REX operation and development in 2006

D. Voulot and F. Wenander for the REX team

Outline

1. Operation 2006
2. Low energy development and tests
3. Linac performance and tests
4. Hardware modifications
5. Minimove
6. Dreams and outlook

Some Practical News

For the users:

for machine details from each run, summary found at:
www.cern.ch/ISOLDE, click on REX-ISOLDE, bottom first page

report from weekly ISOLDE Technical meeting:
www.cern.ch/ISOLDE, click on Committees & Meetings

Operator status

Didier Voulot
(contact person)

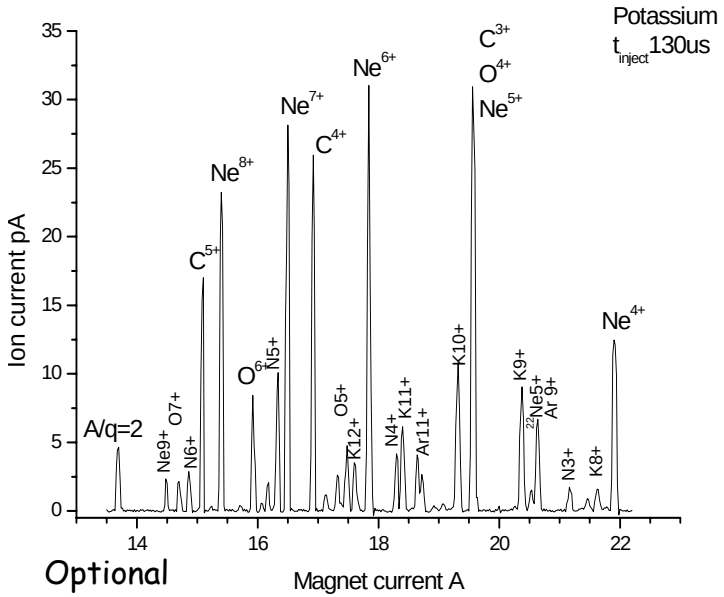
Fredrik Wenander
(contact person)

Emiliano Piselli
new since 1/9 2006
50% REX operator

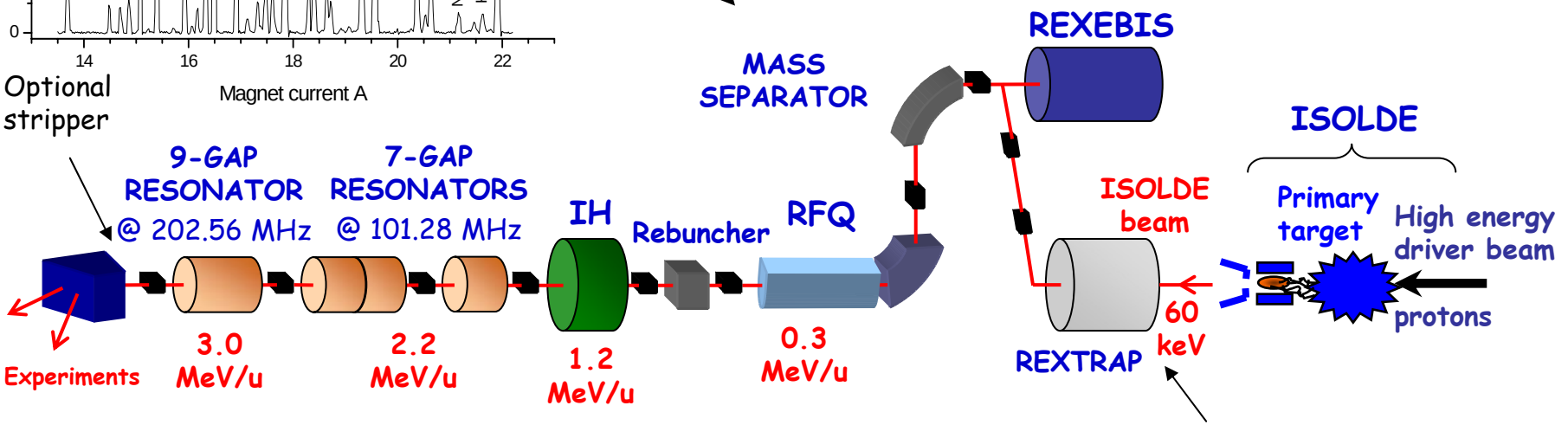
Richard Scrivens

Note: daily operation of REX being transferred to ISOLDE operators 2007

REX-Isolde

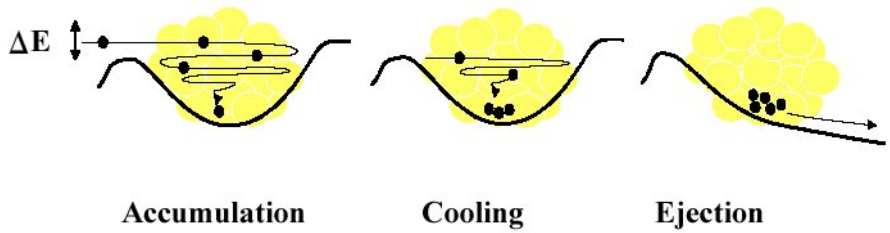


* charge breeding
* 1+ ions to n+



* 6 cavities
* 100 and 200 MHz, ~100 kW
* 300 keV/u to 3 MeV/u

* longitudinal accumulation and bunching
* transverse phase space cooling



Highlights and Hick-ups

☺ 9/11 successful runs (accelerated beam delivered to the experiment)

☺ 9 new radioactive isotopes post-accelerated in 2006:
$^{8}Li^{3+}$, $^{10}Be^{3+}$, $^{29,31}Mg^{9+}$, $^{67,71,73}Cu^{19+,20+}$, $^{80}Zn^{21+}$, $^{144}Xe^{34+}$

☺ Slow extraction from EBIS (more later)

☺ Record beam energy from Linac
3.15 MeV/u for 8Li3+ (A/q=2.67)

☺ REX low energy part exceeding specifications (more later)

☹ No beam delivered to the first run of the year (Mg)
late linac startup: no time for test

☹ One test run (BaF) cancelled due to a sudden cathode failure
Problems during the year:
Non-working FCs; Running in problems with new control system; Mechanical problems with tuners; Water leaks at EBIS; Control unit for IH failed; Serious long power cut; Forced patch installation on computers; Discharge in 9-gap amplifier; Beam diagnostic FEC unstable etc

Main problems – as we see them

* Fragile electron cathode in EBIS
  - No real alternative available (IrCe also breaks)
  - Operate restrictively (i.e. low current ~200 mA)

* Power and duty cycle limitation of 200 MHz amplifier
  - Work underway to improve HV holding and protect power supplies
  - -> goal : 3MeV/u at A/q 3.5 with full duty cycle (90kW/100Hz/1ms)

* Scaling of Linac not always fully reproducible
  - Continued and deepened study this year (linearity, phase, amplitude, optics)

* Problematic to transport the accelerated beam into the experimental setup
  - Realignment of the last linac section with Minimove
  - Extra quadrupole doublet lenses
  - Add extra beam diagnostics before bending magnet and Miniball target

* Late startups – REX lowest on the food chain
  - Stricter time limits for shutdown work
  - (Avoid Witch runs before a REX run)

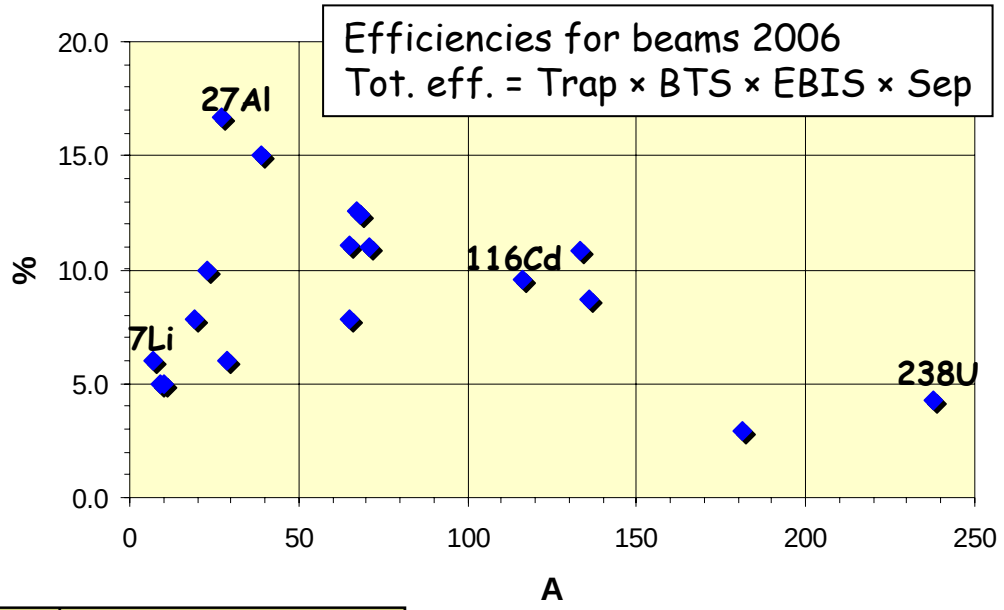
* Yield comparison between ISOLDE target and REX experimental station
  - Clear communication before searching for errors

The constant "quest" for efficiency

☺ REX low energy stage now covers A=7 to >200 with total efficiencies of at least 5%

☺ High current beams can now be charge breed with some efficiency (e.g. 1.8% for a 3nA $7Li^{+}$ beam into $7Li^{3+}$)

☹ Light ions still difficult to breed ≤5%



element	tcool (ms)	tbreed (ms)	charge	total eff (%)	A/q		comments
7Li	20	18	3	6.0	2.333	stable	
9Li	50	15	3	5.0	3.000	radio	low rep due to linac
10Be	50	15	3	5.0	3.333	radio	low rep due to linac
19F	20	7	5	7.8	3.800	stable	
23Na	30	28	9	10.0	2.555	stable	
27Al	20	10	7	16.7	3.857	stable	inj as AlF molecule
29Mg	30	28	9	6.0	3.222	radio	very large error bars
39K	20	12	10	15.0	3.900	stable	
65Cu	100	68	19	11.1	3.421	stable	
65Cu	100	68	20	7.8	3.250	stable	too short breeding time
67Cu	100	68	19	12.6	3.526	radio	
68Zn	80	78	21	12.4	3.238	stable	For 80Zn21
71Cu	100	98	20	11.0	3.550	radio	large error -> overestimated?
116Cd	250	248	31	9.6	3.742	stable	For 124Sn30 and 126Sn31
133Cs	200	198	33	10.8	4.030	stable	For 124Sn30 and 126Sn31
136Xe	200	198	34	8.7	4.000	stable	For 144Xe34 run
181Ta	200	198	40	2.9	4.525	stable	not optimium tuning
238U	500	498	52	4.3	4.577	stable	

-> Charge breeder : generally aiming for 10% total efficiency!

-> Linac efficiency 70-85% (aim for >80% in 2007)

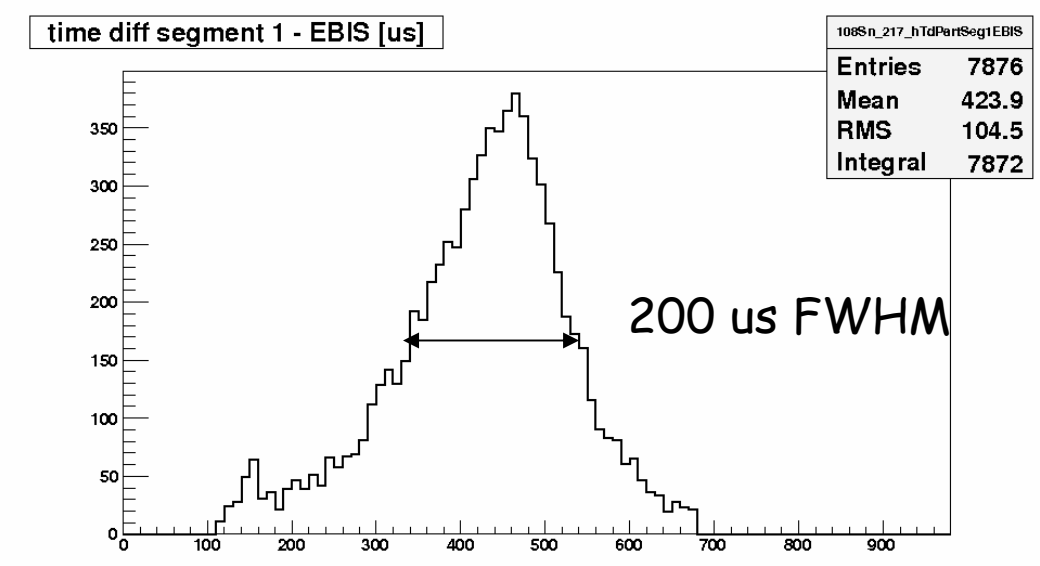
Slow extraction from EBIS

* Beam pulse can be extended from 50 us to >400 us FWHM
  (pulse length limited by linac RF duty cycle to 1ms)

* Same breeding efficiency as for normal extraction

* Fairly easy to tune, setup time <2 h
  (need TOF from experiment for tuning)

* Three experiments have used it so far



Slow extraction, 108Sn

Further beam development

* Tested AlF molecular beams from ISOLDE for Al and F production

* Indicates that Al beams can be efficiently charge bred in molecular form
  (total efficiency (Trap + EBIS) for Al^{7+} >16%)

* Proven that electronegative ions (e.g. F) have less total efficiency in molecular form than if as extracted as positive ions from ISOLDE (e.g. F+)

Report from T. Stora and F. Wenander

Prediction: Ba can similarly be handled in the form of BaF molecule

Development plans for 2007

* C, N, O produced in with the Minimono ECR source
  (uncertain outcome due to high stable beam contaminations from the ECR)

* Sr extracted as a molecule from ISOLDE

Isotopic mass separation in REXTRAP

Isobaric separation inside the REXTRAP was proven feasible with a new cooling and excitation scheme

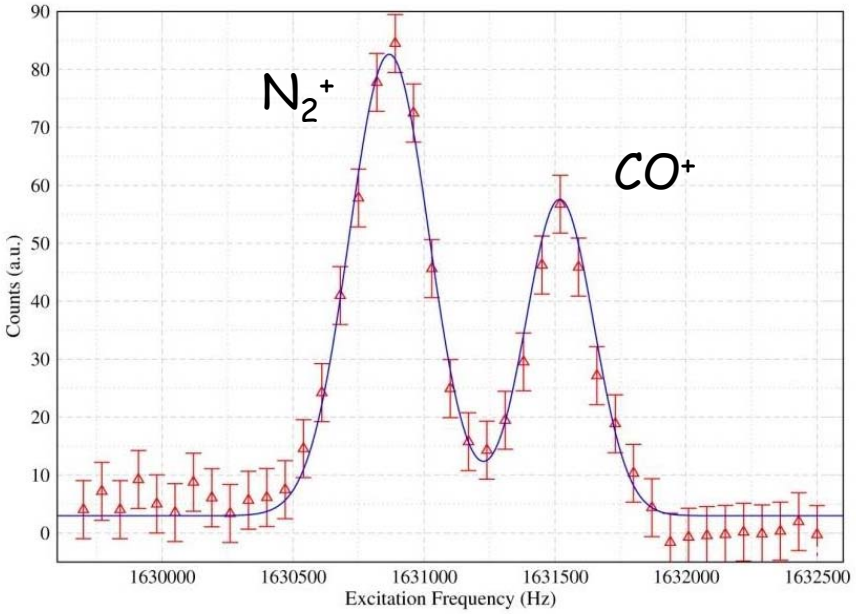
* Attainable resolving power 3E4

* Necessary excitation time ~100ms (compare with lifetime)

* Efficiency / Intensity limitations <10% few pA or 10^5-10^6 ions/bunch

* Setup time a couple of extra hours, partly with protons

* Need evaluation during realistic runs – 1 extra shift setup time with protons, especially for suppression factor measurement



Talk by S. Sturm at this workshop

Alternative electron gun designs

Photo of post-anode gun

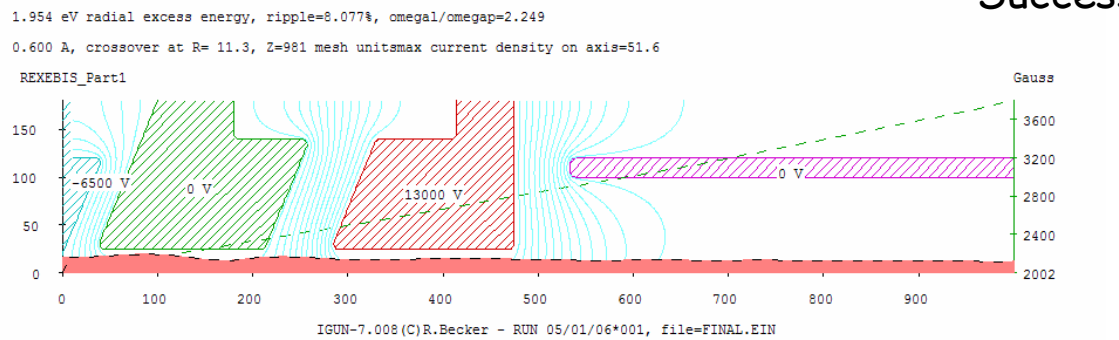
Post anode gun

Goals

* Less beam ripple -> less losses
* Reach 500 mA

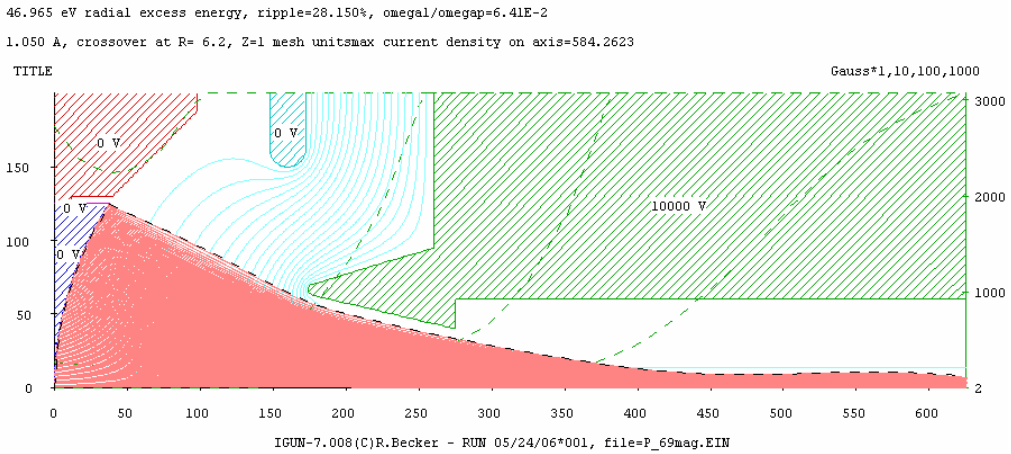
Results

* No loss reduction
* Cathode poisoning during tests
* Poor vacuum and discharges
  (post anode act as Penning trap?)



Final post anode electron gun

High current design

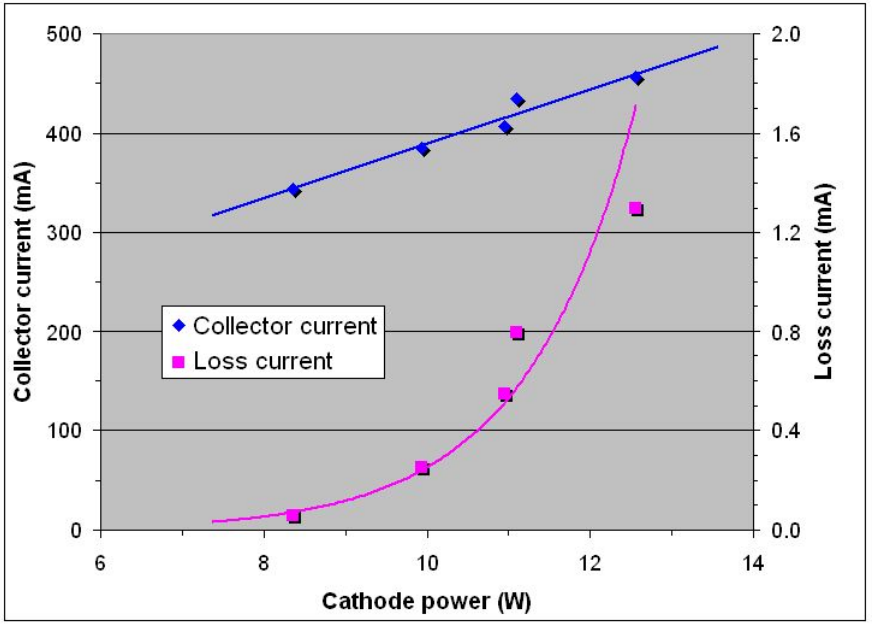


* Electrostatic and magnetic compression
* Goal current 1 A beam; 400 A/cm^2
* Would need considerable EBIS modifications
* Success uncertain

See also Diploma Thesis by K. Allinger

New electron beam current record

Tune old gun design
* Post anode deactivated => ordinary gun
* Limitations: loss current (2.5 mA)
  and gun pressure (~1E-9 mbar)



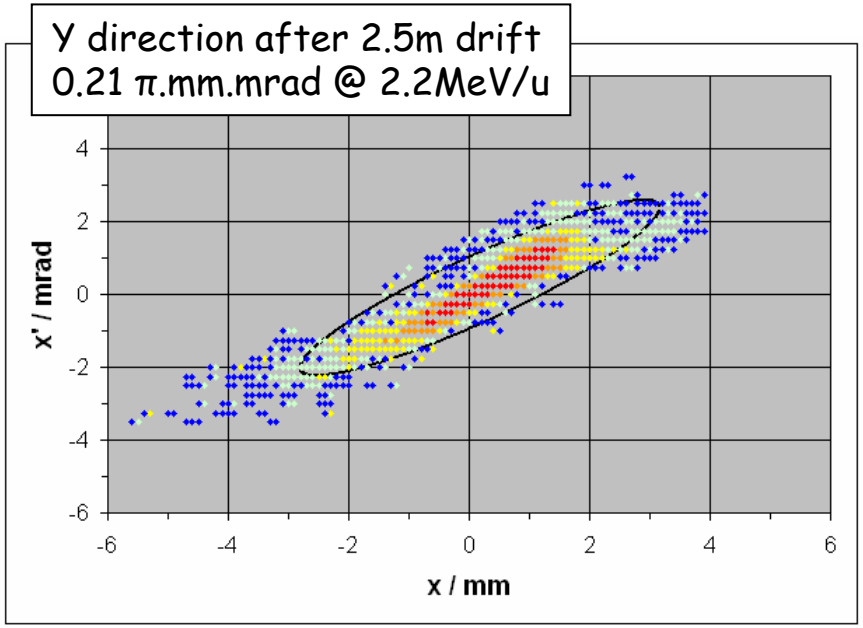
Results
* Record electron current of 460 mA
  (unstable)
* Stable operation at 400 mA
* Close to design value of 500 mA

Consequences
+ Half the breeding time compared with normal ~200 mA operation
+ Expect ion beam acceptance increase by srqt(2)
+ Higher efficiency for heavy highly charged ions as the potential depth is doubled

- Needs high heating power -> very short cathode life-time (maybe <1 month)

Difficult to find a more reliable replacement cathode (also IrCe breaks)
Further development electron gun requires TwinEBIS and manpower

Linac emittance measurements



Results

* Normalised transverse emittance (2σ RMS) = 0.21±0.07 π.mm.mrad at 2.2MeV/u

* Low intensity few 100pA (no space charge effect in EBIS!)

* Horizontal emittance larger than vertical after the bender (energy spread)

* Emittance increased when going from 1.2 to 2.2 MeV/u (mismatch between IHS and 7gaps?)

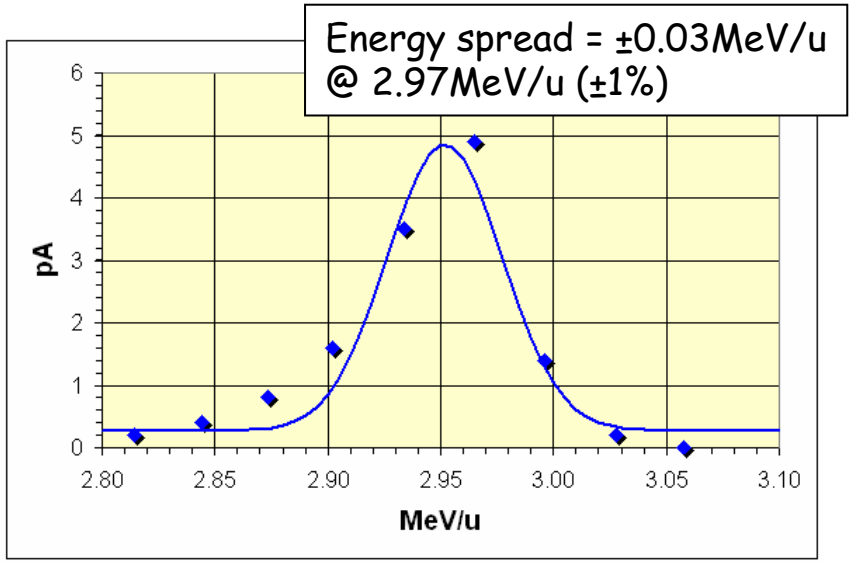
* Emittance increased with stripper foils

Continuation 2007

* Verify results with uninterrupted measurement series

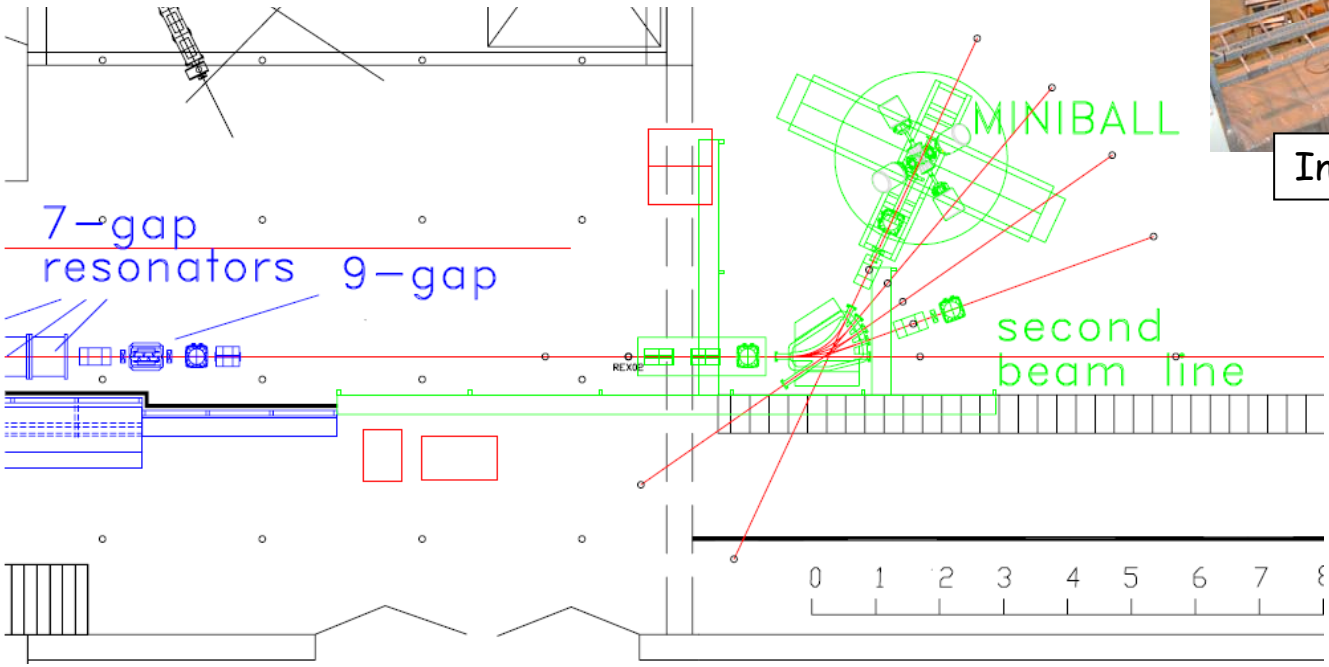
* Verify influence of EBIS operation conditions on the emittance

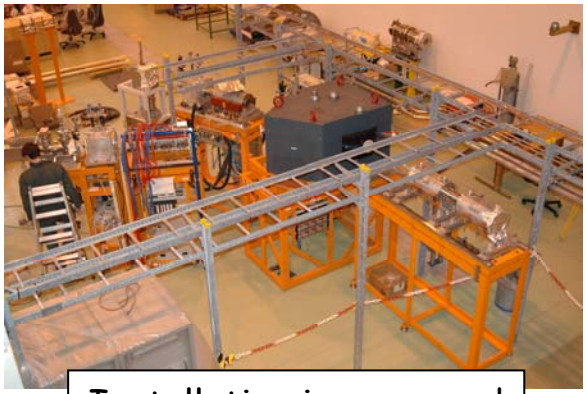
* Measure at 3MeV/u and 300keV/u



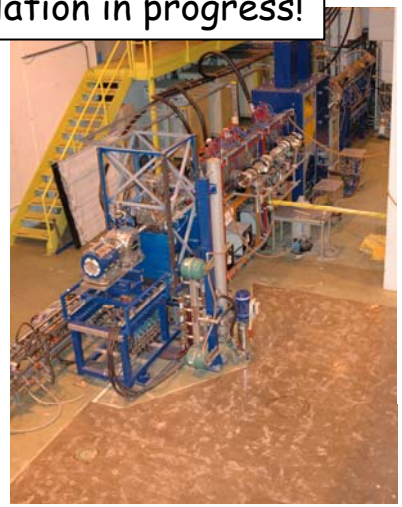
Minimove - Phase 1

* **Phase 1** = First phase of a full installation
  (linac upgrade, recoil separator, HIE-Isolde…)

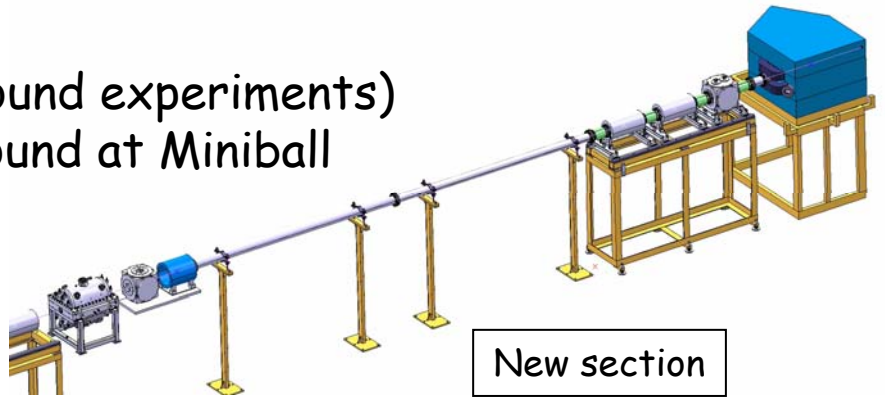




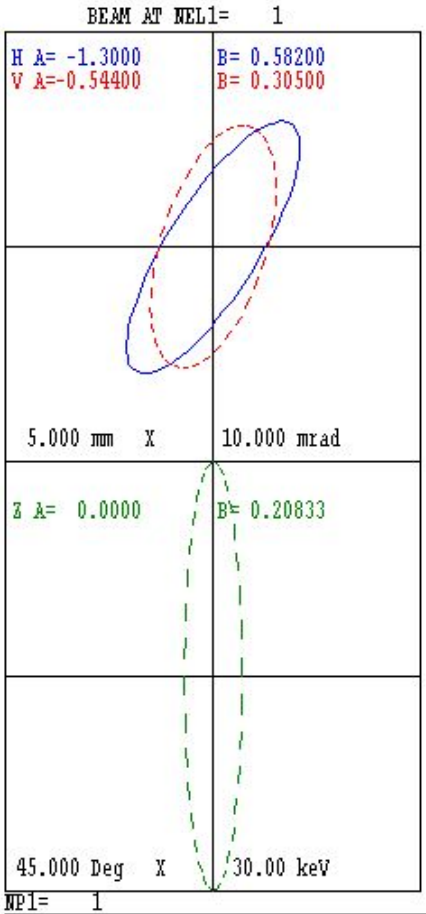
Installation in progress!



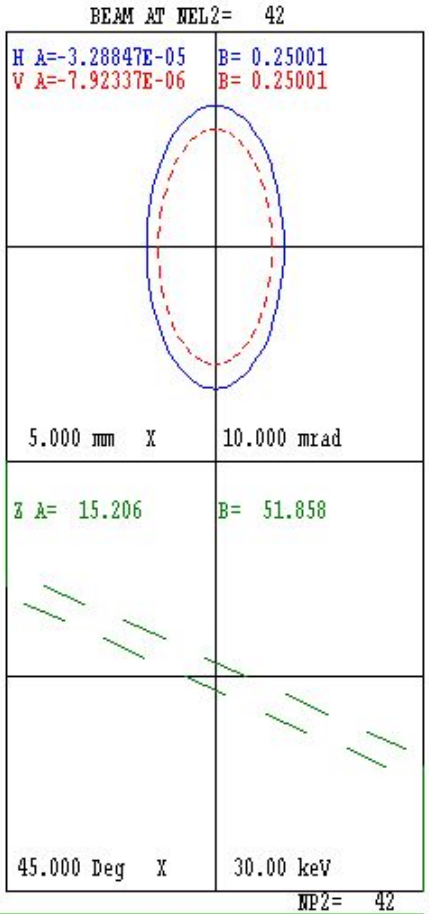
* Goals :
  1. create space (linac upgrade, space around experiments)
  2. improve shielding from X-ray background at Miniball
  3. improve beam properties
     -> more focussing
     -> more beam diagnostics
     -> realignment of beamlines



New section




```
                I=     0.0mA
  W=   3.0000     3.0000 MeV
 FREQ= 101.28MHz   WL=2960.04mm
EMITI=   7.500     7.500   187.50
EMITO=  10.933     7.500   200.99
          N1=    1   N2=   42
        PRINTOUT VALUES
       PP PE       VALUE
        1  9     16.45770
        1 10     10.00000
     MATCHING TYPE =  8
  DESIRED VALUES (BEAMF)
          alpha      beta
x       0.0000     0.2500
y       0.0000     0.2500
  MATCH VARIABLES (NC=4)
    MPP MPE       VALUE
      1  13      4.69493
      1  15     -8.73644
      1  19     12.57570
      1  21     -9.71845
```



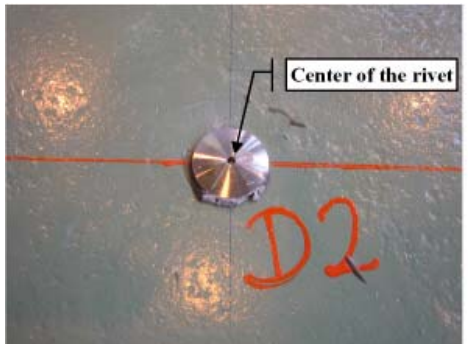
Beam optics calculation 9-GP to MB target

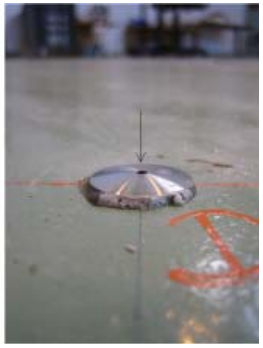
* 3MeV/u A/q3.5
* 0.6π.mm.mrad normalised
* ±1% energy spread

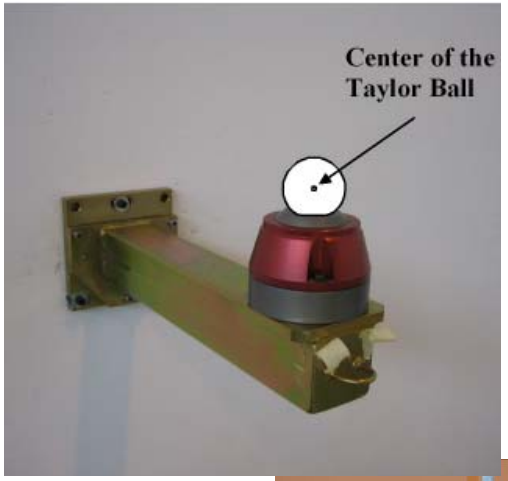
Diploma Thesis by T. Arronsson

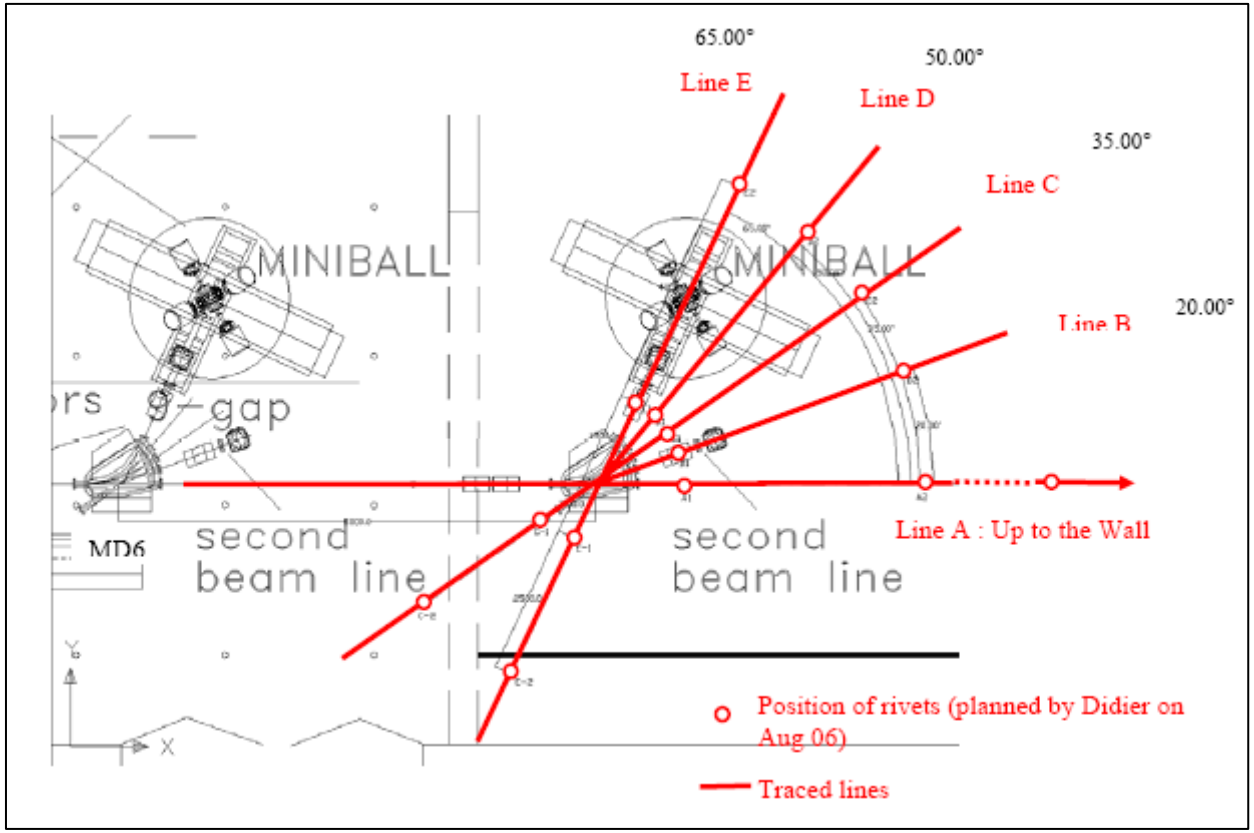
Survey and alignment of Rex

* New associate (Jérôme Sarret TS/SU)
* Realignment of 9-gap, bender and beamlines
* Installation of ref. points in the new hall
* Linac and beamlines survey
* Possibility to align exp. targets externally (without letting up to air the whole linac!)









Hardware modifications

past year

* New Linux based AB/CO CS for
  mass separator and linac beam optics and RF controls
* REXTRAP roughing pumps moved
  -> higher beam intensities from ISOLDE allowed
* New inlet system for the REXTRAP buffer gas

In addition to slow extraction, isotopic separation, post anode gun

coming year

* New CS for EBIS
* New CS for beam diagnostics
  startup unclear, missing application programmes
* Consolidate RF amplifiers
* Improve RF air cooling (need cleaner system)

Worry - many challenging and difficult task

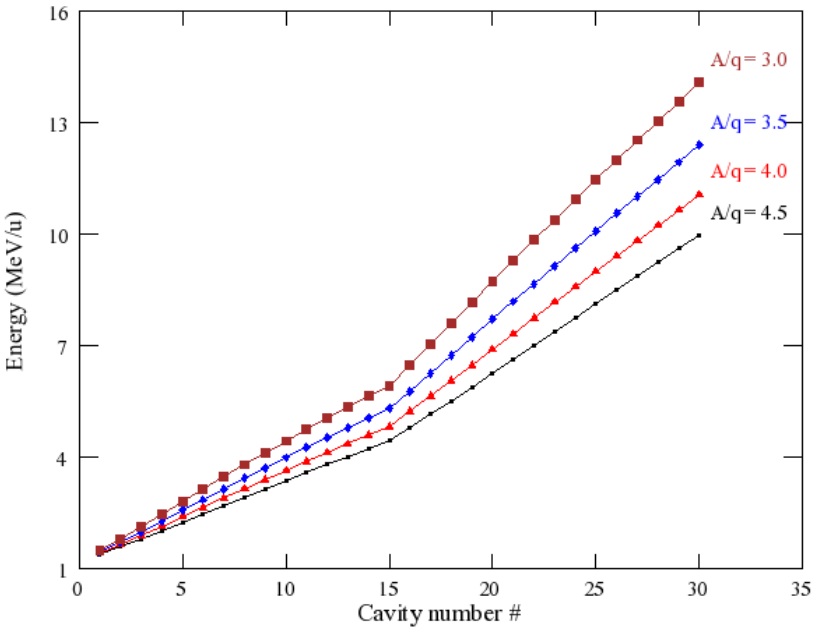
Linac upgrade

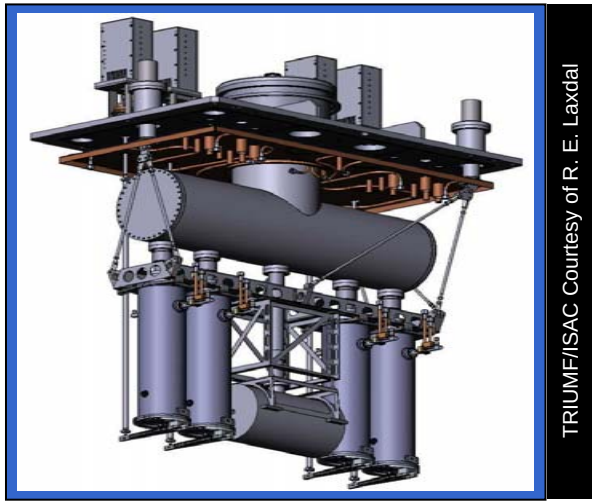
* IAP meeting May 2006

Alex C. MUELLER (IN2P3), Robert LAXDAL (TRIUMF), Oliver KESTER (GSI)

-> "a SC linac is much more attractive"

* Pre-study (M. Pasini)





TRIUMF/ISAC Courtesy of R. E. Laxdal

- 6 cryostats / 5 cavities per cryostat
- 30 quarter-wave SC cavities (2 types)
- 15.2m
- 10MeV/u @ A/q 4.5
- full energy variability

* A position will be opened for a R&D programme for a prototypical quarter-wave SC-cavity

Future dreams / Pending projects

Serious development project needs to be carried out externally

1. Energy upgrade up to 10 MeV/u
   Apart from money need further
   - beam optics calculations
   - beam dynamics simulations
   - SC cavity design (and prototyping)

2. Radioactive beam detection system after the REX mass separator
   - detailed design
   - electrostatic bender
   - tape station

3. Test bench for alternative electron beam systems for the EBIS
   - Setup TwinEBIS
   - test new gun designs and cathode types

Interested groups are encouraged to contact Didier, Fredrik or Mats
(External PhD and post doc desired)

The future of REX is dependent on the users