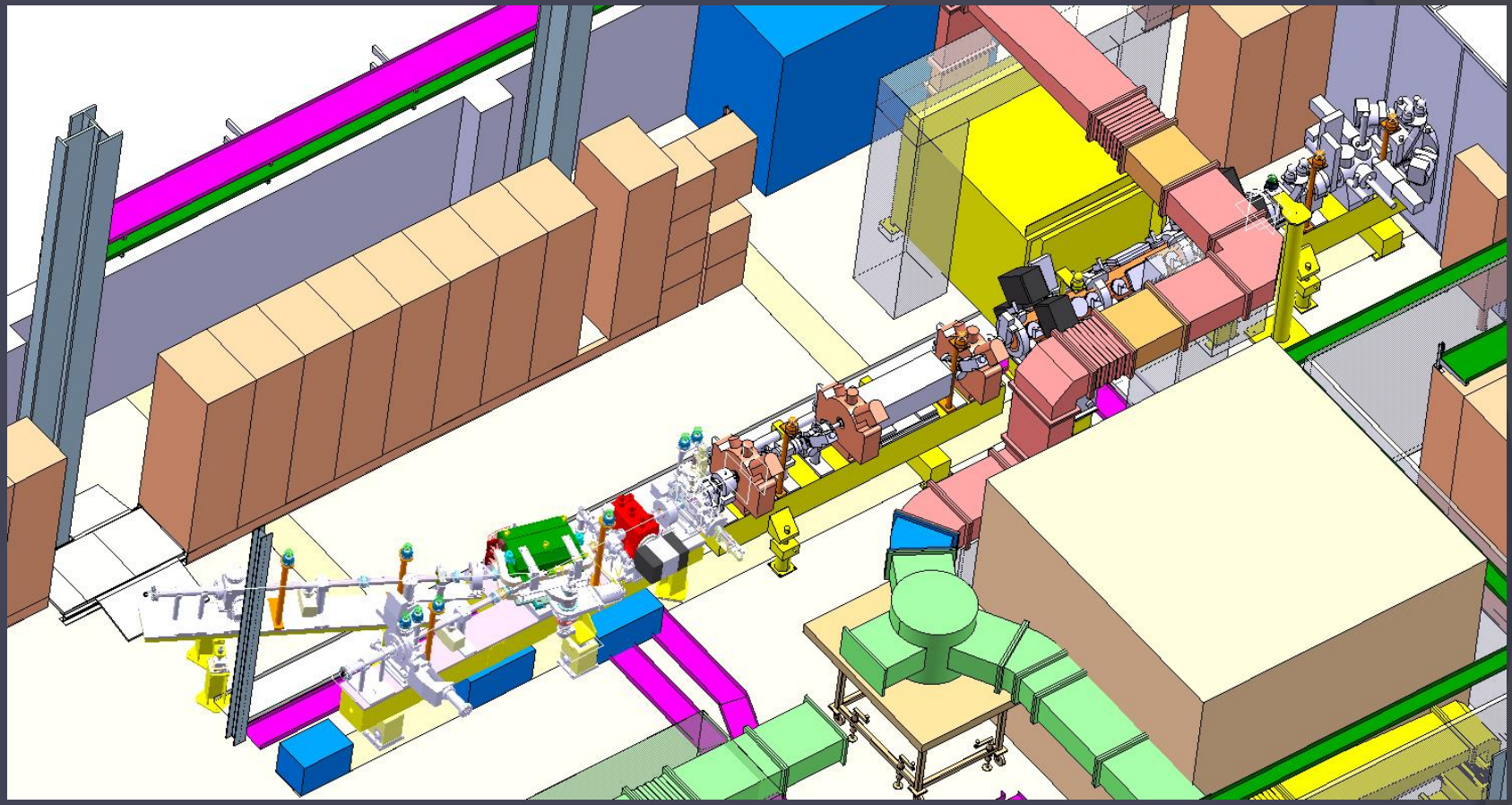
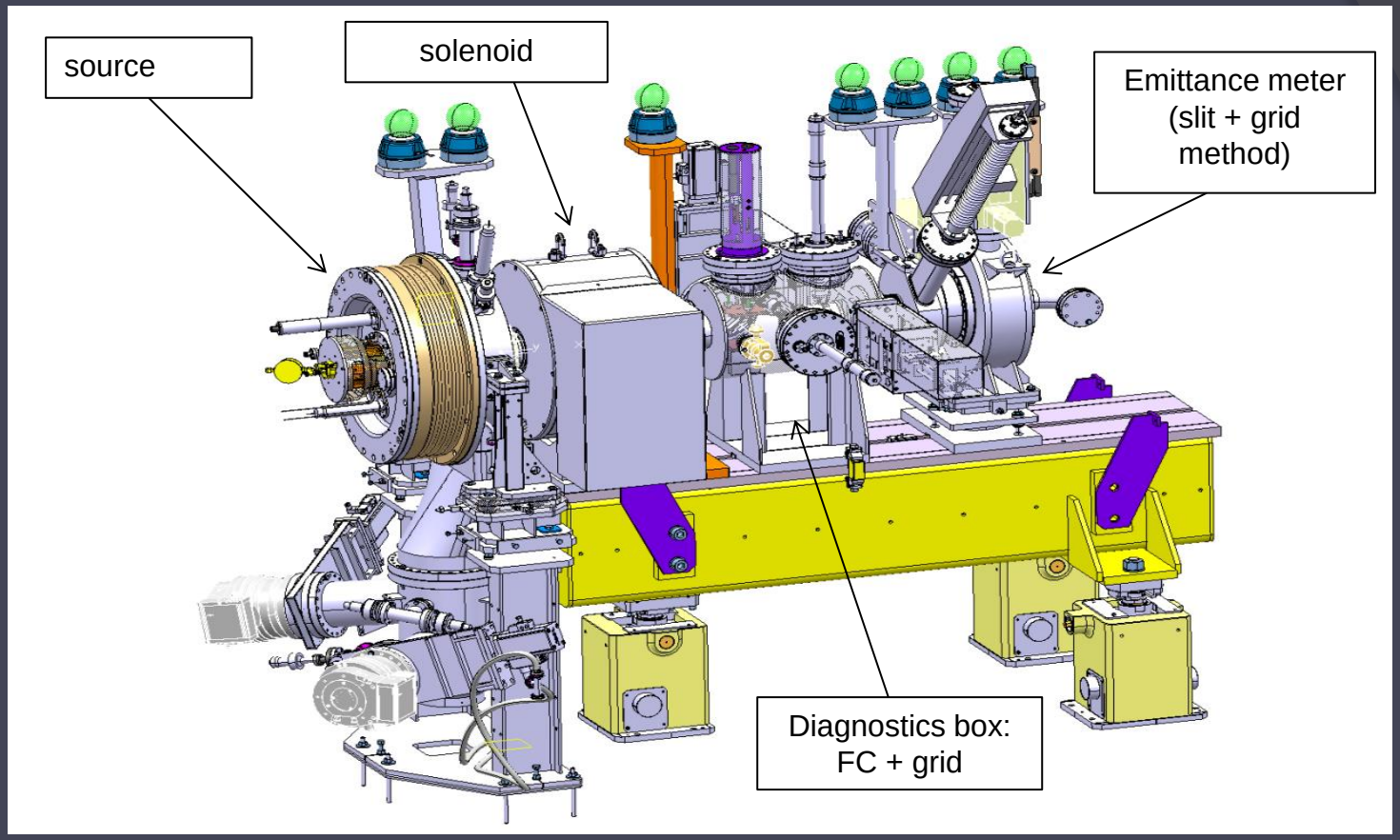
LATEST RESULTS AT THE LINAC4 3 MEV TEST STAND

Lego view of installation area



3 MeV Test stand in the PS South Hall – bldg 152
Linac4 front end beam commissioning, from January to June 2013 in staged approach

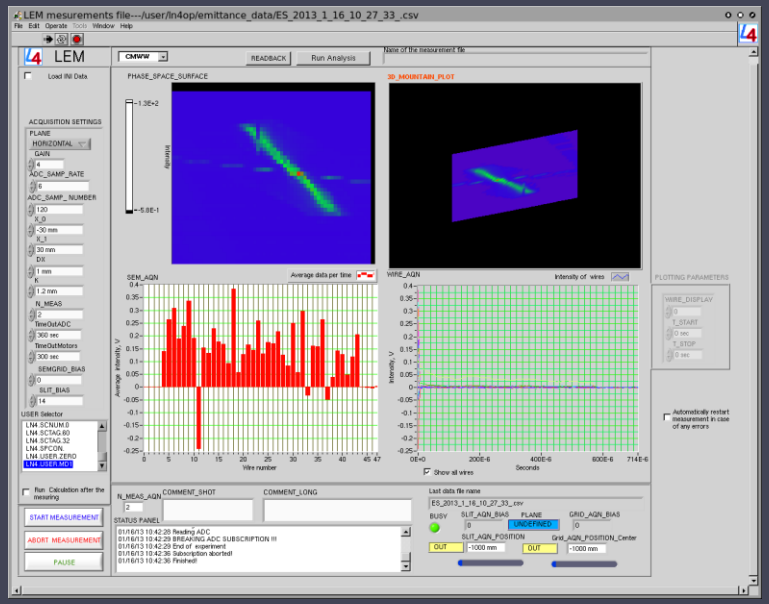
Mid-January 45keV initial setup



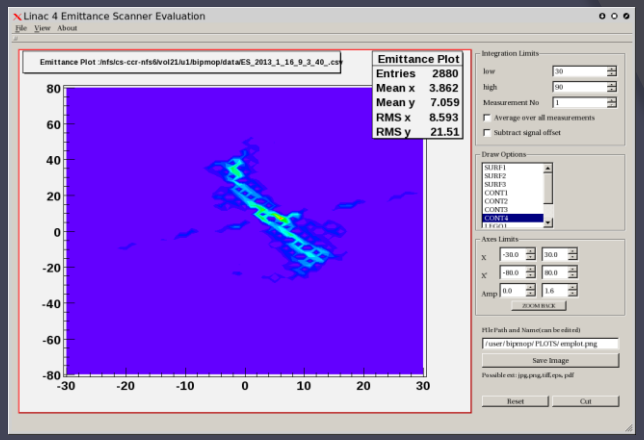
Started in proton mode, achieved 50-60mA proton beam production in 2 source extraction configurations:

- fully characterised LEBT transport: steerer and solenoid calibration
- Validated techniques of emittance calculation, beam reconstruction, forward and backward tracking for different space charge neutralisation factors

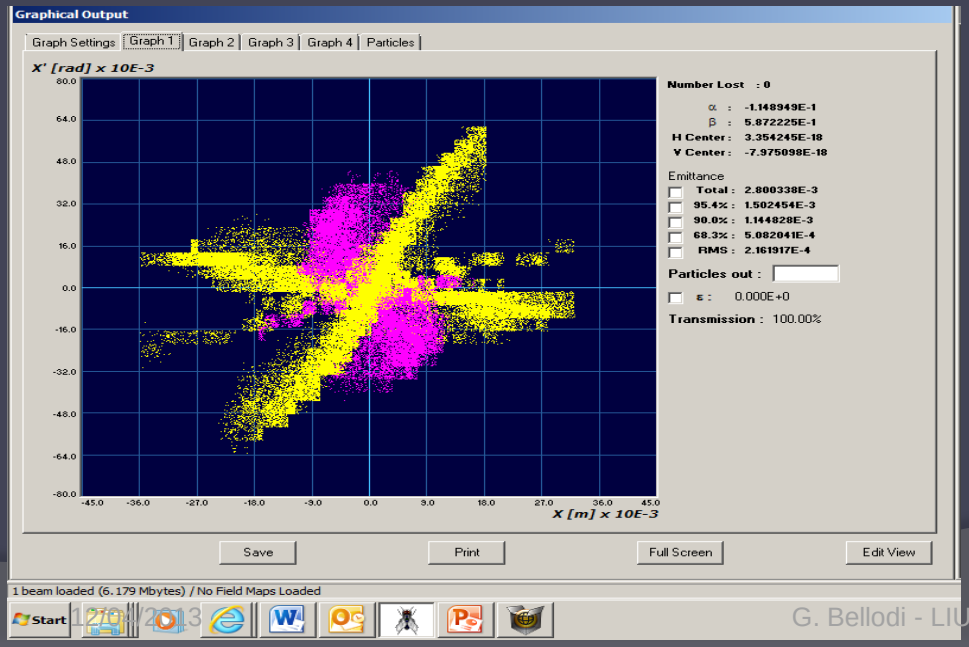
Emittance scan screenshot



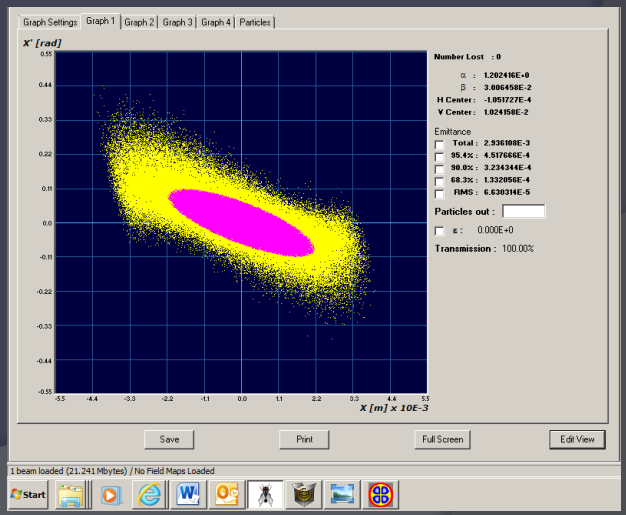
Beam footprint



Reconstructed beams for 85, 95 & 105A solenoid currents



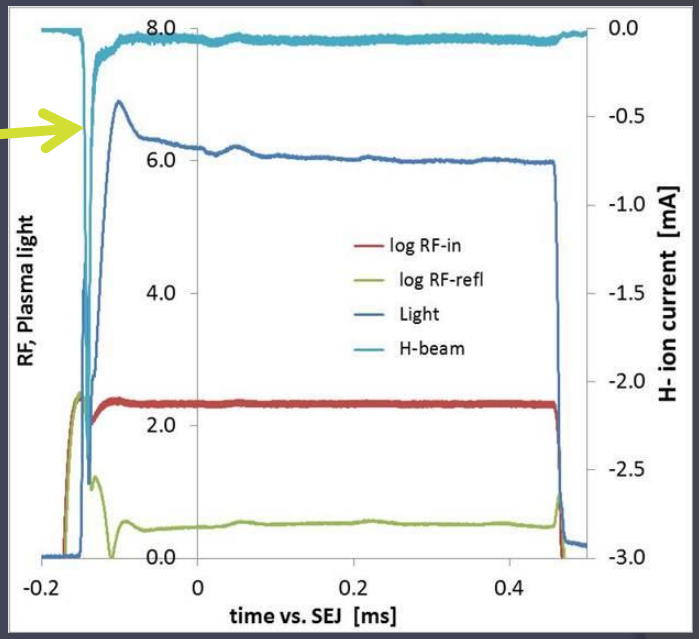
RFQ input plane: measured vs nominal (3:1 emittance ratio)



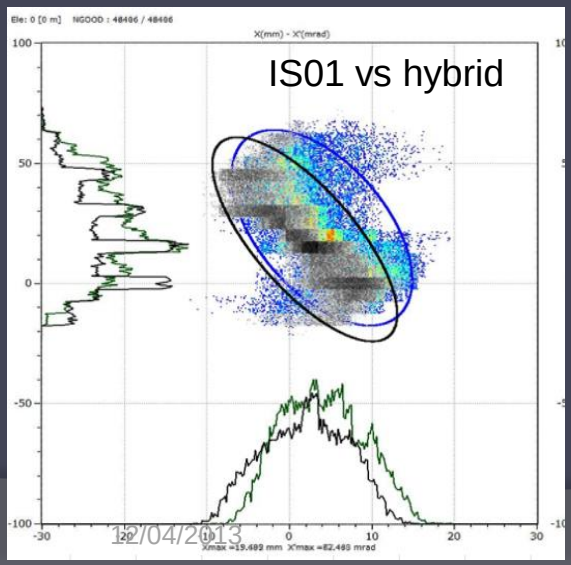
When switched to H- beam production the IS-01 prototype delivered short pulses of 2-3mA current and 20us duration, with a 3A over-current of co-extracted electrons.

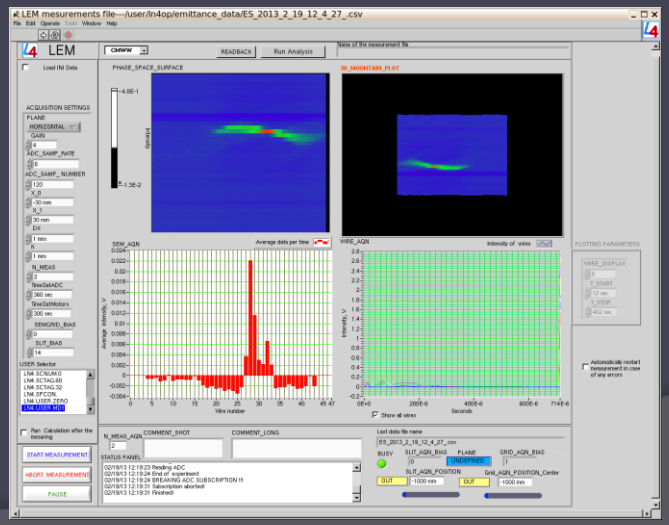
As back-up solution the Desy-type plasma generator was installed on the IS-01 front end extraction and electron dumping body.

This provided **16-18mA** H- beam for 0.5A co-extracted electrons (and similar performance to the IS-01 prototype in proton mode).

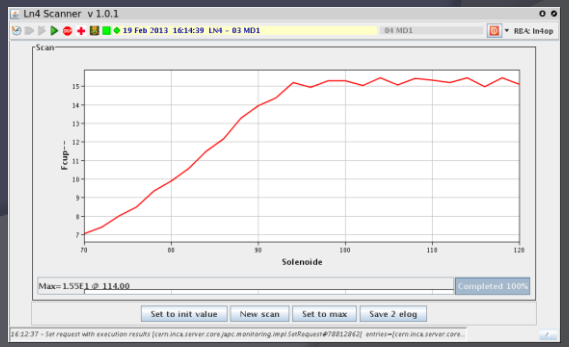


Similar proton mode performance

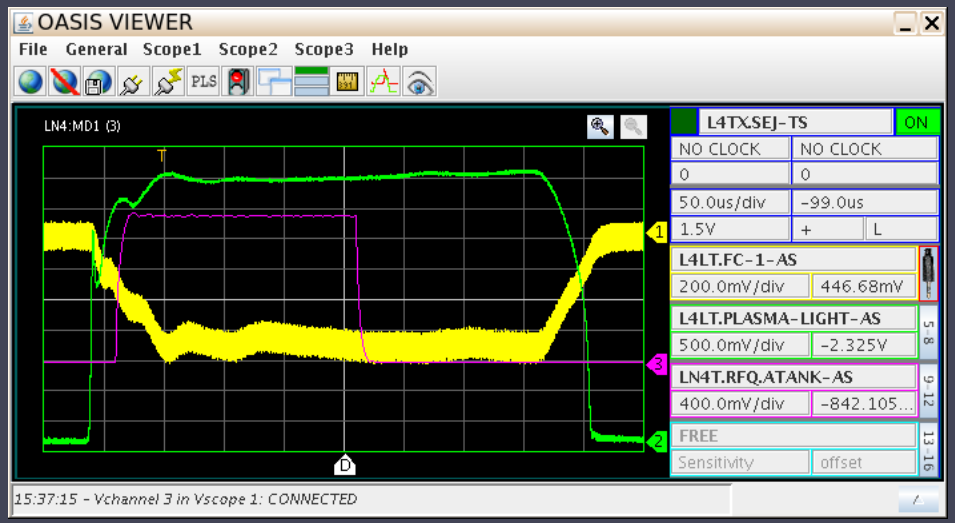


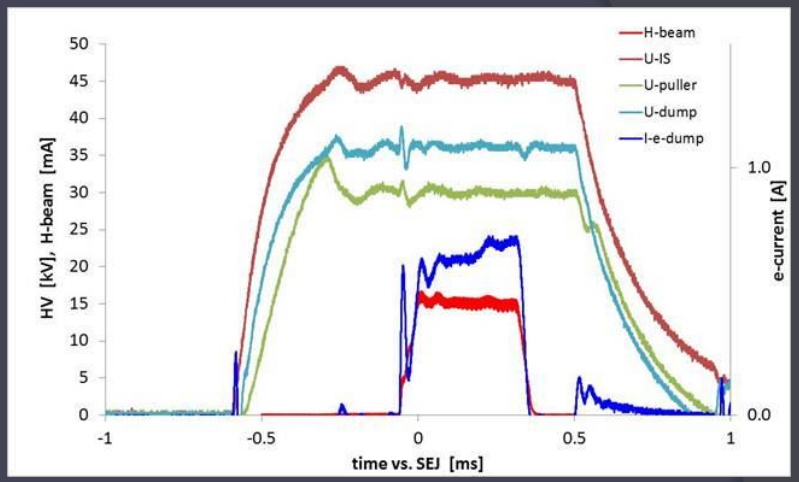


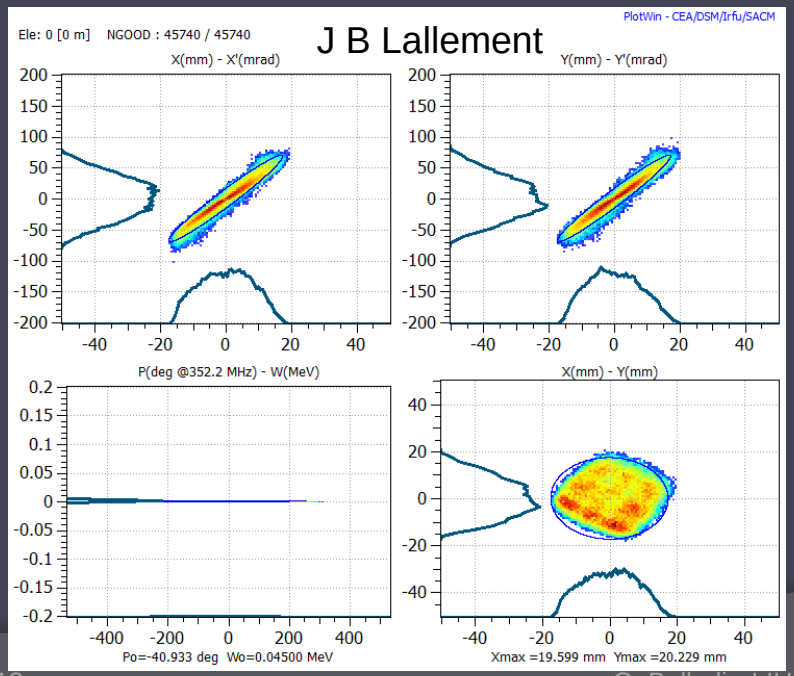
First H- beam – (19 February)



Followed source tuning and optimisation to improve RF power coupling, timings, RF power ramp, stability of extraction voltages. Very good stability has been achieved!





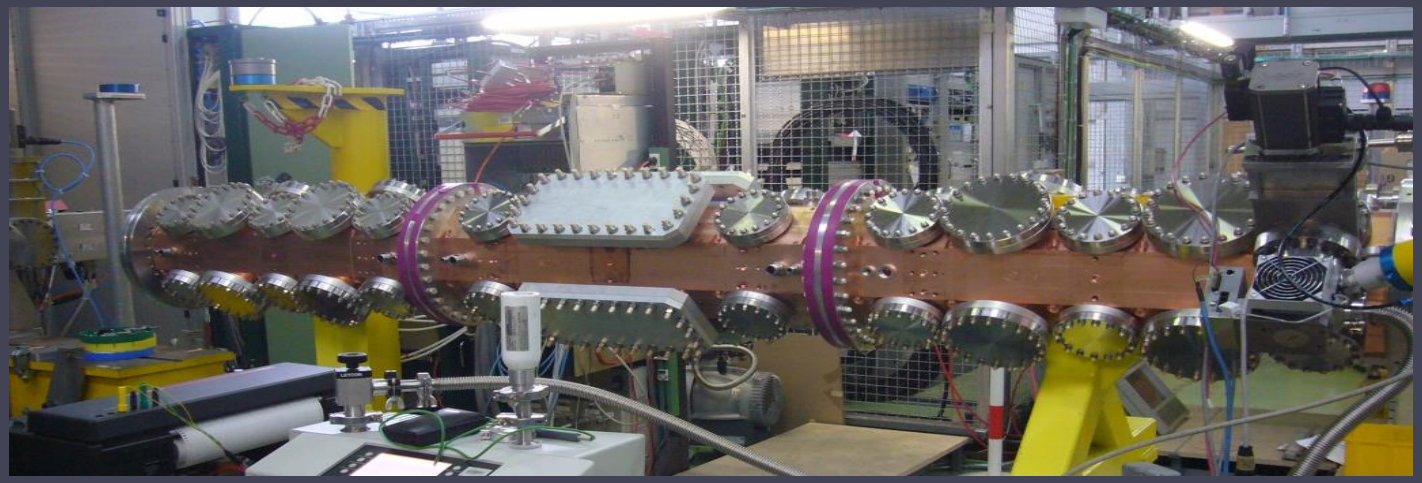


Beam tracked back to the source output:

X-X'
Emit [rms] = 0.55 Pi.mm.mrad [Norm.]
Beta = 1.1 mm/Pi.mrad
Alpha = -4.2
Y-Y'
Emit [rms] = 0.545 Pi.mm.mrad [Norm.]
Beta = 1.1 mm/Pi.mrad
Alpha = -4.2

Sigma_X [rms] = 7.8 mm
Sigma_Y [rms] = 7.7 mm

Assembly of the RFQ final components (power coupler, tuning pistons, RF pick-ups) was completed by the end of January and the bead-pull test bench dismantled.

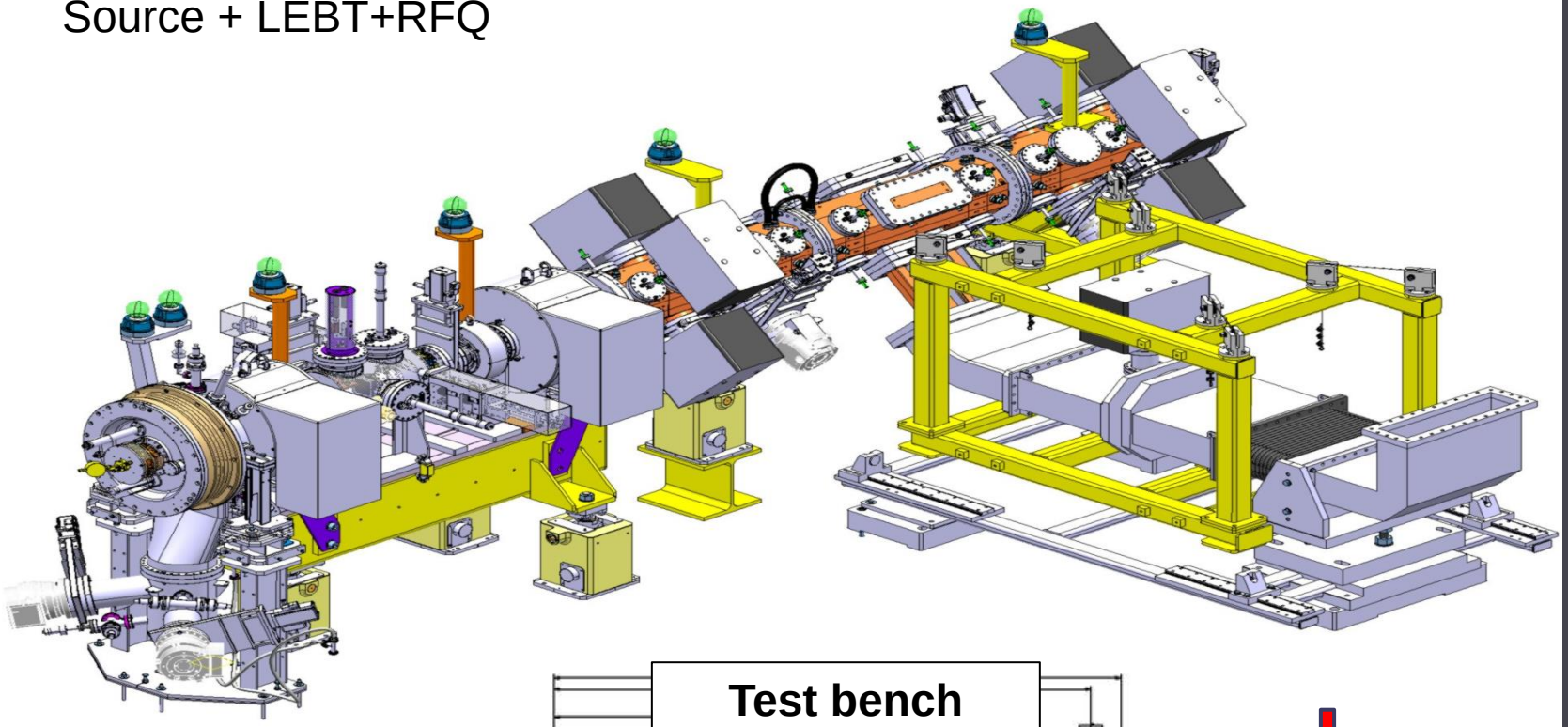


Accelerating field flatness better than ± 1% can be achieved with just half of the piston tuner range. Dipole components are larger than expected (3%). A further tuning step is foreseen when moving the RFQ from the 3 MeV Test Stand to the Linac4 tunnel.

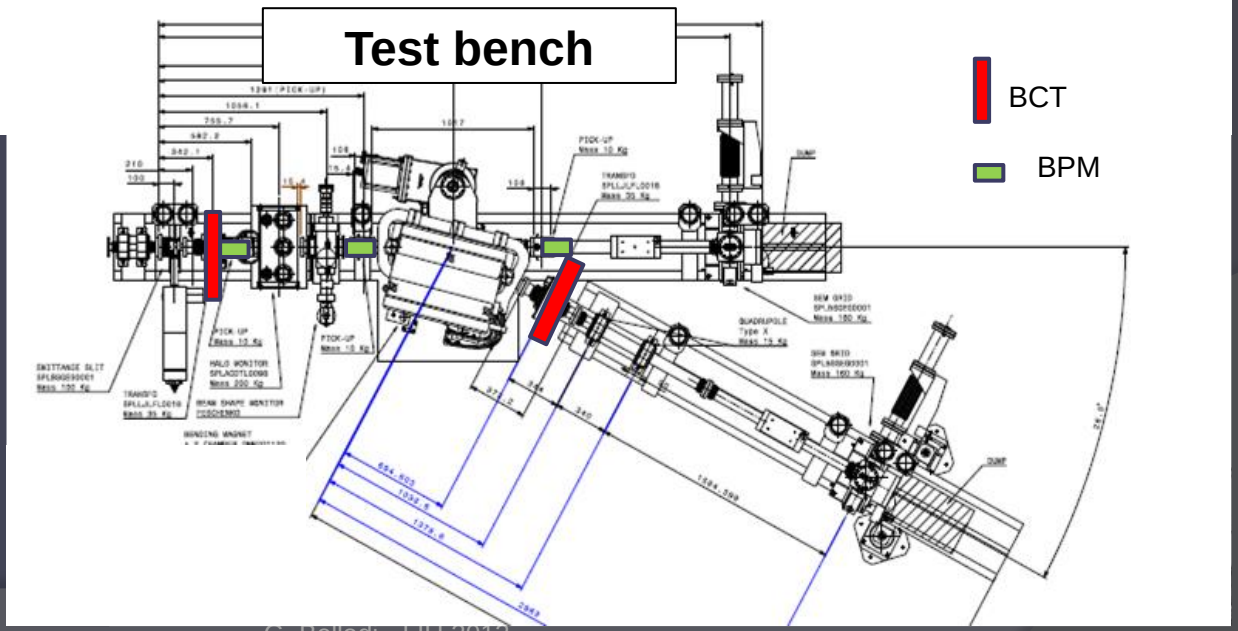
Waveguides installed mid-February, followed by pick-up calibration and closure under vacuum.

RF tests started on 19/02 slowly stepping up in power. Achieved (13/03/2013) :
P max fw = 460 kW, P rev = 24.3 kW, pulse length = 250 microsec;
RFQ vac = 7E-9 mbar, Ridge vac = 1.8E-8 mbar.

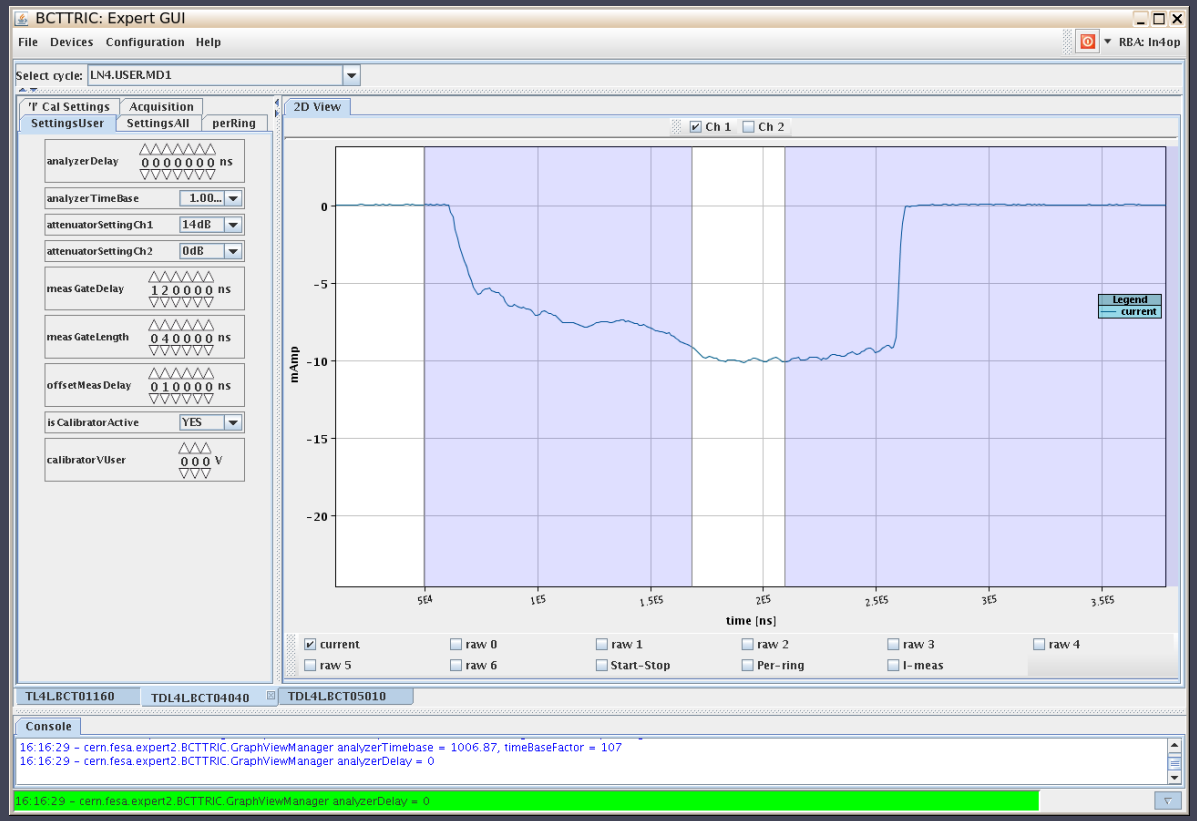
Source + LEBT+RFQ



3 MeV test bench setup:

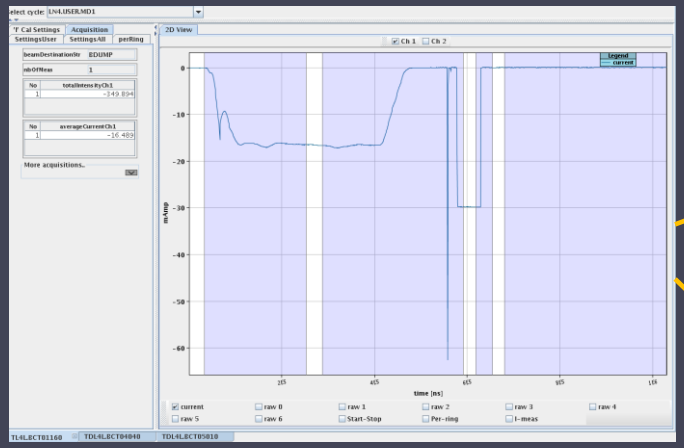


Wednesday 13/03/13 at 16h10

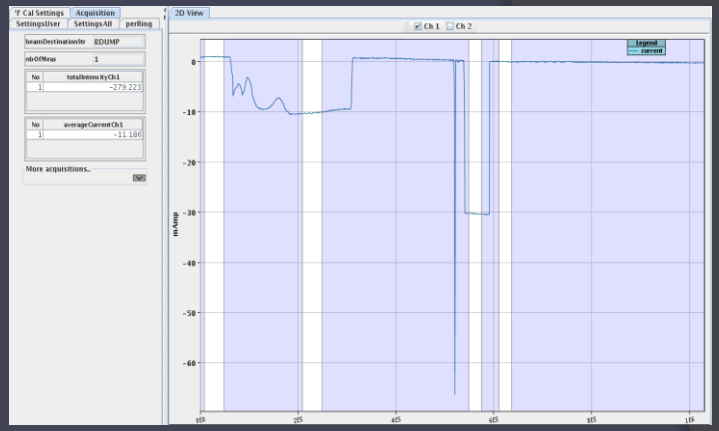


First 3 MeV beam seen on BCT:
10mA H- accelerated through the RFQ at first shot!

3 MeV measurements

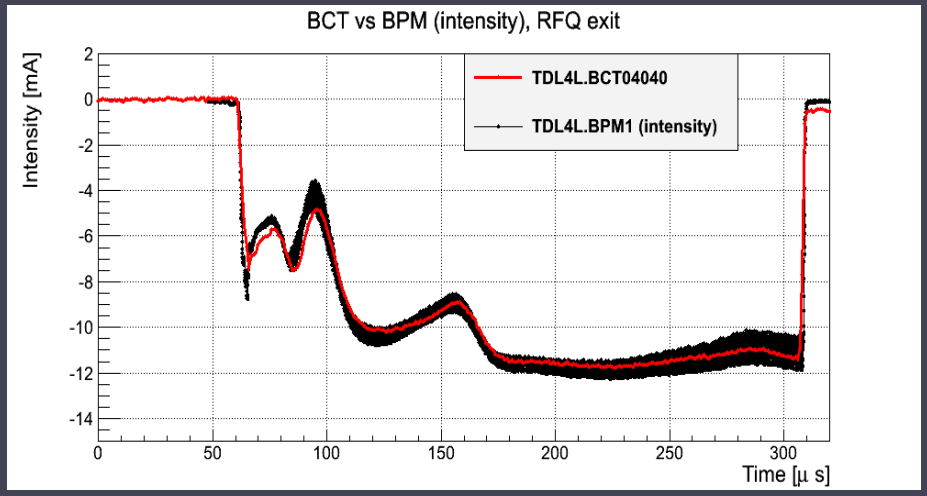


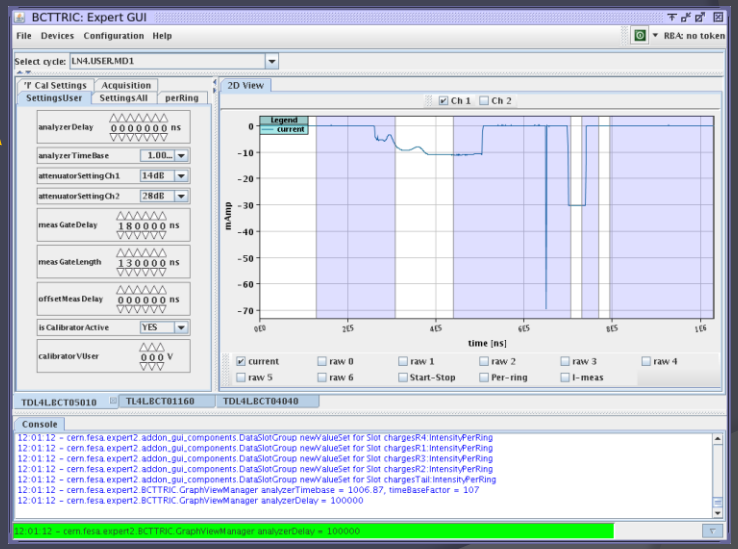
16.2mA on BCT.L4L01160 (before RFQ)



~11.9 mA on BCT.L4L04040 (after RFQ, straight line) → **~75% transmission**

BCT vs BPM crosscheck - F Roncarolo

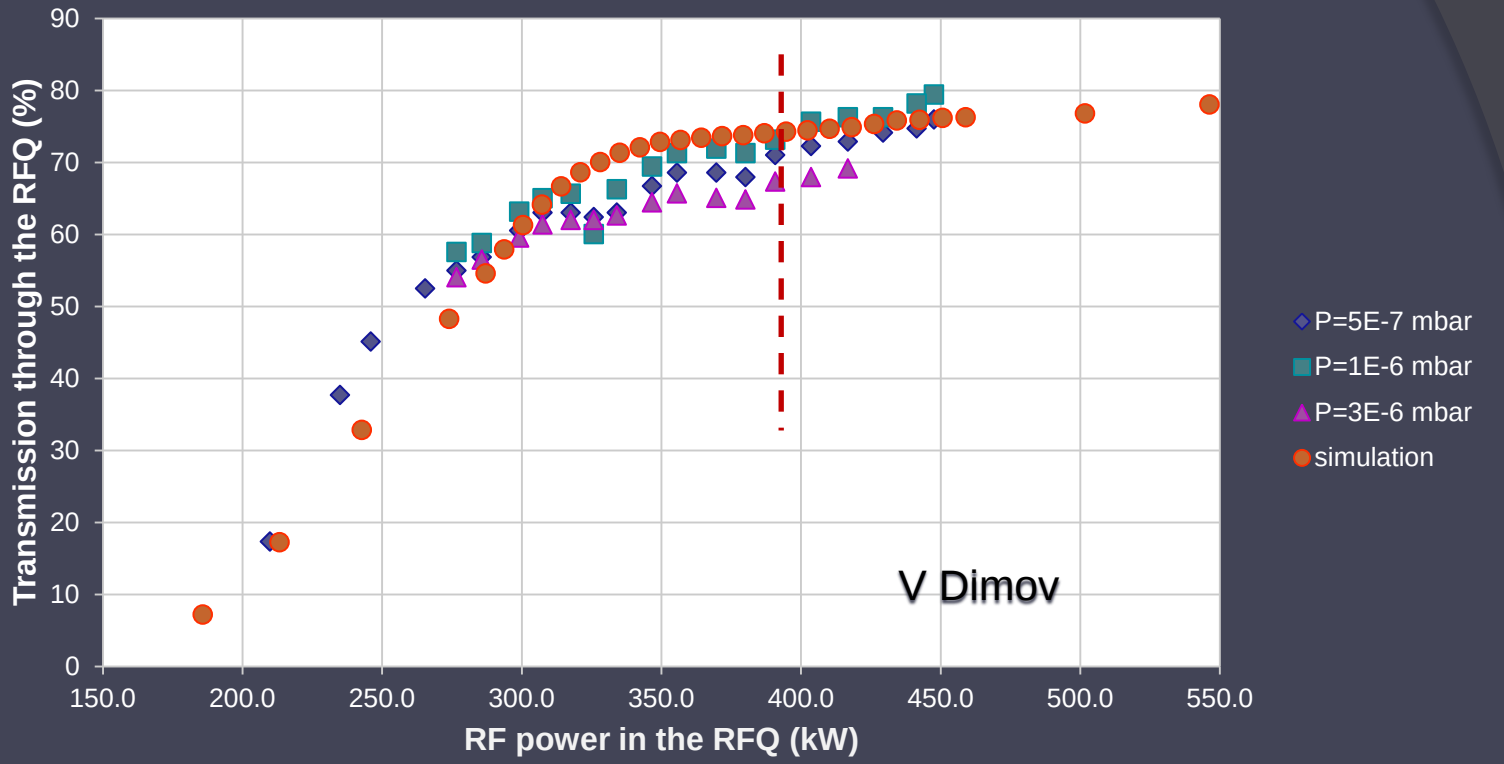




~11.2 mA on BCT.L4L05010 (after RFQ, spectrometer line)

→ **Most of the particles at the RFQ exit are at the right energy**

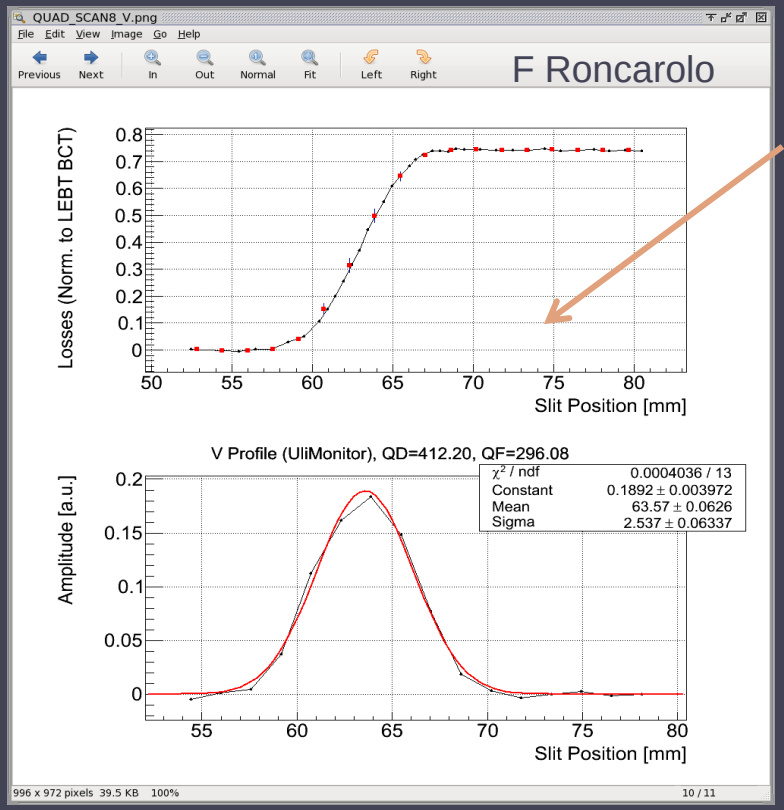
RFQ transmission vs RFQ RF power measurements and simulation



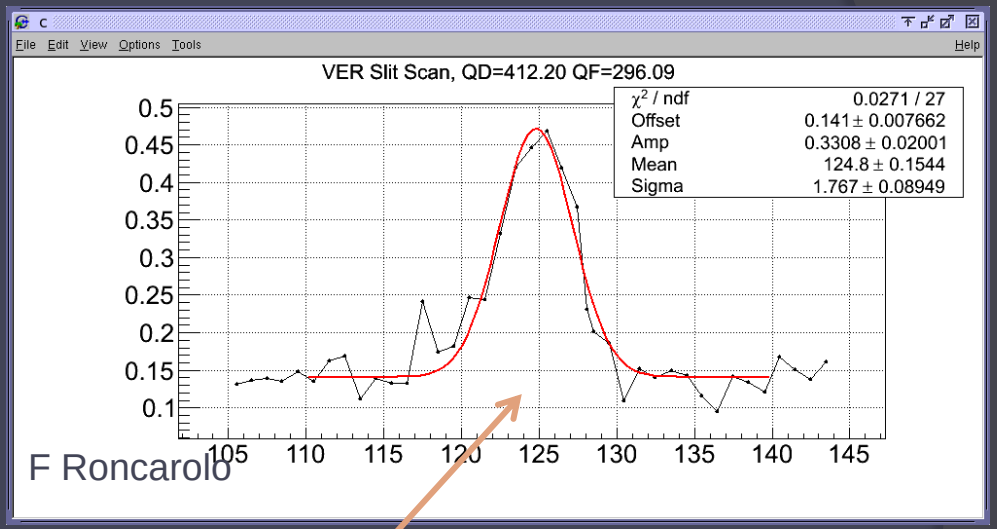
- 70-75% RFQ transmission achieved at nominal settings (<94% design value, but as expected and confirmed by simulations because of the bigger input beam emittance)
- LEBT H2 gas pressure was changed to study experimentally the effect of neutralisation

Emittance meter still needed some debugging → alternative solutions found to record beam profiles at the exit of the RFQ → 3 quad method to derive emittance value and reconstruct output beam

Measured profiles



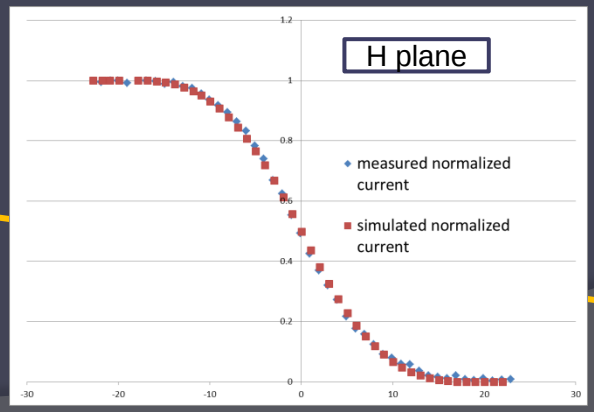
Scraping with slit and measuring downstream losses

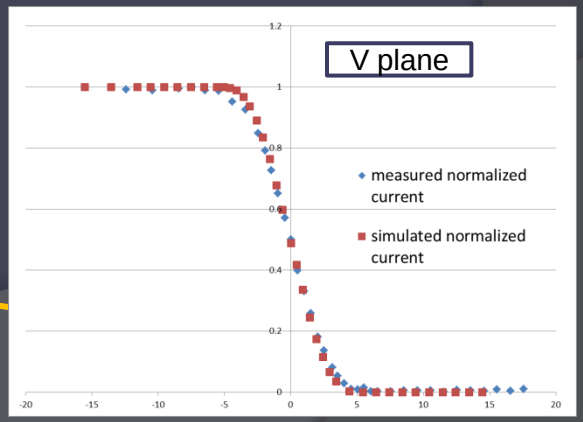


Scan with slit and measure downstream current

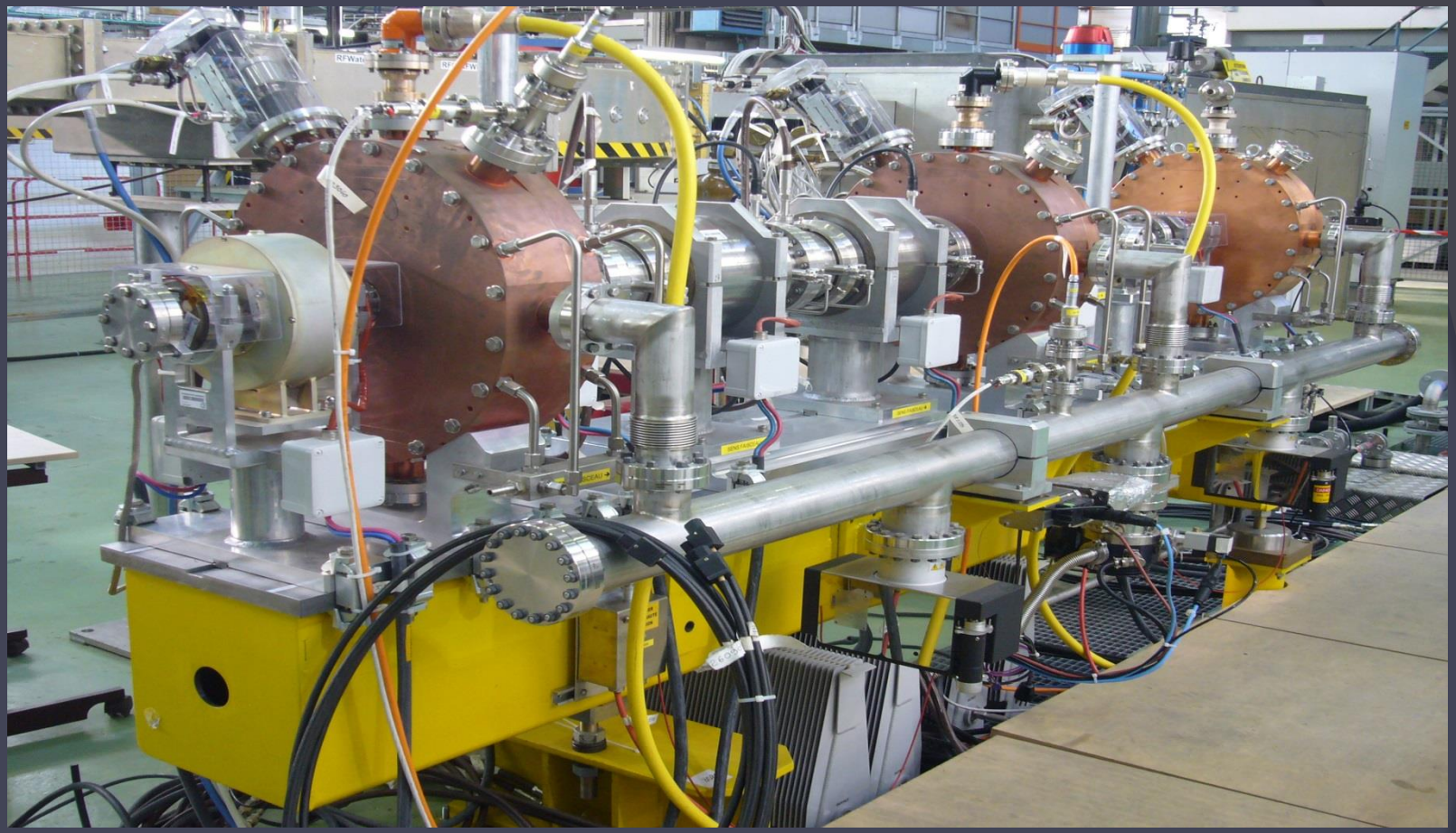
Measurements vs simulations

(using reconstructed beam at RFQ exit)





Next addition and plans



Chopper line was installed in the week following the Easter break.
2-3 weeks foreseen for RF commissioning of buncher cavities (tuning, calibration, LLRF commissioning..).
Beam measurements periods in parallel (with bunchers OFF) optimising time share to avoid interference with RF work.
Follows full-time commissioning with beam until June 1st (LS1 water cooling cut)

Conclusions

In 3 months' commissioning work we have achieved:

- Stable production of a 16-18mA flat-top, 400μs H- beam from the source @20kW
- Successful conditioning and commissioning of the RFQ, with fully functional LLRF
- Validation of online operational control SW
- Progressive validation of diagnostics devices for beam measurement and characterisation as we go along, fighting tight schedules
- Validation of techniques for offline analysis (emittance calculation, beam reconstruction, forward and backward tracking)

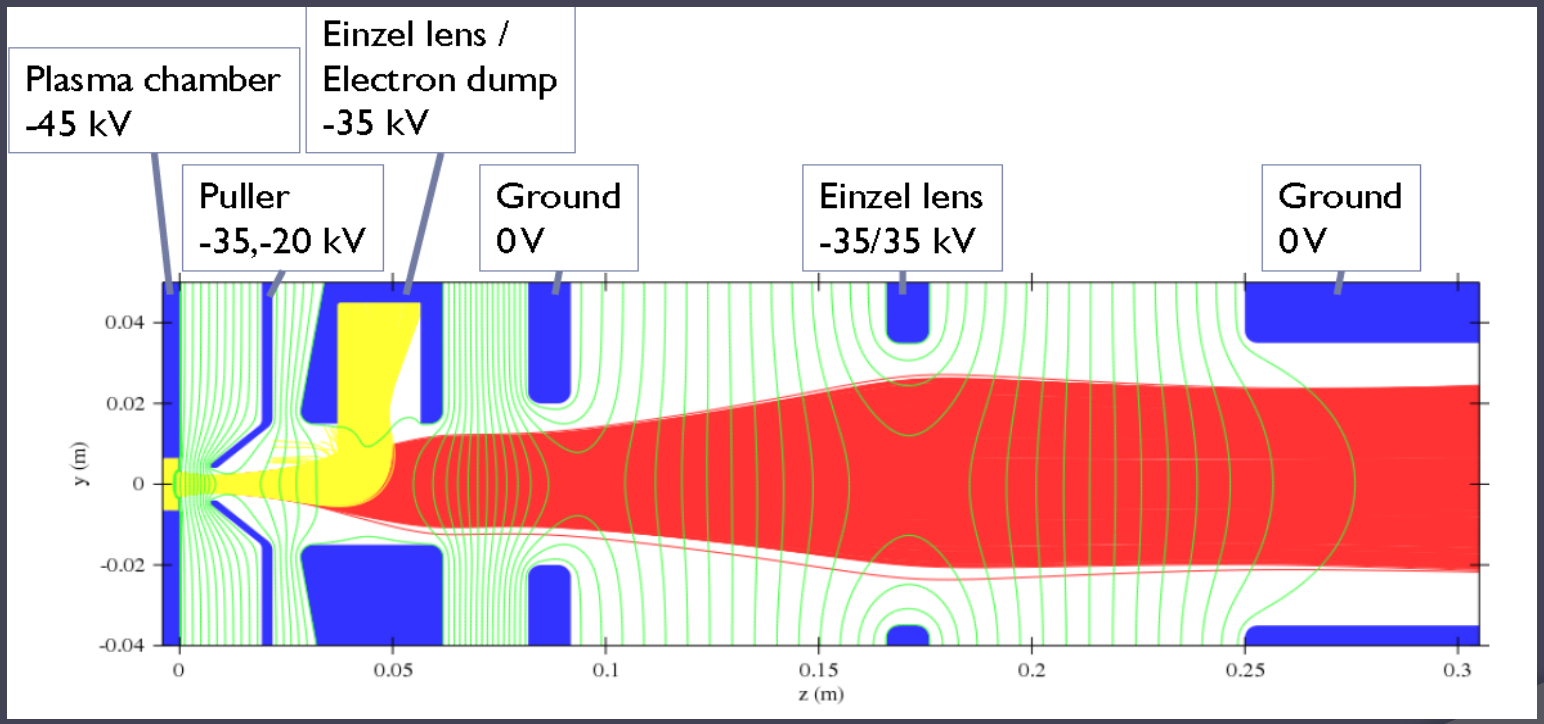
- ❑ We find very good agreement between measurements and simulations (RFQ transmission curves, beam profiles etc)
- ❑ Confident that we have a good characterization of the beam at the exit of the RFQ (emittance and Twiss parameters), as basis and starting point for the setup of the chopper line ahead of us
- ❑ Space charge neutralization in the LEBT is a measurable effect and difficult to simulate (more 'dynamic' model might need to be used) → important to thoroughly characterise the beam at the source output!

Thanks to all who contributed to this intermediate success!

Source: J Lettry, O Middtun, R Scrivens, C Valerio, M O'Neil, S Bertolo, C Mastrostefano, P Andersson, E Mahner
LEBT: D Grenier, C Mitifiot, S Blanchard, B Riffaud, P Moyret, L Zuccalli
BI : U Raich, F Roncarolo, F Zocca, M Duraffourg, D Gerard, J Tan, M Sordet, M Ludwig, F Lenardon, JC Allica, B Kolad, L Jensen, M Andersen, J Tassan-Viol
RF: C Rossi, J Broere, J Balula, M Paoluzzi
VAC : J Hansen, N Thaus, A Sinturel, C Collomb Patton
Beam dynamics: A Lombardi, JB Lallement, V Dimov, M Satri, E Souza
Controls: I Kozsar, J Sanchez, JF Comblin, O Andreassen
Power: D Nisbet, D Aguglia, S Joffe, C Machado, S Putz
and: M Vretenar, C Martin, O Crettiez, A Dallocchio, D Steyaert, T Dobers, S Mathot

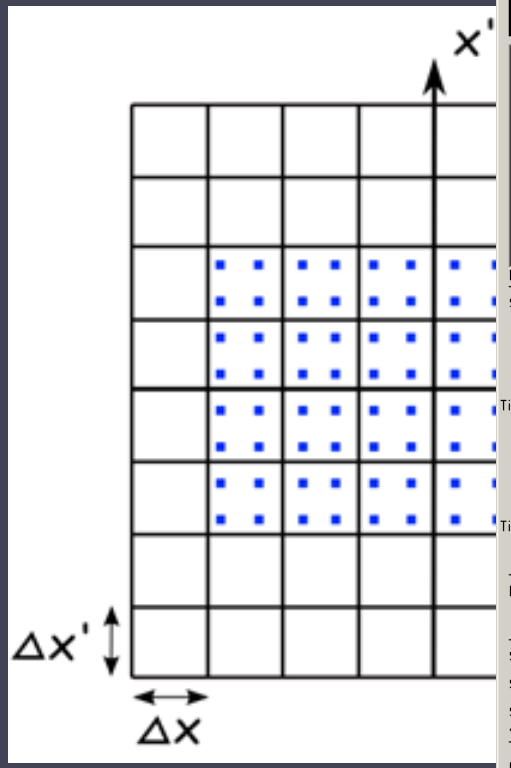
..and apologies to those I involuntarily left out!

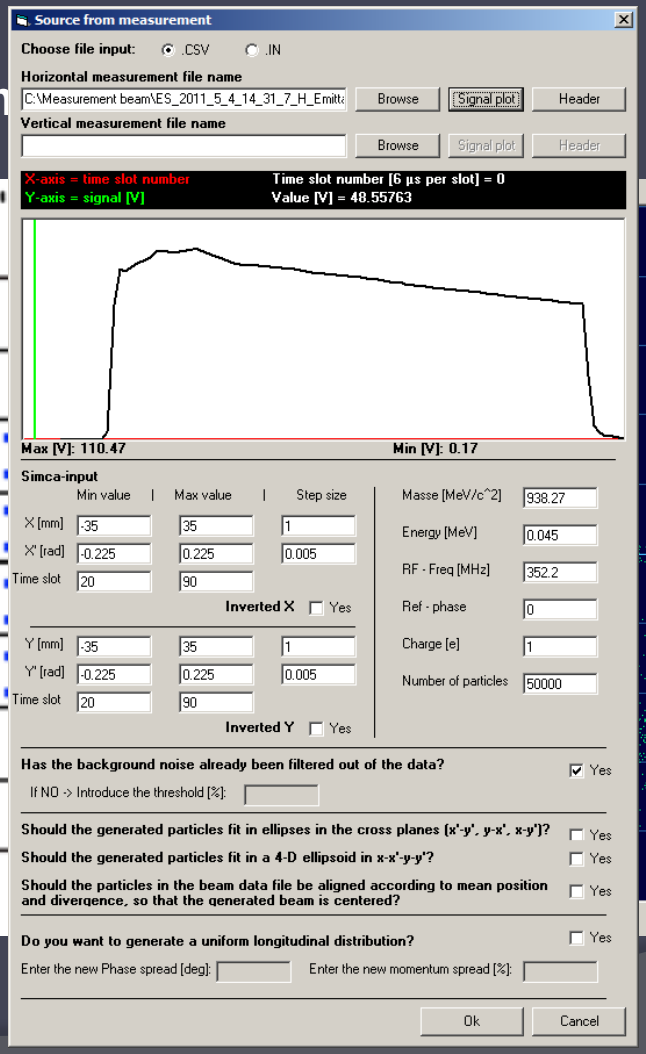
RESERVE SLIDES


Plasma chamber
-45 kV
Einzel lens /
Electron dump
-35 kV
Puller
-35,-20 kV
Ground
0V
Einzel lens
-35/35 kV
Ground
0V
0.04
0.02
0
-0.02
-0.04
y (m)
0
0.05
0.1
0.15
0.2
0.25
0.3
z (m)

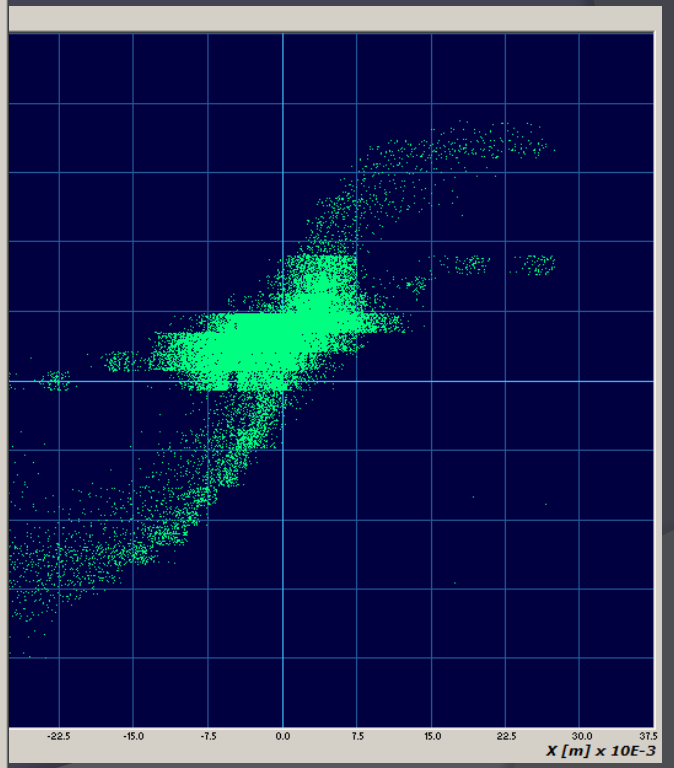
Multi-particle beam emittance reconstruction - PATH

Measuren



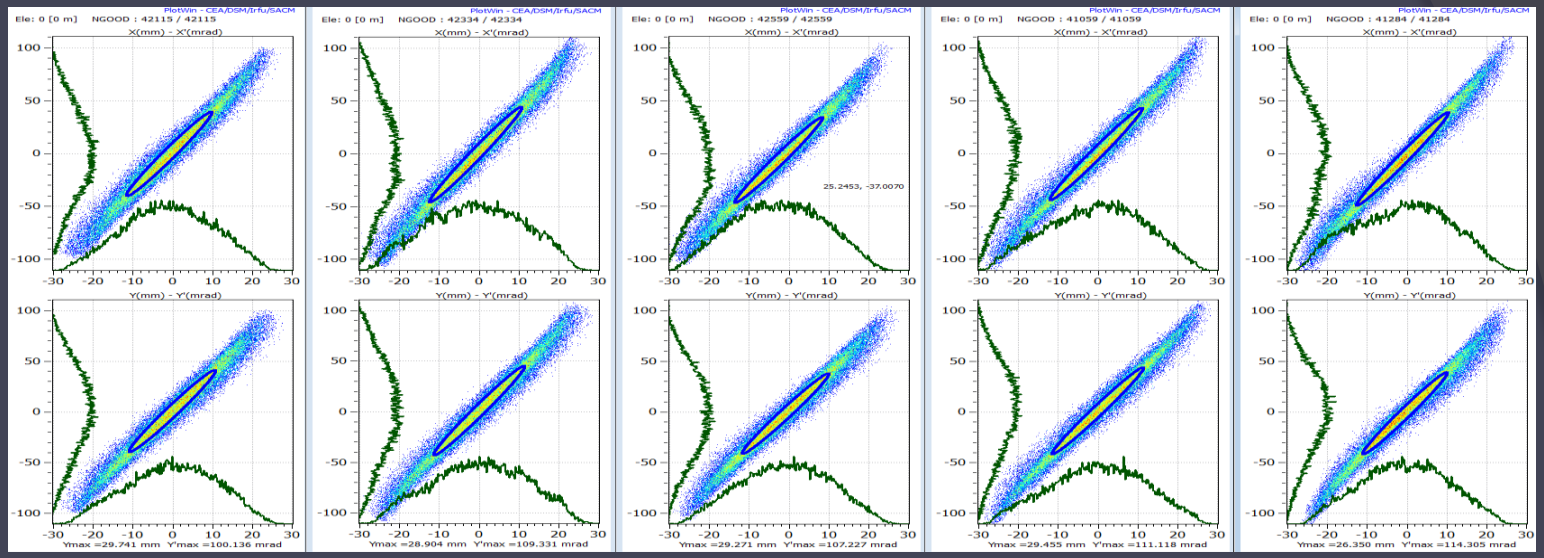


Reconstructed beam



A Mesic

P+ tracked back to Solenoid entrance



Twiss	85A	90A	95A	100A	105A
AlphaX	-5.23	-5.88	-5.75	-5.85	-6.27
BetaX (mm/mrad)	1.44	1.53	1.6	1.58	1.67
AplhaY	-5.24	-5.91	-5.56	-6.01	-5.65
BetaY (mm/mrad)	1.44	1.55	1.56	1.64	1.51
Emit.X (mm.mrad)	0.79	0.86	0.75	0.84	0.79
Emit.Y (mm.mrad)	0.81	0.84	0.75	0.80	0.74

JB Lallement, V Dimov