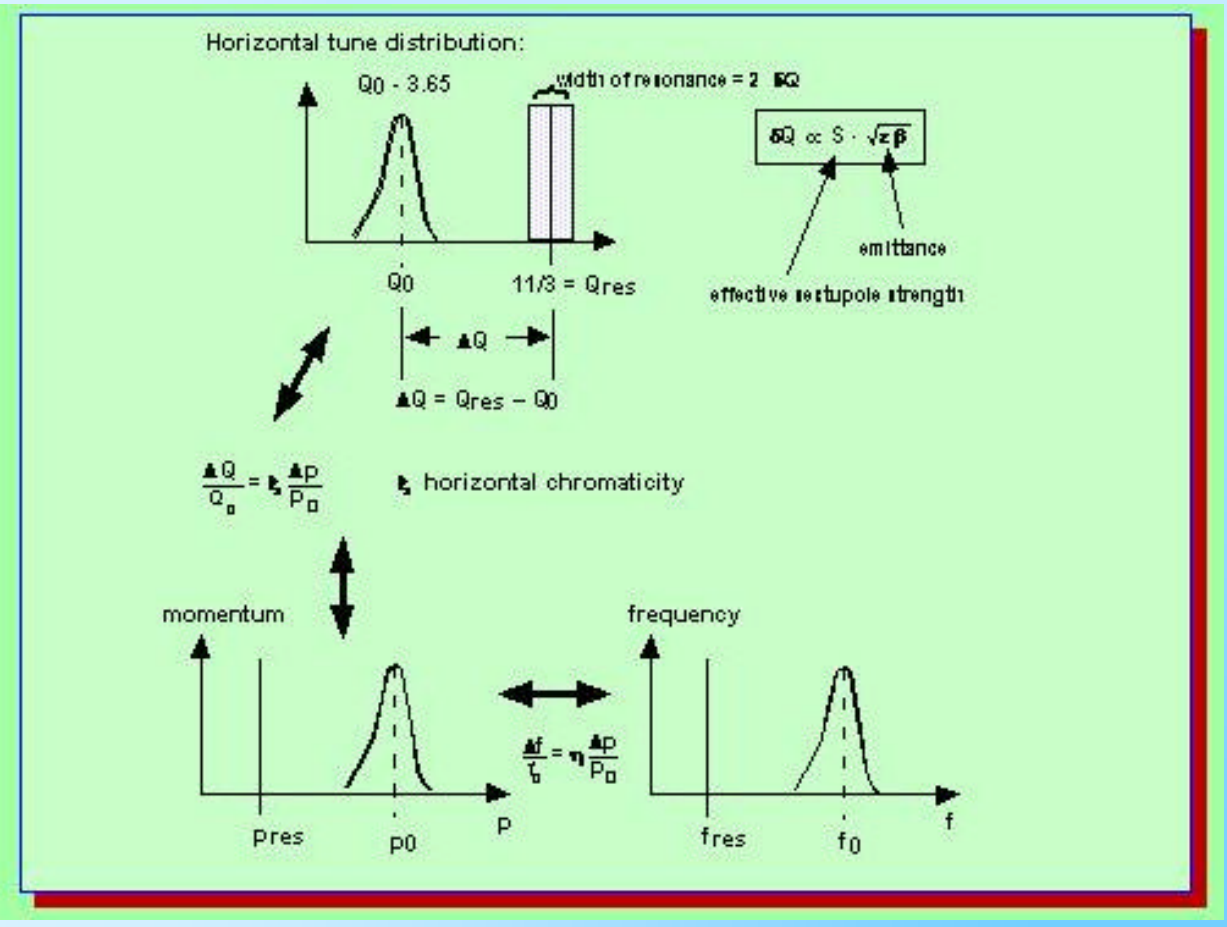
- Quadrupoles with a slow ramp move the tune slowly towards the 11/3 resonance
- Sextupoles define the orientation of the separatrix

⇒ The whole primary momentum spread is extracted

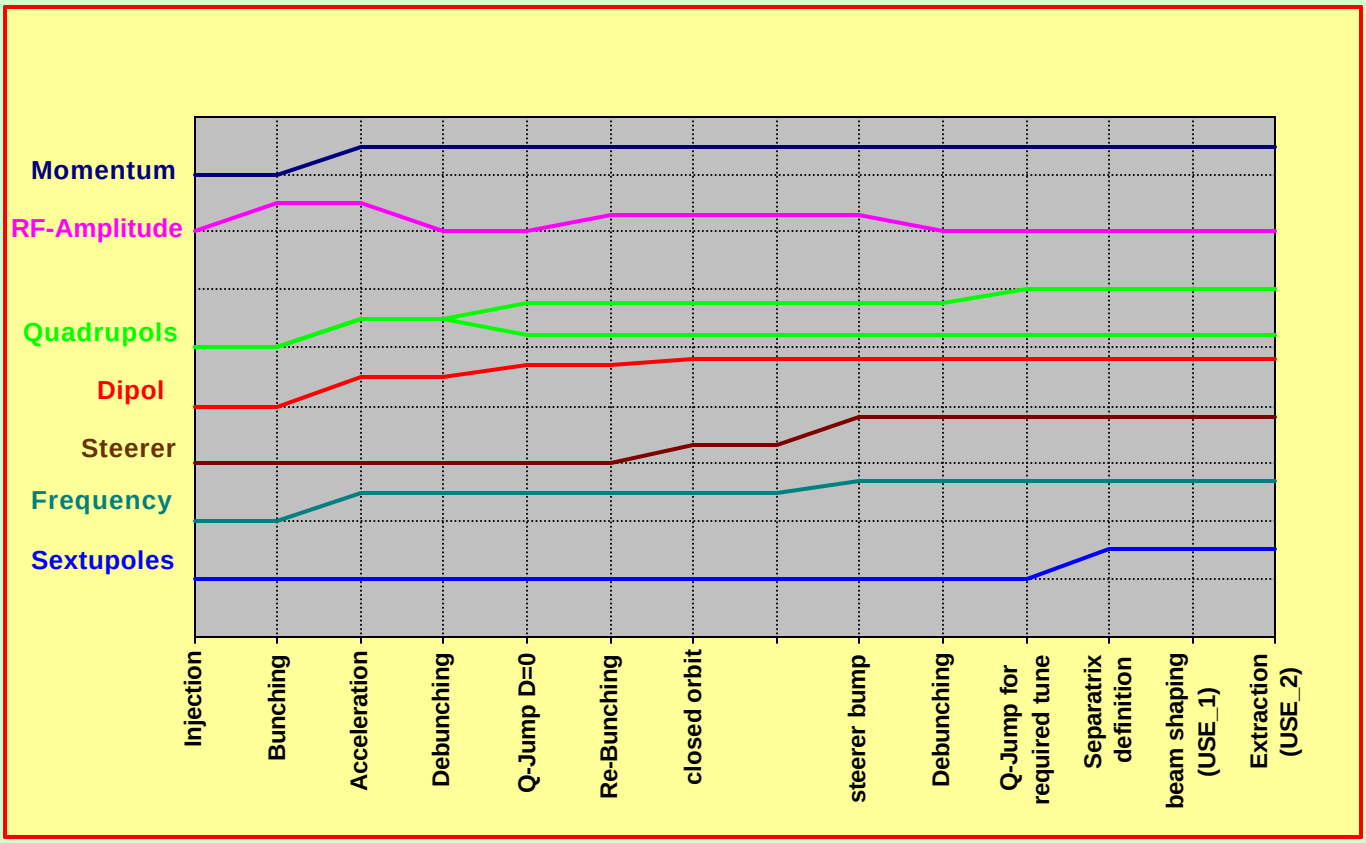
⇒ The spill structure is sensitive to power supply ripple

Stochastic Extraction

Relation between Tune Distribution and Frequency Distribution

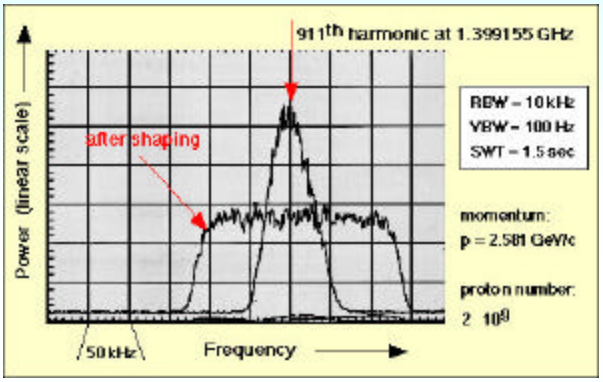


Beam Gymnastics for the Stochastic Extraction

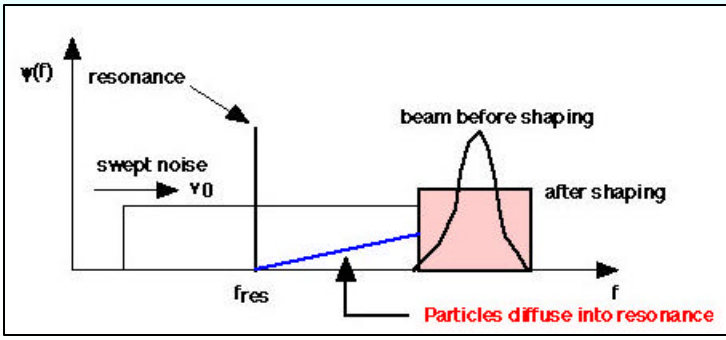


RF-Manipulation for the Extraction

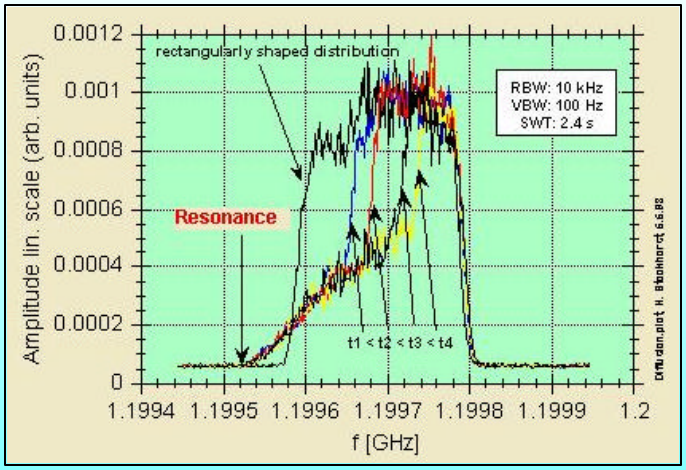
Rectangular frequency spectrum flattens the momentum distribution

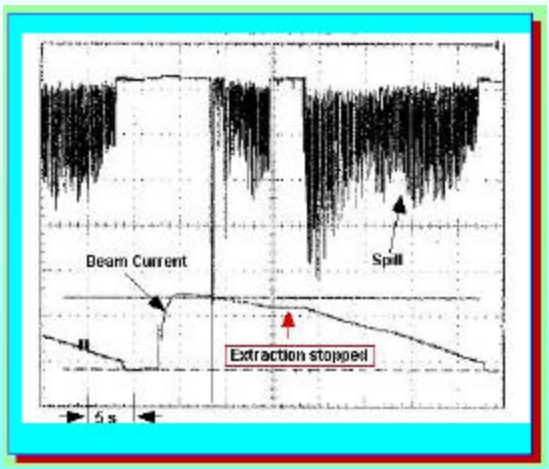


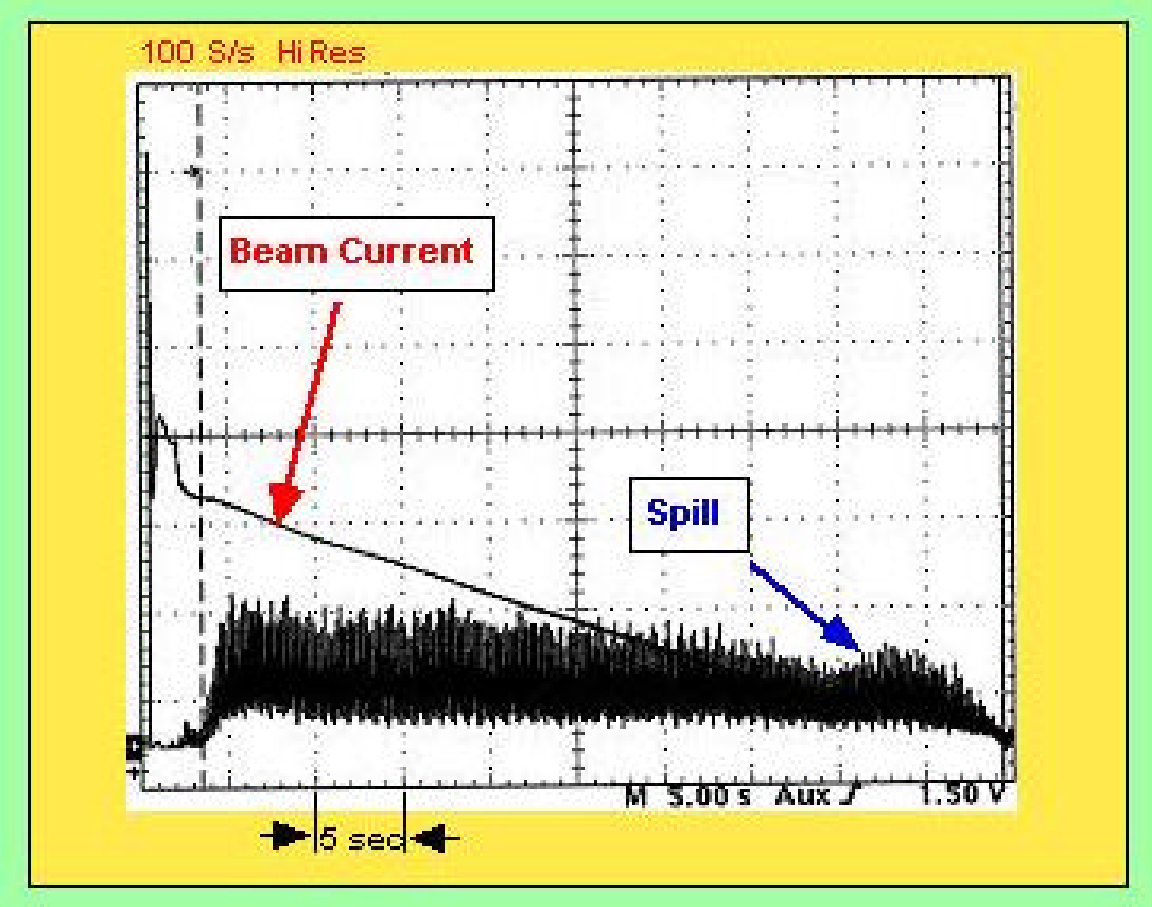
Sweeping noise drives the ions into the resonance



Stopping the sweeping noise stops the extraction





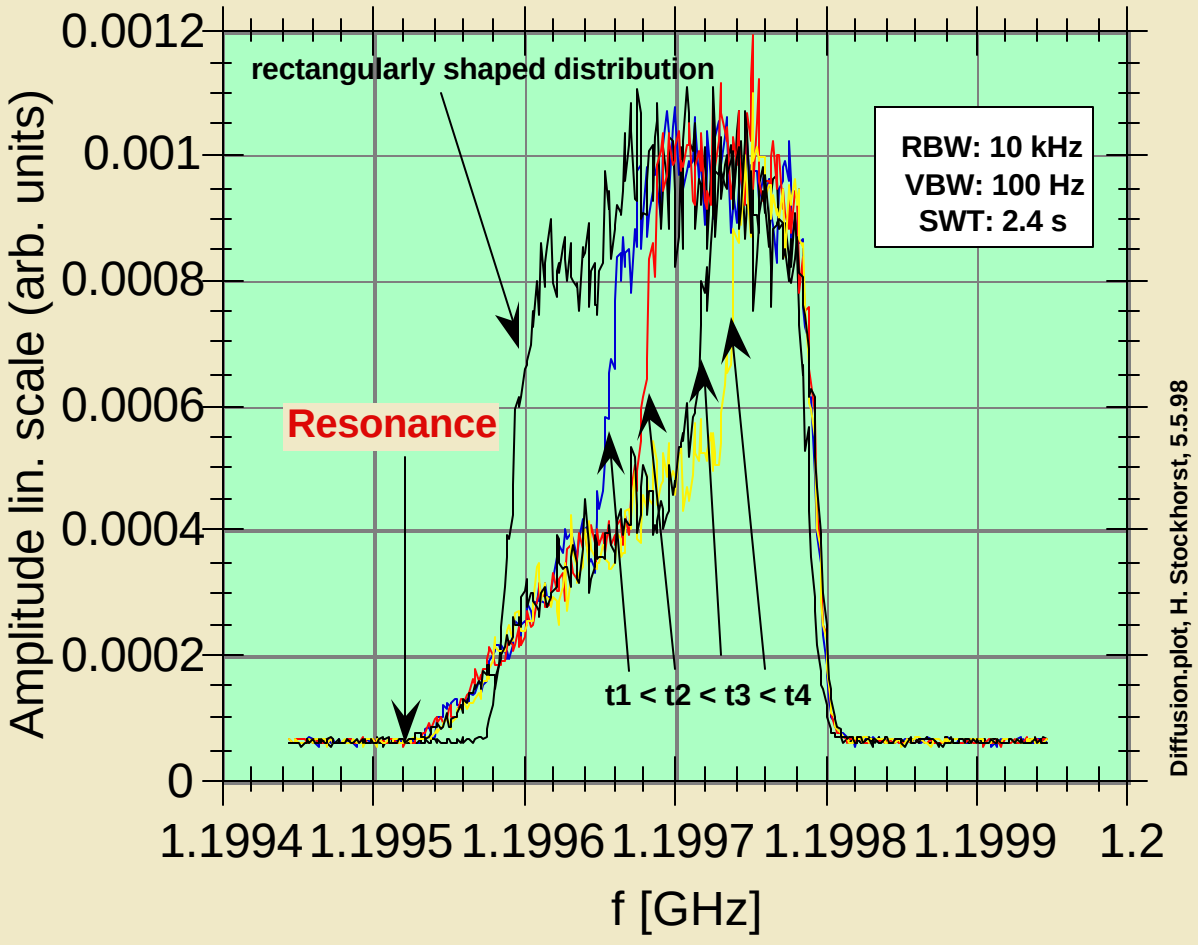


Stochastic Extraction leads to a uniform extraction rate.

The extraction can be prolonged over long times

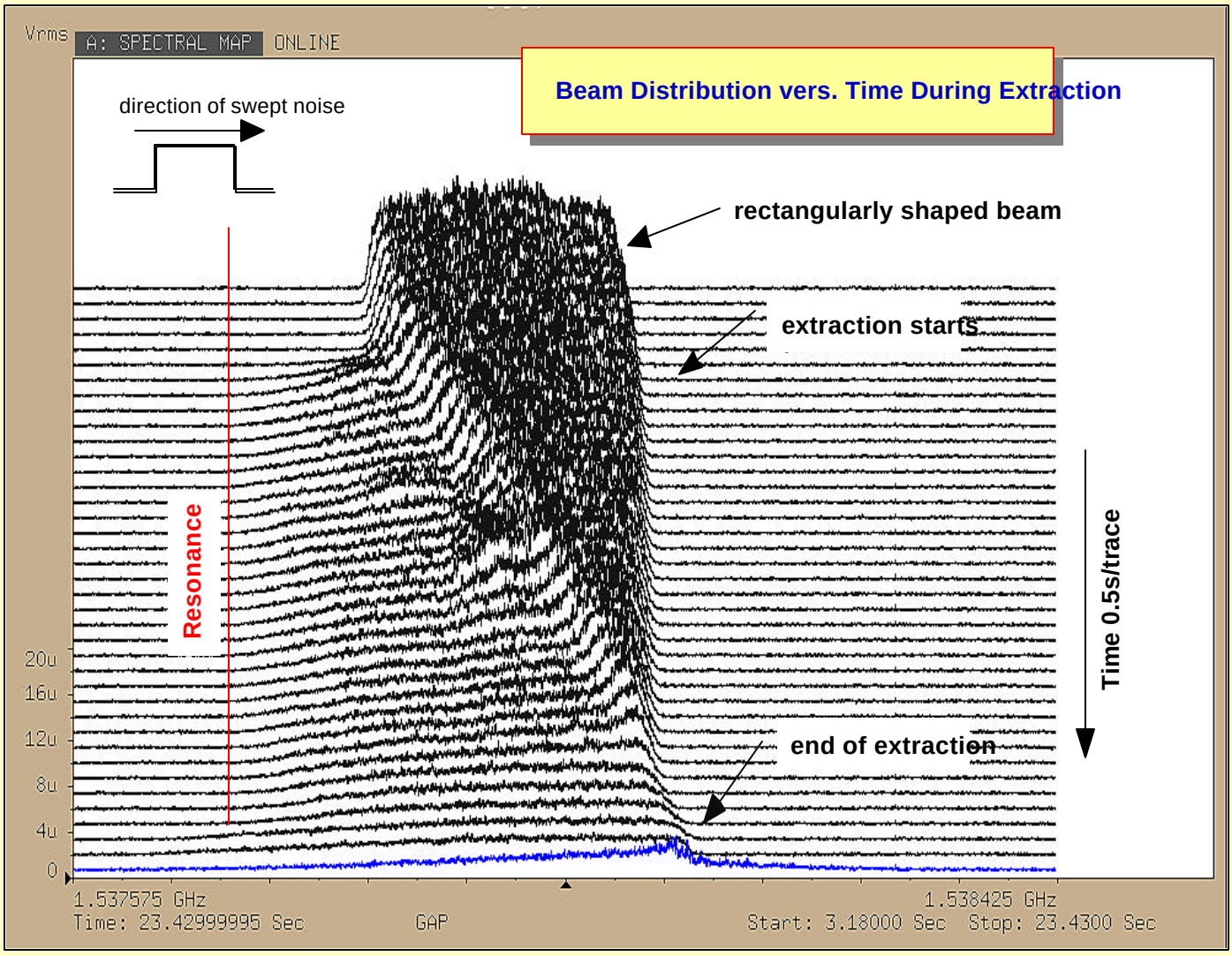
(up to 10 minutes for the NESSI experiment)

Time Evolution of the Particle Distribution during Stochastic Extraction at 2.6 GeV/c



Stochastic Extraction at 2.6 GeV/c

Experiment MOMO, KW 33/34 1999,
Spill length 20 s



Problems at COSY: "Halo" of the extracted beam

- Intensity of the uncooled extracted beam

$$5 \cdot 10^{10}\ protons$$

- Averaged proton beam intensity

$$1 \times 10^{10}\ \frac{protons}{s}$$

- But: Counting rate on a detector with a 3 mm hole (veto-counter):

$$\frac{1}{100}$$

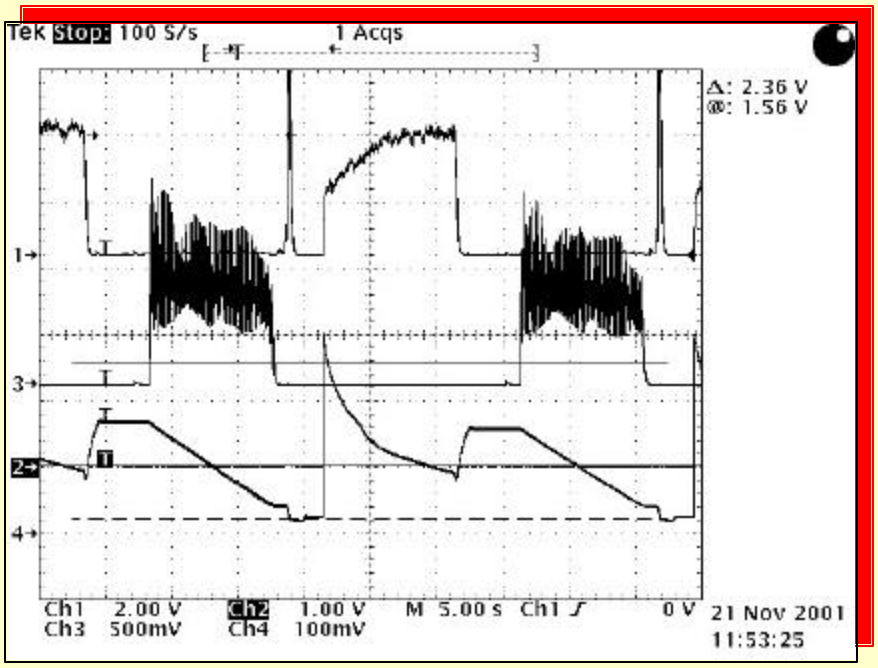
Solution:
Electron Cooling at Injection, Acceleration and Extraction

- Averaged proton beam intensity

$$3 \times 10^{8} \; protons / s$$

- Counting rate on the veto counter

$$\frac{1}{2000}$$



Additional Difficulty: Extraction of Polarised Protons

- Depolarising Resonances

  $\Rightarrow$ **Forbidden momenta**

The Depolarizing Resonances for Protons in COSY

(G_{proton} = 1.792846, Q_y = 3.667 for extraction)

Momentum MeV/c	Kinetic energy MeV	Relativistic Lorentz factor γ	Imperfection resonance $\gamma \cdot G = \ldots$	Intrinsic resonance $\gamma \cdot G = \ldots \pm Q_y$
463.9	108.4	1.116	2	
781.2	282.7	1.301		6-
1033.3	457.5	1.488		-1+
1258.8	631.7	1.673	3	
1470.4	806.0	1.859		7-
1674.1	980.8	2.045		0+
1871.3	1155.1	2.231	4	
2064.4	1329.4	2.417		8-
2255.0	1504.1	2.603		1+
2442.7	1678.4	2.789	5	
2628.5	1852.7	2.975		9-
2813.4	2027.5	3.161		2+
2996.6	2201.8	3.347	6	
3178.7	2376.0	3.532		10-
3360.6	2550.8	3.719		3+

Fast Kicker Extraction at COSY

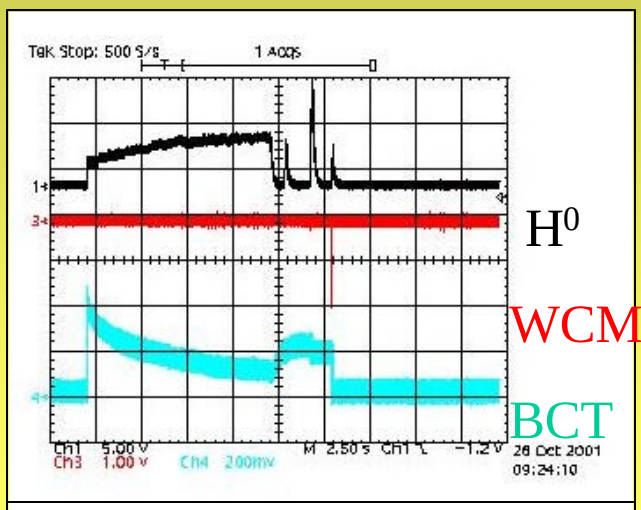
- COSY has never planned a kicker extraction, so no extraction kicker is installed

- The only fast device is a diagnostic kicker, which allows the excitation of coherent betatron oscillations by a small angle kick

Solution:

1. We cool the beam at injection energy
2. The beam is accelerated
3. A closed orbit bump moves the beam as close as possible to the electrostatic septum
4. The diagnostic kicker moves the beam across the septum foil

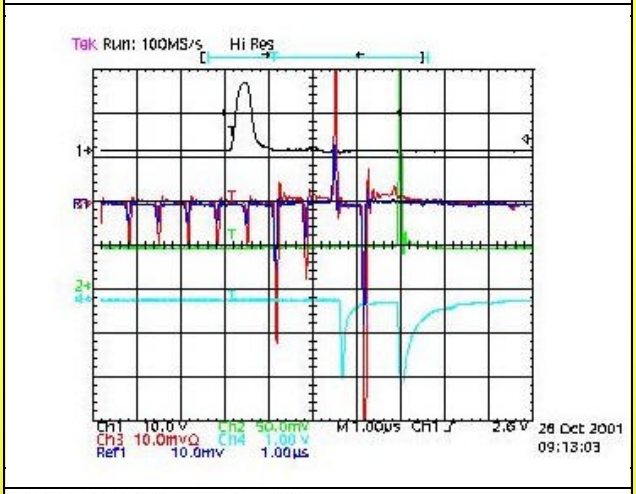
Fast Extraction of the Electron Cooled Beam

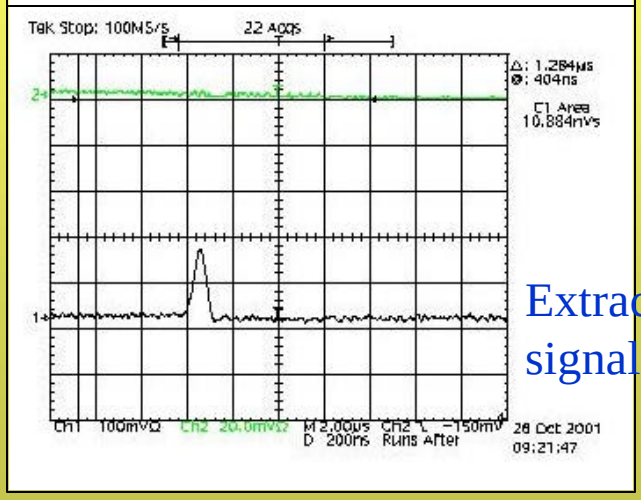


H^0

WCM

BCT





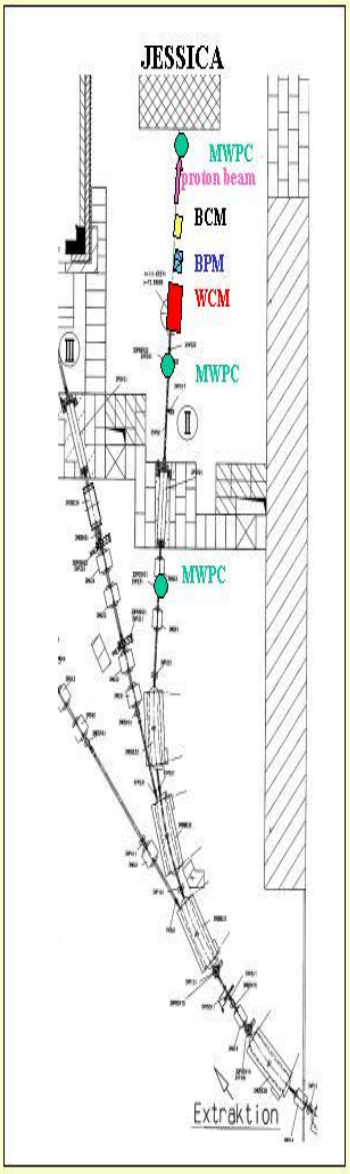
The electron cooled beam is kicked by the diagnostic kicker

$2 \cdot 10^9$ Protons extracted in 200 ns

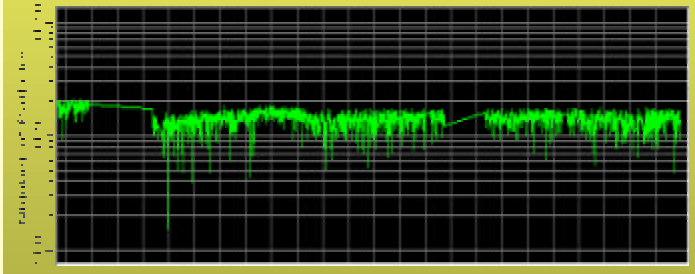
Extracted beam signal

Monitoring of Intensity and Position of the pulsed beam

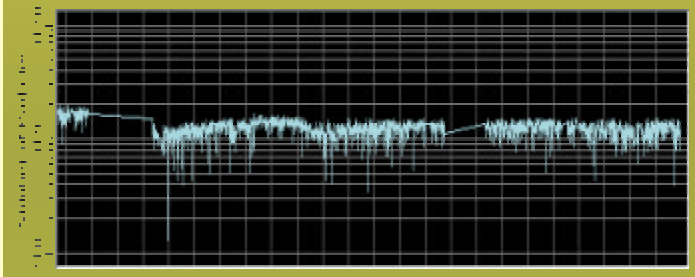
Beamline to JESSICA



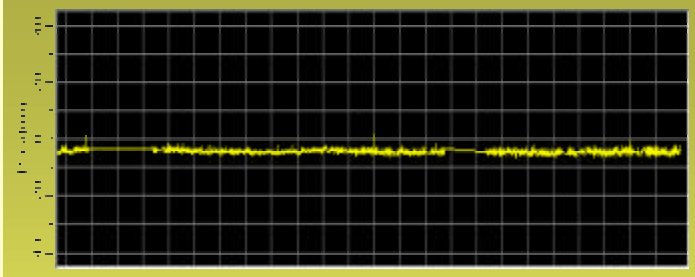
JESSICA Horizontal Intensity Plot



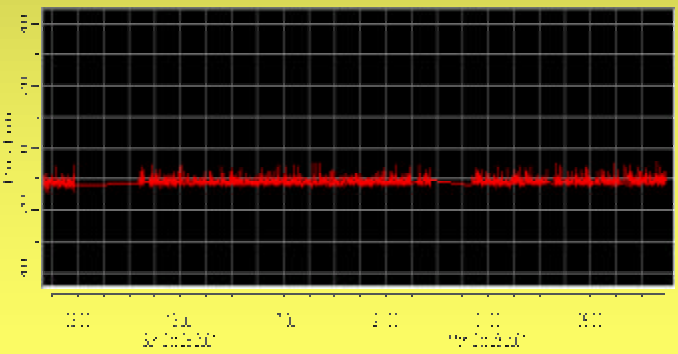
JESSICA Vertical Intensity Plot



JESSICA Horizontal Position Plot



JESSICA Vertical Position Plot



Summary

- With the pure resonant extraction an extraction efficiency between 50% and 60% were achieved
- The stochastic extraction allows extraction efficiencies up to 90%
- The kicker extraction, though never planned, is possible only due to the electron cooling

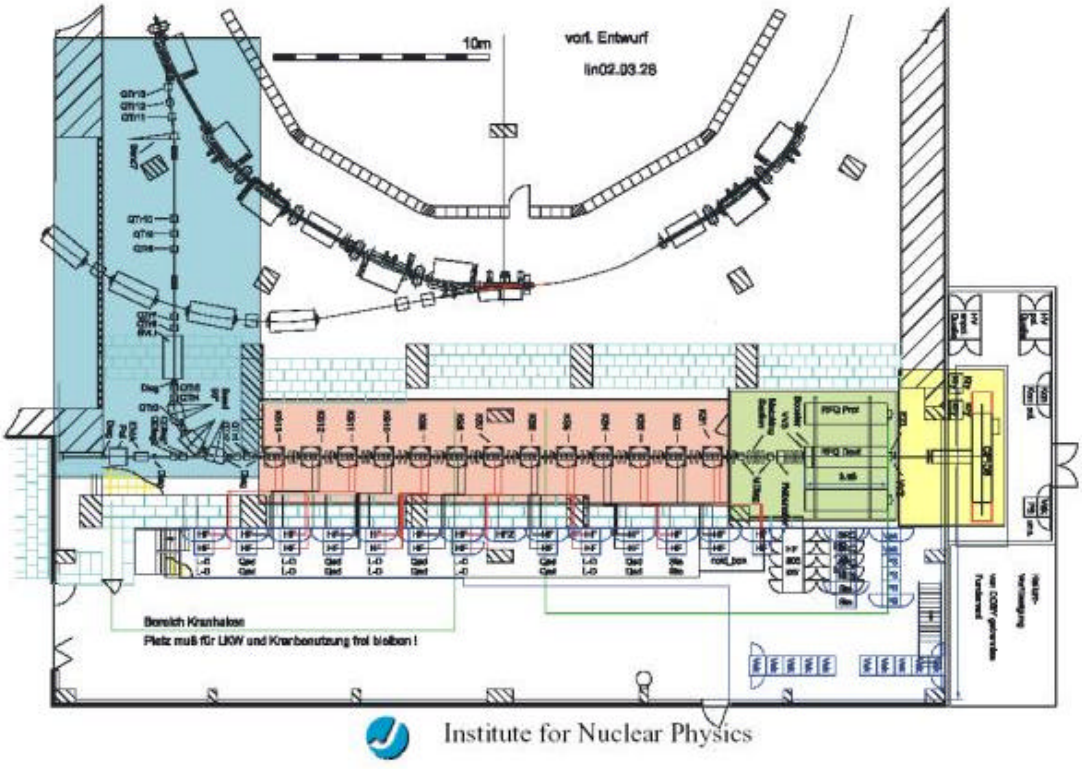
Future Project:

The **S**uper **C**onducting Injector **L**INAC for **COSY**

Motivation:

Fill COSY with *polarised* protons and *polarised* deuterons up to the space charge limit (presently limited by the ion source and the transmission through the cyclotron)

Installation in the existing COSY Hall



LINAC Parameters

Key components

Polarized Ion Source	Like CIPIOS @ IUCF Peak current < 2 mA pol. H^-, pol. D^- Pulse length < 500 µs extraction energy 25 keV for both ion species normalized emittance 1.2 π mm mrad for H^-, 1.6 π mm mrad for D^- operation pulsed dc repetition rate 2 Hz
RFQ section	Elements: Einzel-lens + RFQ + focussing cavity Interchangable with Einzel-lens + RFQ + 1 MeV booster cavity Followed by beam matching system Frequency 160 MHz Extraction energy 2.5 MeV for H^-, 5 MeV for D^- RF power (RFQ, booster) 600 kW 125 kW Cryoplant power rating 150 W @ 4.2 K, 2 kW @ 60 K Aperture and gradients Ø 38 mm with 45 T/m
Linac section	Inspired by ALPI @ LNL/Legnaro (Italy) 52 (56) MeV final energy H^- (D^-), superconducting, 160 MHz up to 20 MeV, and 320 MHz up to final energy 44 half wave resonators with one solid state RF amplifier (3 kW) per cavity (amplitude and phase adjustable) total LINAC length < 19 m