Beam manipulation and purification

ENSAR meeting CERN 27-28/6

F. Wenander

Brief overview of:

Recent results
* Mass resolving tests
* REXTRAP upgrade
* Diamond detector results
* New fast tape-station

On-going projects
* MCP for stable beam counting
* Monolithic Si-detector as ΔE-E
* Polarized beams
* TwinEBIS setup
* Polarized post-accelerated beams

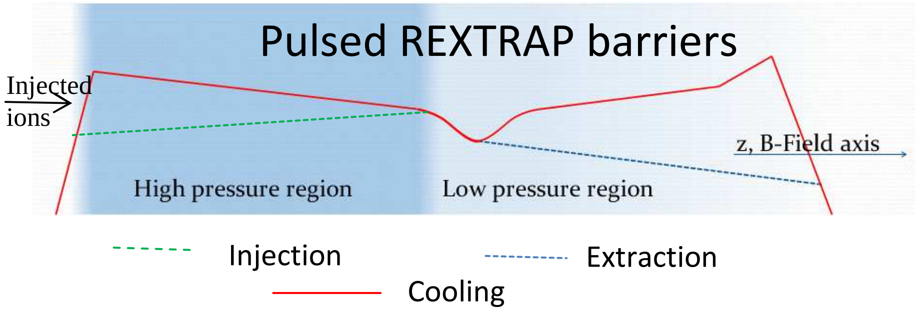
Future ideas
* Upgrade of REX charge breeder
* Going towards CW beams in REX
* REXTRAP-ISCOOL Ping-Pong
* "Super" resolution separator

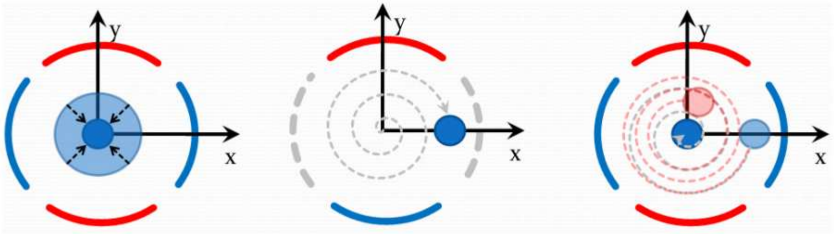
Isobaric mass resolution in REXTRAP

Challenges for isobaric separation inside REXTRAP:

1. Maintain efficiency
2. Rapid cooling
3. Large number of ions (compared with mass measurement)

1. ISCOOL used as cooler and buncher
2. REXTRAP for mass separation





Cooling 60 ms | Dipolar excitation 20 ms | Selective cooling 200 ms

Latest: Measure beam after the REXEBIS -> trap cooling sufficient

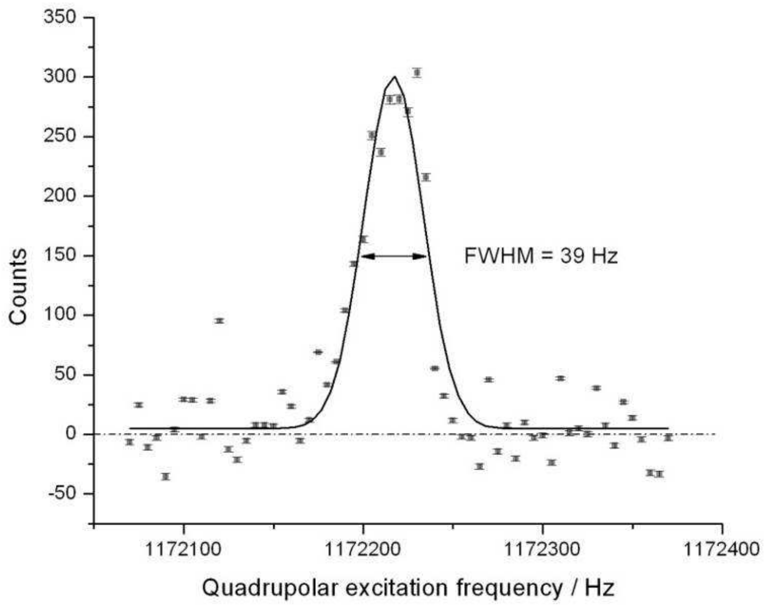
Work by:

S. Sturm, Master Thesis, Universität Heidelberg (2007)

S. Sturm et al. Investigation of Space-Charge Phenomena in Gas-Filled Penning Traps, AIP Conf. Proc. 1114, 185

A. Gustafsson, Mass-selective operation with REXTRAP Nucl. Instrum. Meth. 626-627, 8

Mass separation results and follow up



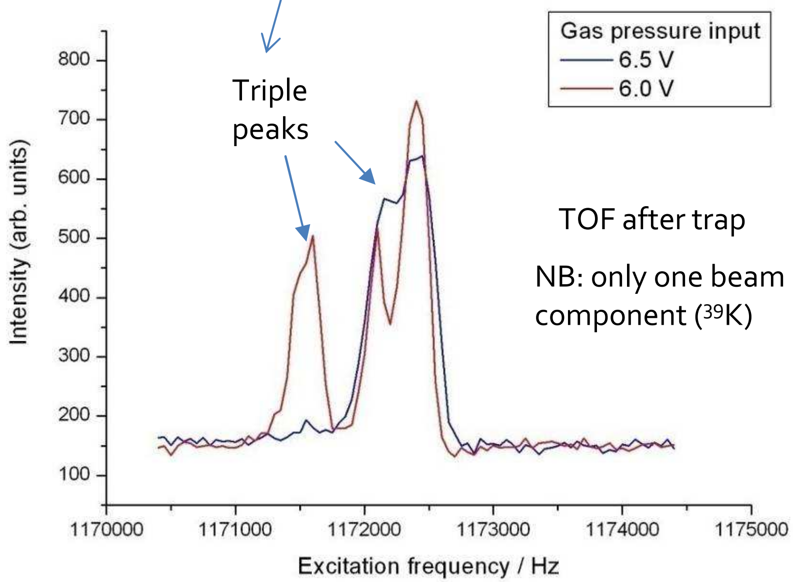
Resonance curve for ^{39}**K**
Mass resolution = **3.0e4**
REXTRAP + REXEBIS transmission **2.5 %**
98% suppression
ISCOOL used as pre-buncher and cooler

Compare with HRS resolution of 5000

Space charge effects > 1E6 ions/pulse

Frequency shifts – can be compensated for
Peak broadening -> reduced mass resolution
Limit includes stable contaminants

Multiple peaks appearing (for single element)



TOF after trap

NB: only one beam component (^{39}K)

Multiple peaks sometimes visible

REXTRAP upgrade

Complete renovation of REXTRAP auxiliary systems

controls, beam diagnostics, RF generation etc

1. RF excitation more linear over 0 Hz to 15 MHz

   no $\lambda/4$ notches as before

2. Easy setup of different RF excitation sequences
3. Quadrupolar, dipolar and rotating wall
4. Soon also backwards ejection

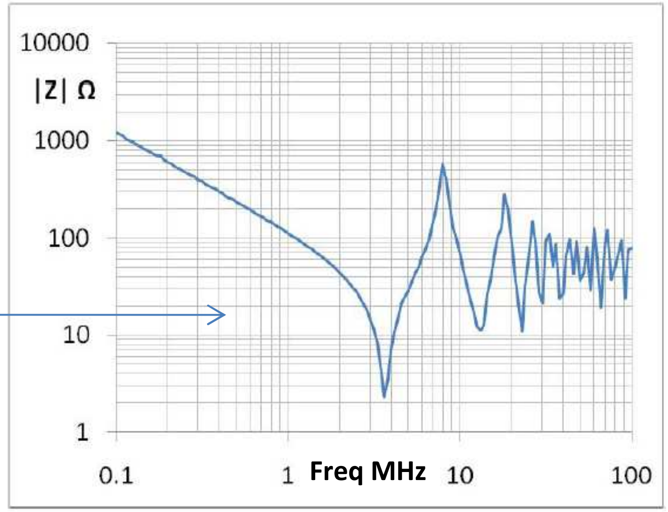
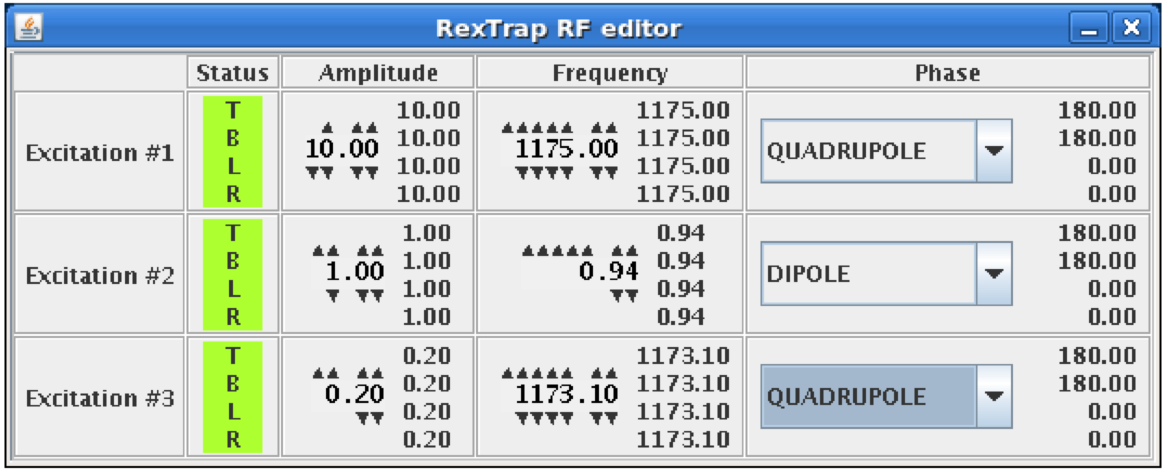


Fig. 1 – Measured amplifier load impedance

Courtesy of M. Paoluzzi, CERN

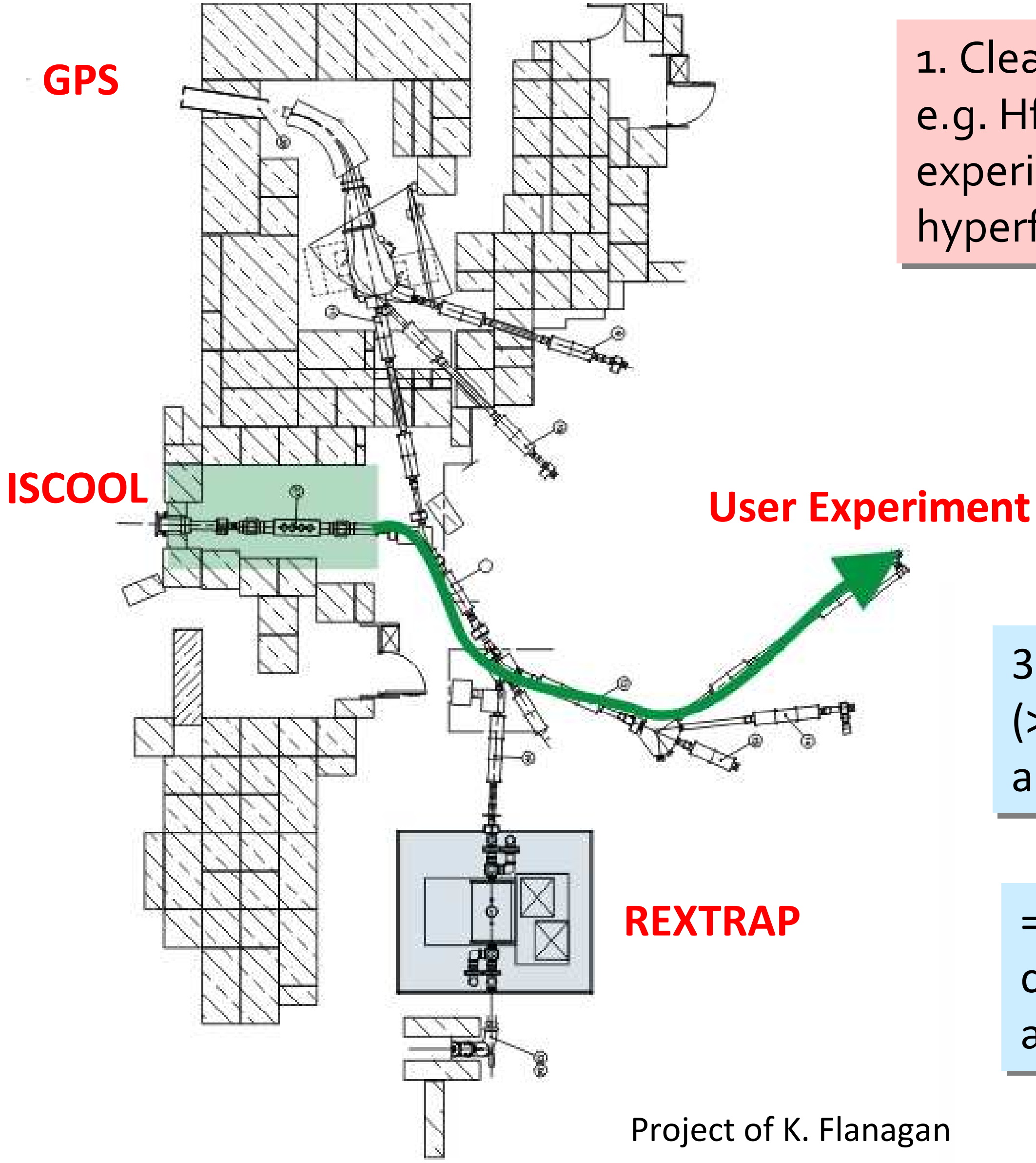


On the horizon

Better prepared in case of mass-resolving beams required

Future tests with octupolar and rotating wall cooling

REXTRAP-ISCOOL ping-pong



1. Clean side-band beam from GPS, e.g. HfF. But difficult for laser spectroscopy experiments to use molecular beams for hyperfine structure studies.

2. Use REXTRAP to break apart the HfF molecules. Send them backwards to ISCOOL.

3. Once trapped and cooled in ISCOOL (>5ms) the bunch would be released and directed to the experiment area.

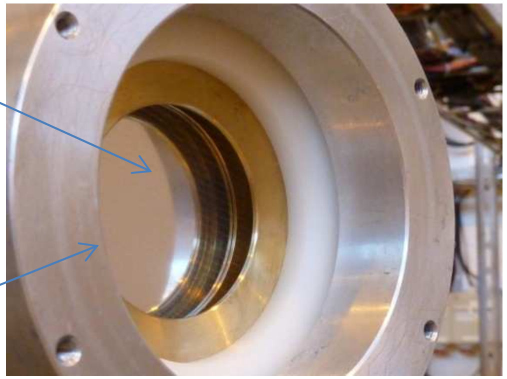
=> moments, spins and charge radii of neutron rich Hf isotopes and isomers can be studied.

Project of K. Flanagan

Beam identification

* Post-accelerated beams can suffer from severe (stable) contamination:
  isobaric (from ISOLDE or REX)
  non-isobaric (from REX) contamination

* Until now the beam composition analysis has been handled by the experiment



Gas-Si telescope detector at Miniball
* Work horse at REX, Z<40
* Isobaric resolution
* Difficult to improve resolution

Isobaric resolution results with ΔE-E (gas-Si) for 3 MeV/u beams

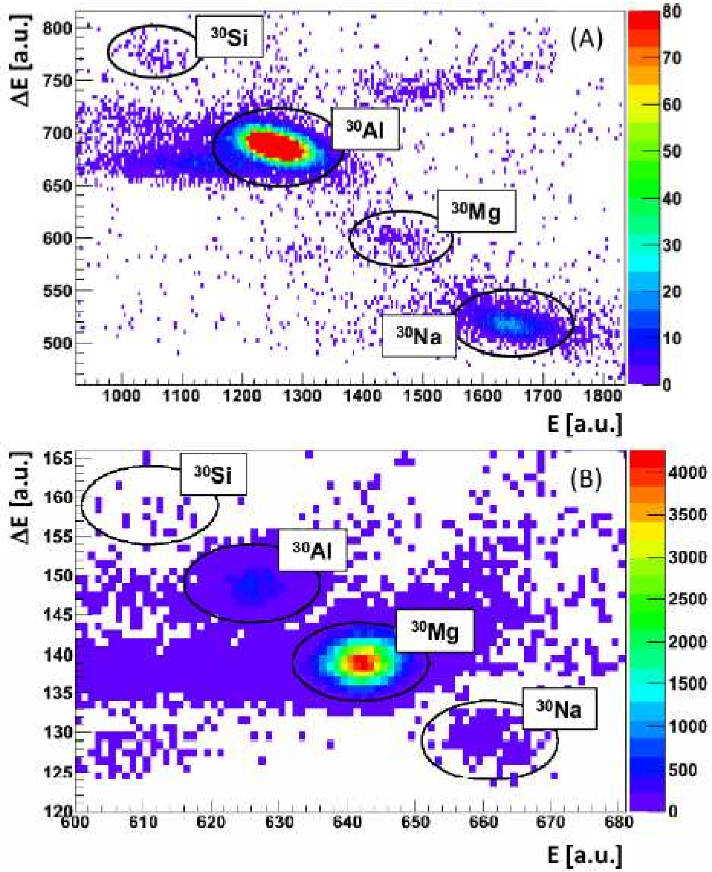
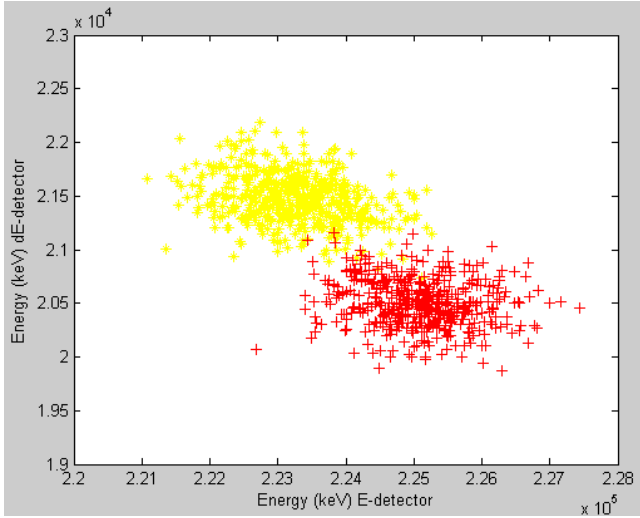


Fig. 20. Δ-E spectrum, measured with a radioactive A=30 beam, produced with a standard surface ionization ion source (A) and with a laser ion source (RILIS) tuned to resonance ionization of Mg (B). A huge enhancement of the laser ionized species is observed in (B).

Courtesy of J. van de Walle

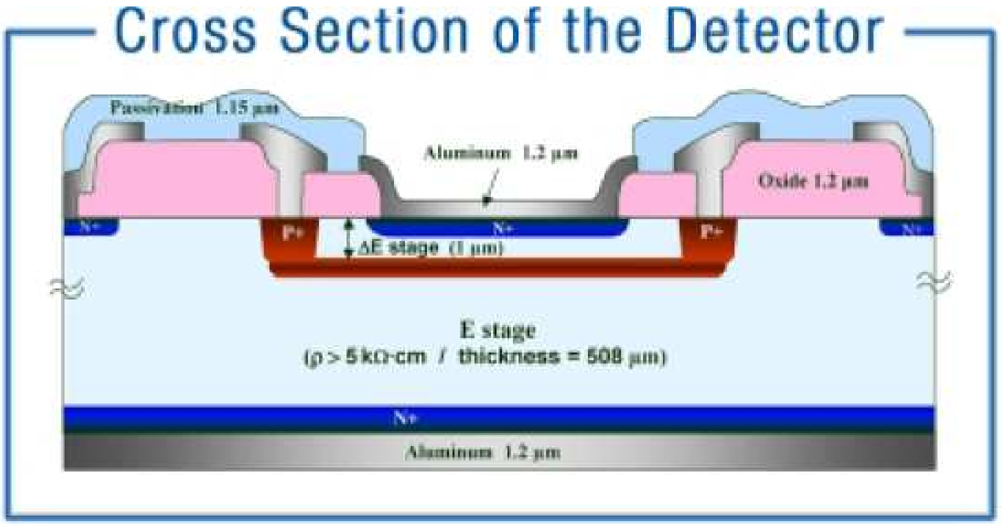
Monolithic Si detector as telescope

* ST Microelectronics in Catania made some integrated ΔE-E in Si
* Robust; no gas (risk); mounted on actuator before the experiment
* SRIM simulation suggests similar resolution as present ΔE-E (gas-Si setup)



Simulated the signal response in a monolithic ΔE-E detector.

Yellow=88Sr, Red=88Rb, 3 MeV/u, deltaE=2 um
Mean energy loss in dE: Sr=21477 keV,
Rb= 20561 keV, difference= 916 keV
Standard deviation in dE: Sr= 258 keV, Rb= 1264 keV
Mean energy difference / Standard deviation = 4.9



This monolithic silicon telescope allows simultaneous charge and energy determination of heavy ions with low energy threshold.

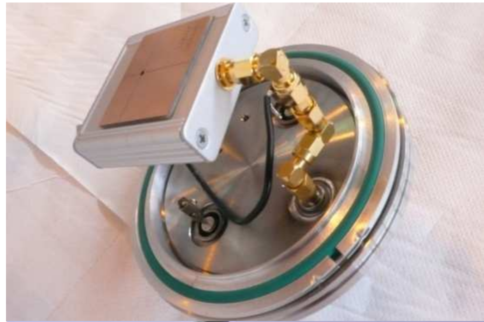
Courtesy of ST Microelectronics

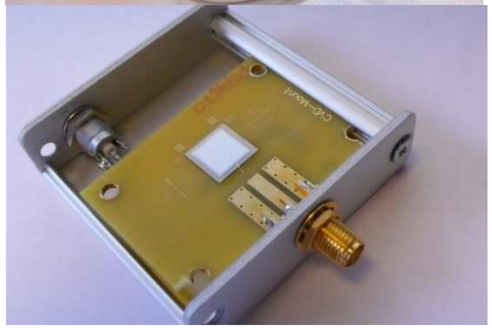
Tentative beam test with Sr/Rb beam (Z=37,38) in autumn 2011. Detector setup from and specialist support by O. Tengblad.

Diamond detectors for REX beam diagnostics

Possible applications:

- intensity measurements: large dynamic range (from particle counting mode to pA) + radiation hardness
- energy measurements/beam composition
- ToF/bunch length/cavity phase measurements (fast response)



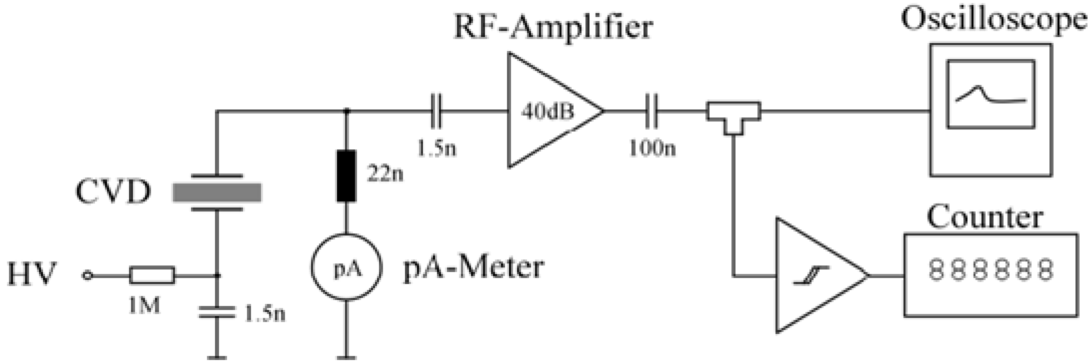


Test with poly-crystalline and single crystal CVD diamond detectors with C4+ and A/q=4 beam at 1.9 and 2.8 MeV/u

pCVD, 10x10 mm^2, 500 um thick
plated with square 8x8 mm^2 Al electrodes
thickness of 25 nm

sCVD, 5x5 mm^2, 500 um thick
plated with 3 mm diameter Au electrodes
thickness of 500 nm

Manufacturer: Diamond Detectors Ltd
own contact layers



Test 'outsourced' to:
E. Griesmayer, Vienna and Bergoz Instrumentation, St Genis, France

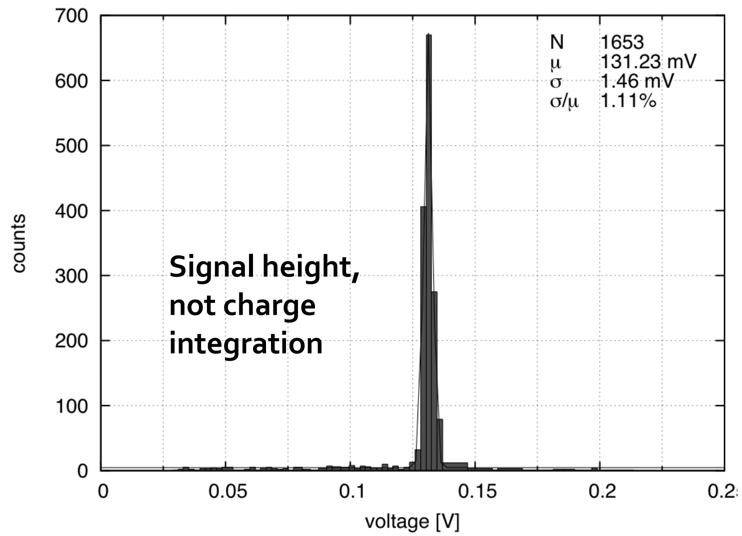
Diamond detectors results

For sCVD

+ Very low noise level (< 1mV)
  -> Noise discrimination easy

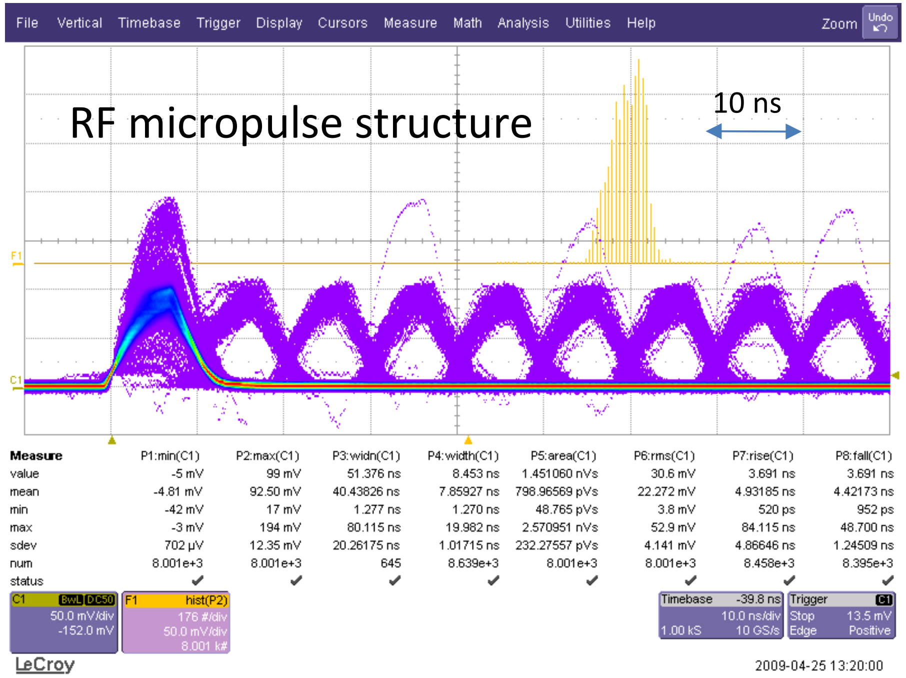
+ Particle counting up to 1E7 part/s

+ ~1% energy resolution 12C4+ 1.9 MeV/u
  with 1000 V bias



See also: 'High-Resolution Energy and Intensity…'.
E. Griesmayer et l., CERN-BE-Note-2009-028

Follow up of diamond tests by M. Parlog within HIE-REX framework



<u>Some problems with pCVD</u> :

1.fluctuating leakage current (tens pA to nA)

-> current amplification mode not viable

2. signal height polarity and time dependent

-> counting problems

3. signal size decreases with beam loading / time

-> position tuning difficult; always better at fresh pixel

-> counting problems

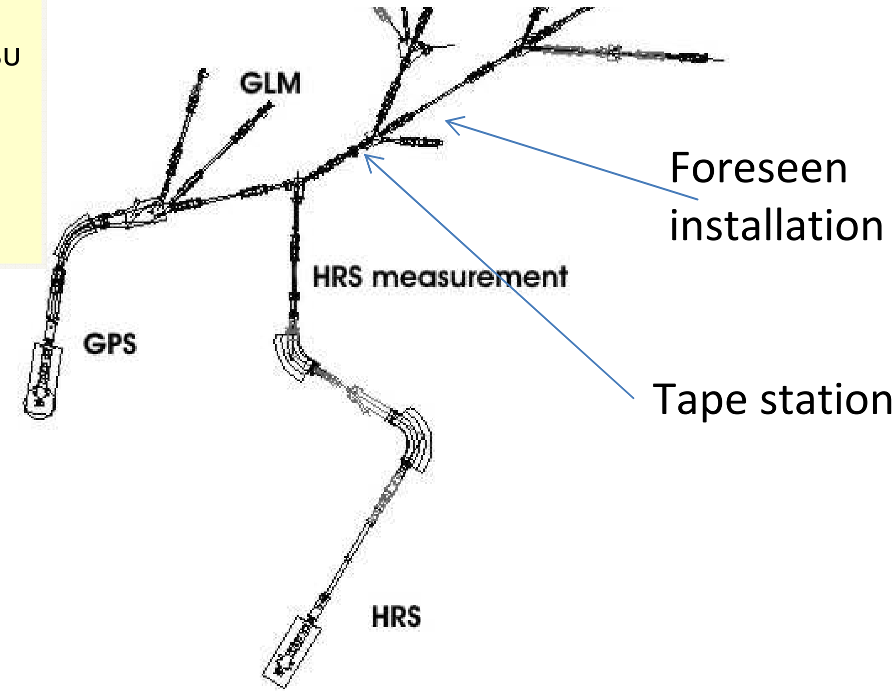
MCP in ISOLDE low-energy beam line

* Identification of stable isobaric beam composition not possible,
  only total particle counting
* Complement to the radioactive beam yield measurement

1. Initial tests with old MCP
   Particle counting rate (discriminator and counter or scope) showed too low values.
   Peak height distribution from anode signal not optimal?

2. New MCP ordered
   Double stage MCP F9890-13S221 from Hamamatsu
   Low-resistance extended range
   Negligible ringing
   Fast for TOF
   Counting rate up to 1E6 particles/s

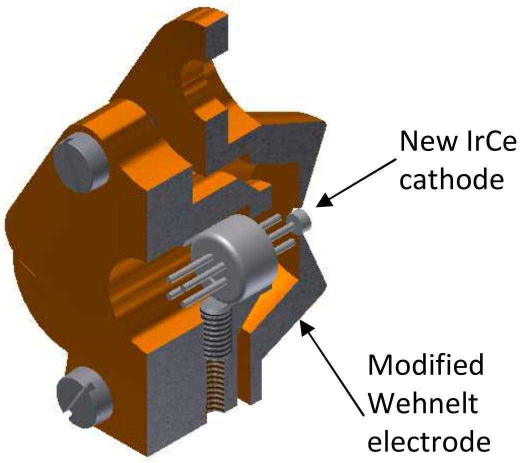
Courtesy of Hamamatsu



TwinEBIS testbench

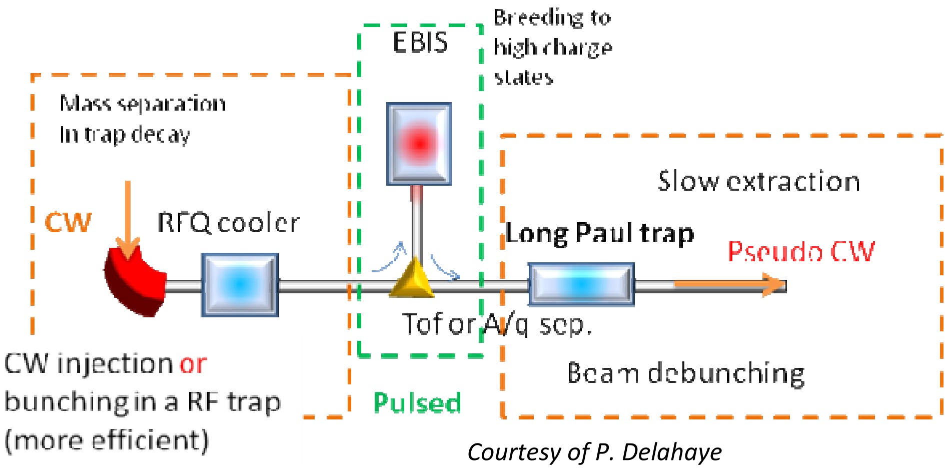
Act as:
1. spare solenoid for REXEBIS

2. test bench for new REX electron cathodes and guns



Courtesy of T. Berg

3. provider of highly charged ions (if possible) for cw trap tests (EMILIE proposal by P. Delahaye)



Courtesy of P. Delahaye

From Manne Siegbahn Laboratory

Collaborations and postdocs/students are welcome!

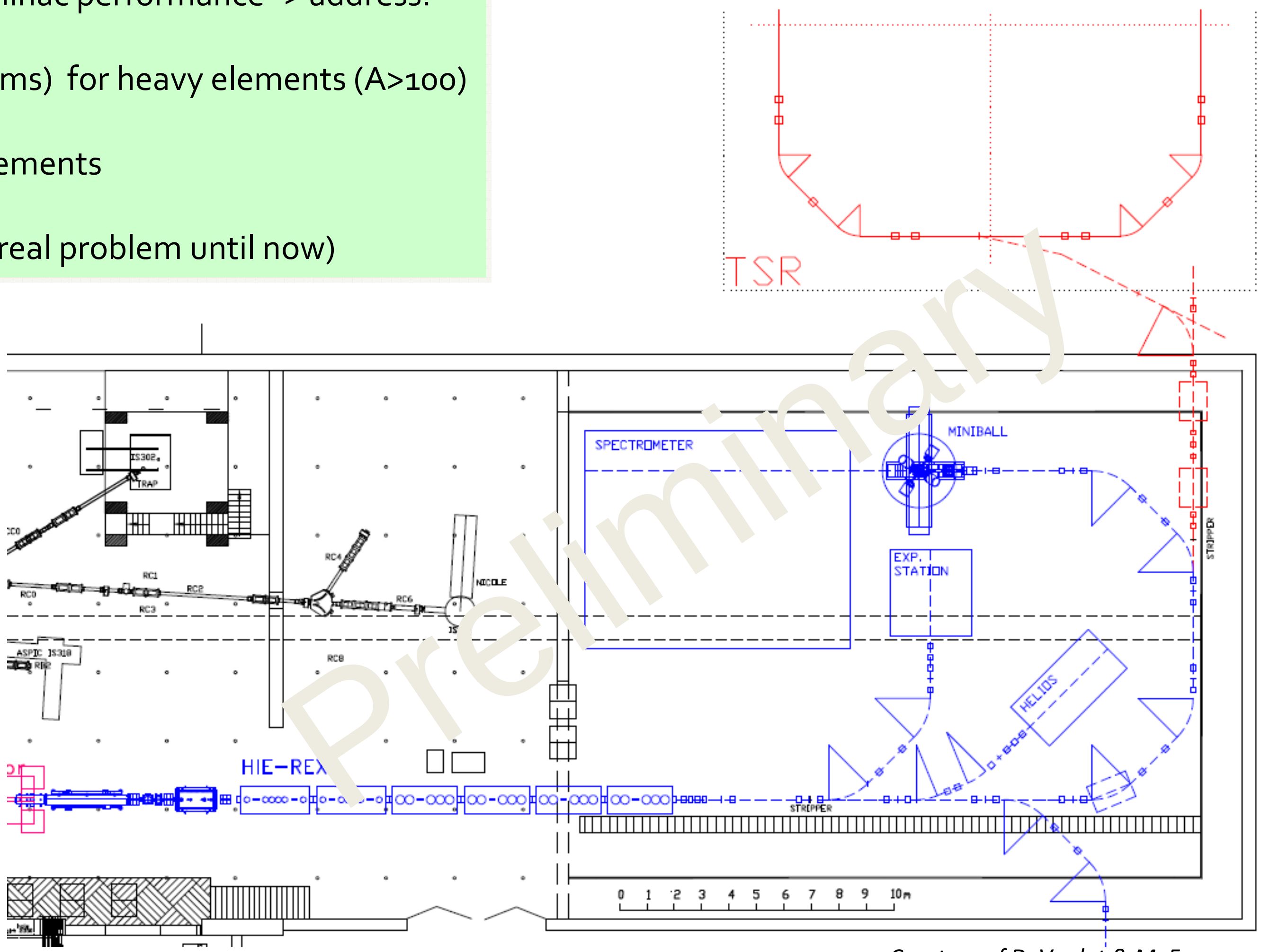
REX charge breeder upgrade

To fully make use of HIE-REX linac performance -> address:

1. Long breeding times (>100 ms) for heavy elements (A>100)

2. Low efficiency for heavy elements

3. Limited ion capacity (not a real problem until now)



Courtesy of D. Voulot & M. Fraser

* Design study within HIE-ISOLDE about to start

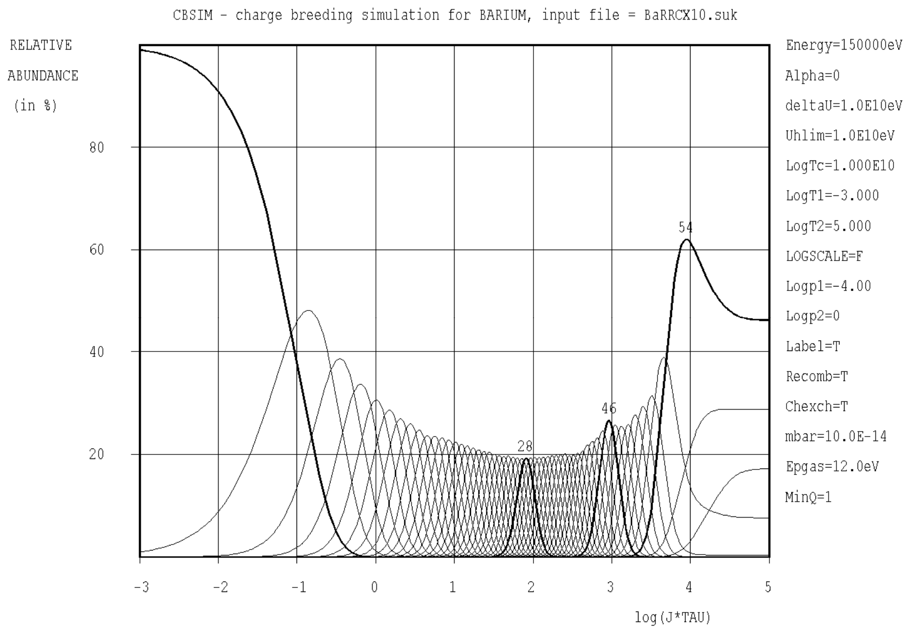
*** 2 years post doc post open within CATHI network**

What does Test Storage Ring require?

Preliminary TSR requirements

For most of the suggested experiments
REXEBIS + stripper foil after 10 MeV/u will give sufficient charge state

However some experiences require:
* Fully stripped to Z=60 (REXEBIS goes to Z=19)
* Few-electron system, ideally down to Li-like for very heavy ions, such as Th/U (REXEBIS goes to 56+)



Charge state development simulations for Z=56 for an electron beam energy of 150 keV. Radiative recombination has been included as well as charge exchange with a residual gas pressure of 1E-13 mbar and neutral ionization potential of 12 eV.

	Superbreeder	**REXEBIS**
Electron current	>5 A	0.3 A
Electron current density	>50 kA/cm2	150 A/cm2
Electron beam energy	>100 keV	<5 keV
Solenoid field	>6 T	2 T
Full-field trap length	>50 cm	80 cm
Trap region pressure	<1E-13 mbar	1E-11 mbar

Main design parameters for an upgraded EBIS/T charge breeder aimed to produce very highly charged ions for TSR injection.

Extreme challenge to produce *a few stable* ions with this charge state.

Doing it as an efficient charge breeding is one step further!

In conclusion:

1. Plenty of projects

   Several not mentioned here:

   New commissioned fast tape-station

   Polarized post-accelerated beams

   Going towards CW beams in REX

   Super resolution separator

2. Several opportunities for involvement

3. Two years fellow position open for challenging charge breeder development

   https://hr-recruit.web.cern.ch/hr-recruit/special/CATHI.asp