Linac4 H^- Ion Sources

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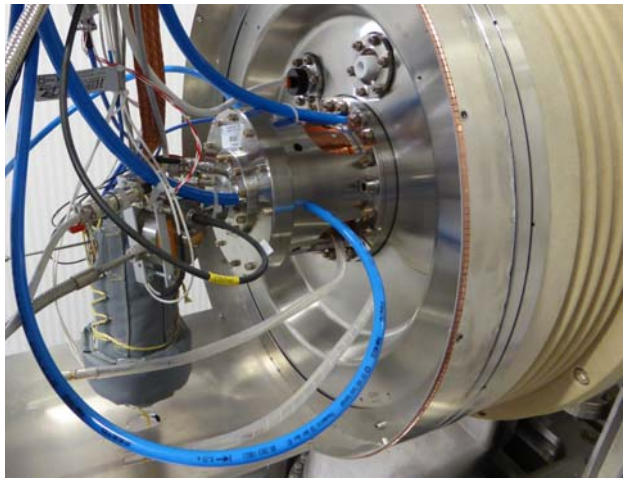
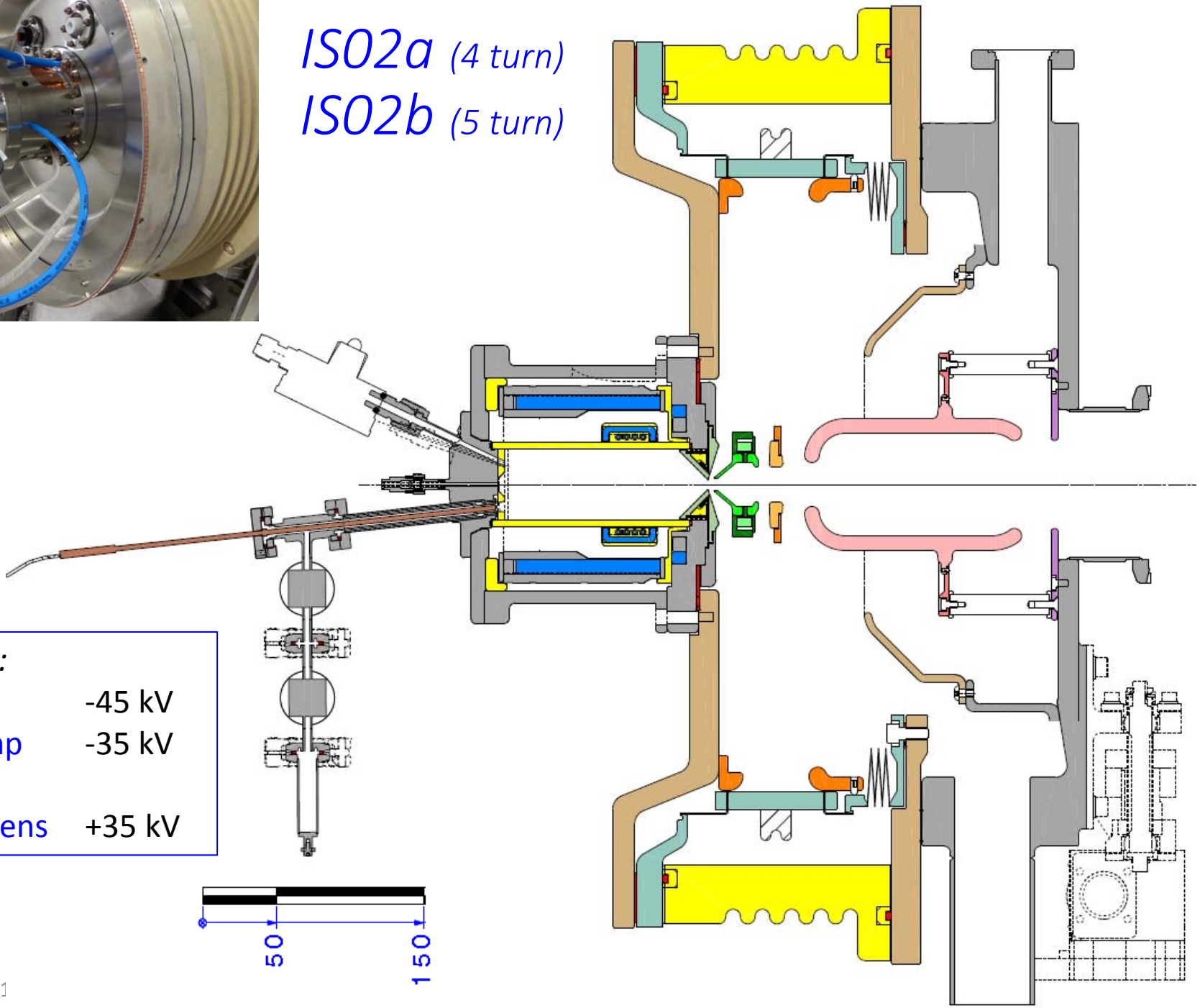
- Linac4 ion source front-end
- H^- sources: Simulation, Test, Operation
  - Cesiated 2MHz RF-driven plasma H^- source test stand results
  - Operating a cesiated 2MHz RF-driven plasma H^- source in Linac4
  - Preliminary results of the BNL's magnetron at CERN



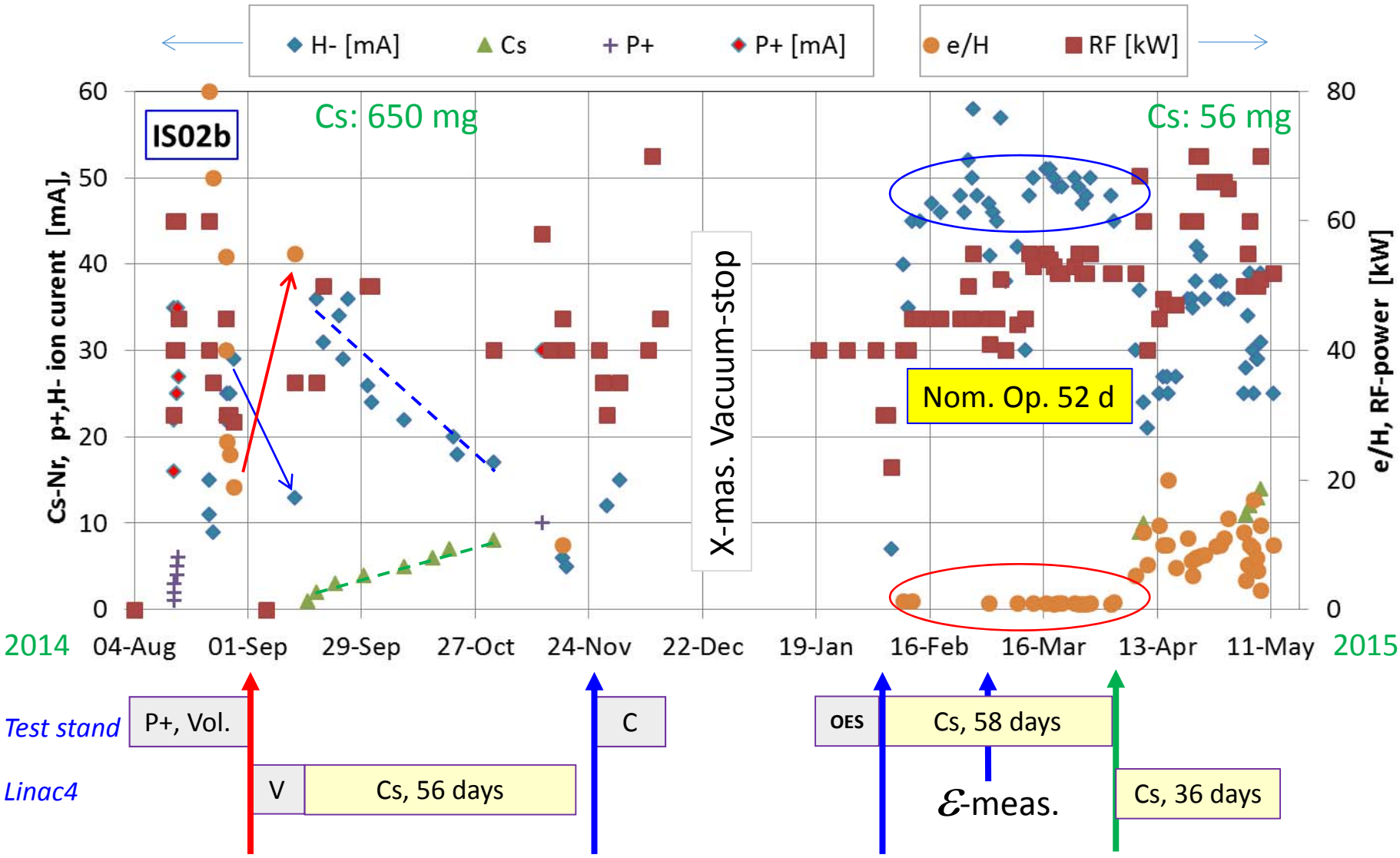
IS02a *(4 turn)*
IS02b *(5 turn)*



Beam optics:

Source	-45 kV
Puller / Dump	-35 kV
Gnd. El.	
Long Einzel lens	+35 kV

IS02b, 5 turn Puller-dump – Long-Einzel optics



Transport
Atm.

Mo-plasma el.
Cleaning: H_2O + heat.

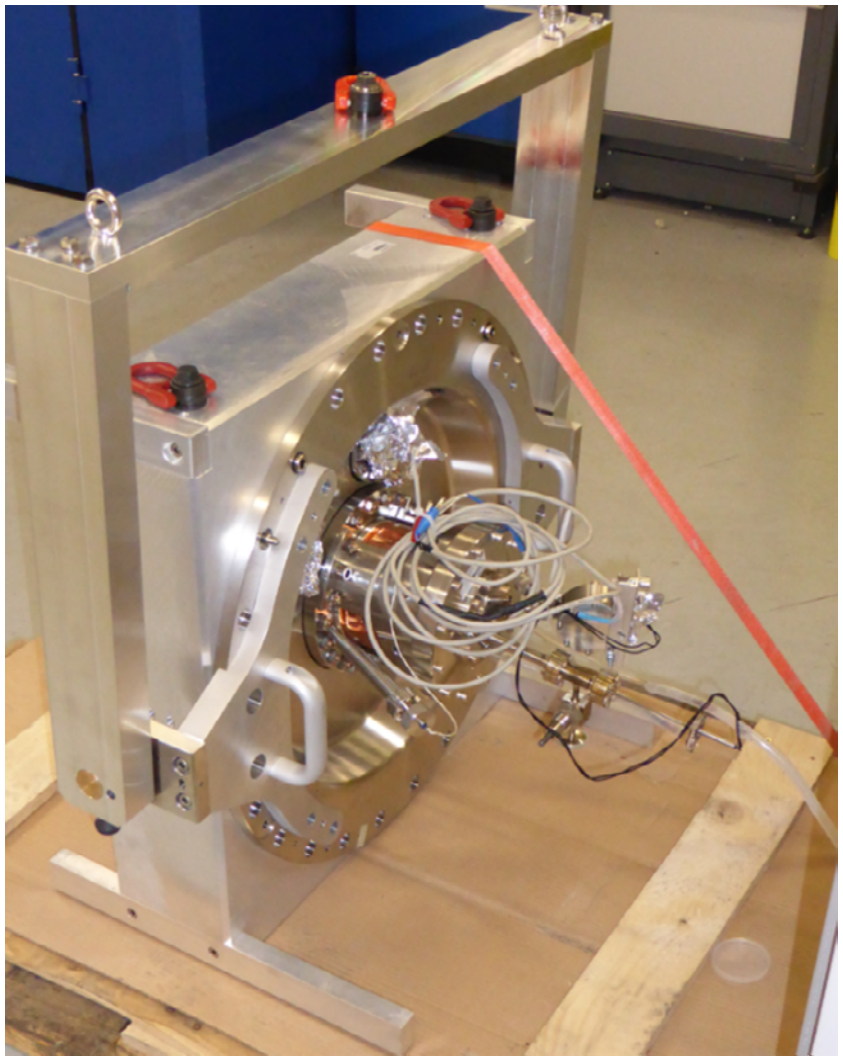
Kr-plasma
Etching

Transport
N_2 - vacuum

IS-Transfer Test-stand – Linac4 under inert gas / vacuum

- ✓ Cs-Oven removed
- ✓ N_2-injection via the Cs-transfer line
- ➢ The air trapped between the Cs-injection valves is the remaining source of O_2-pollution at reconnection of the Cs-Oven

- ✓ Intermediate Storage & Transport under vacuum



IS02$_b$ post mortem *13/11/2014*

Mo Plasma electrode

Overheated Ti-puller electrode

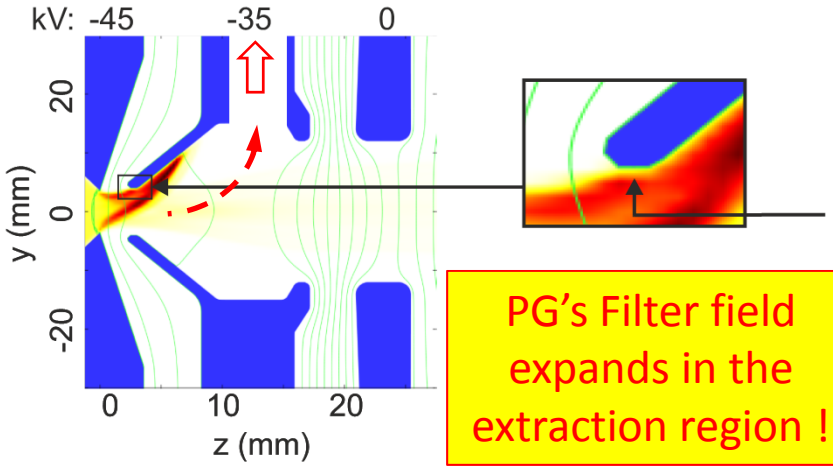
Traces cleaned
with a wet tissue

Al_2O_3 plasma Chamber

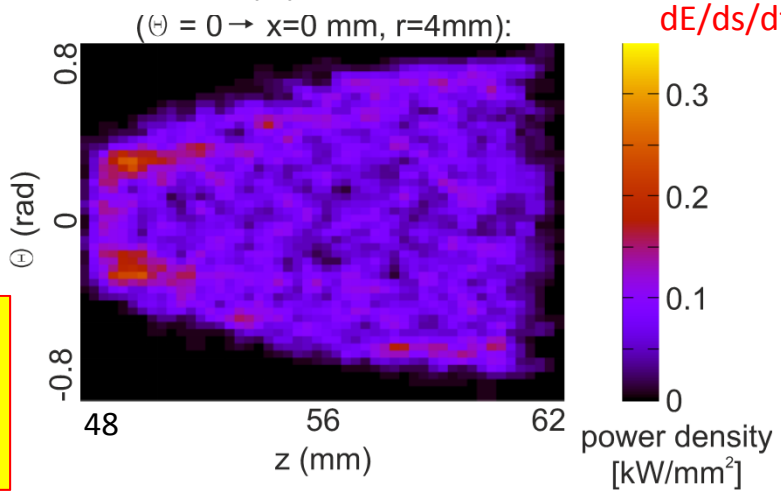
Power Density on Titanium Puller-Dump

Ti -Damage threshold
@ 0.1% duty factor
dE/ds/dt = 0.4 kW/mm²

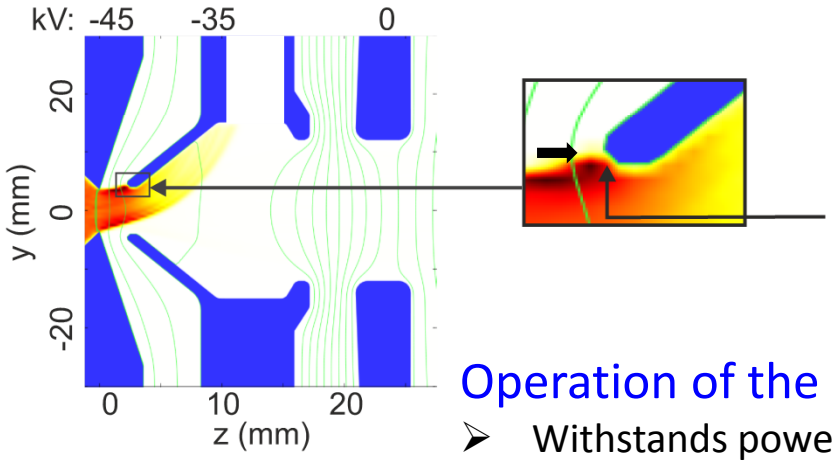
I) Cesiated surface production: I(H⁻): 40-50 mA, e/H⁻: 4, I(e): 200 mA

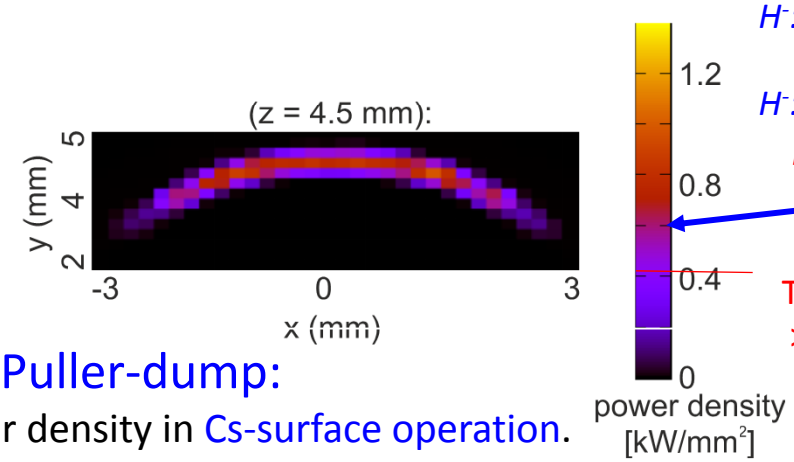


PG's Filter field expands in the extraction region !



II) Vol. prod.: I(H⁻): 40-50 mA, e/H⁻: 40, I(e): 1600 mA





H⁻: 30 mA, e/H=20

H⁻: 15 mA, e/H=40

I(e): 600 mA

At Linac4

Ti Damage
> 500 mA

No magnets in the e-Dump

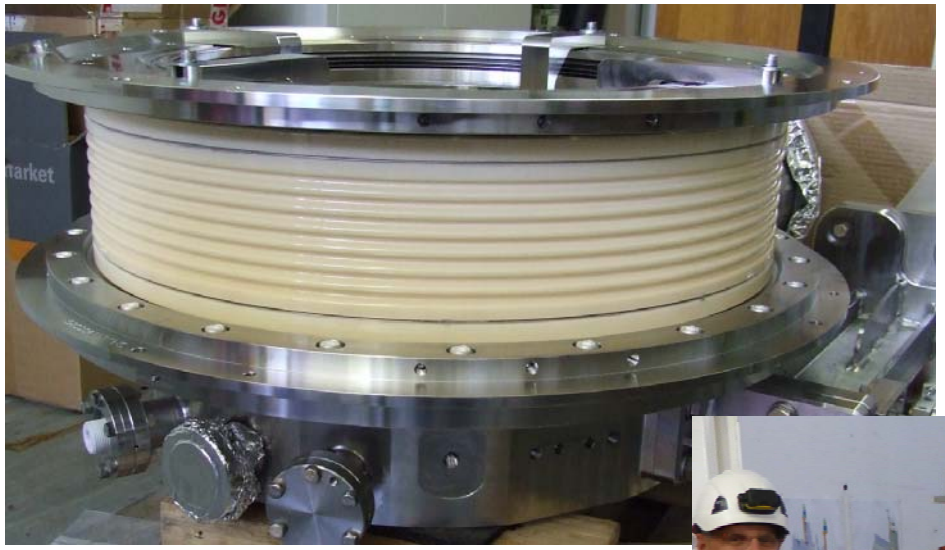
Operation of the Puller-dump:

- Withstands power density in Cs-surface operation.
- Limited to 500 mA electron current in vol.-mode
- Production of secondaries by e-dumped at the wrong spot, those are extracted at 45 keV and load the pulsed HV.

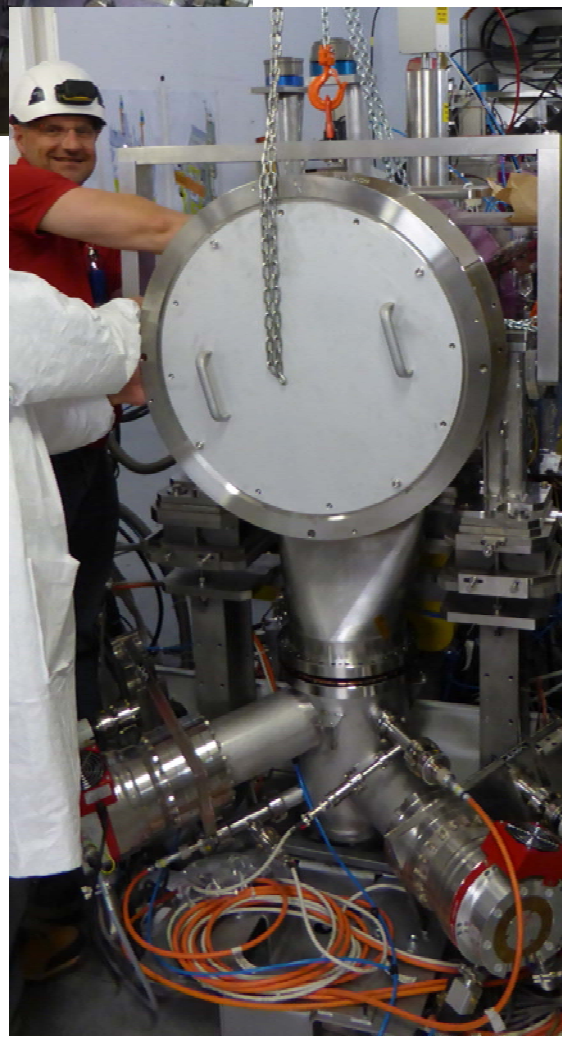
Courtesy of D. Fink

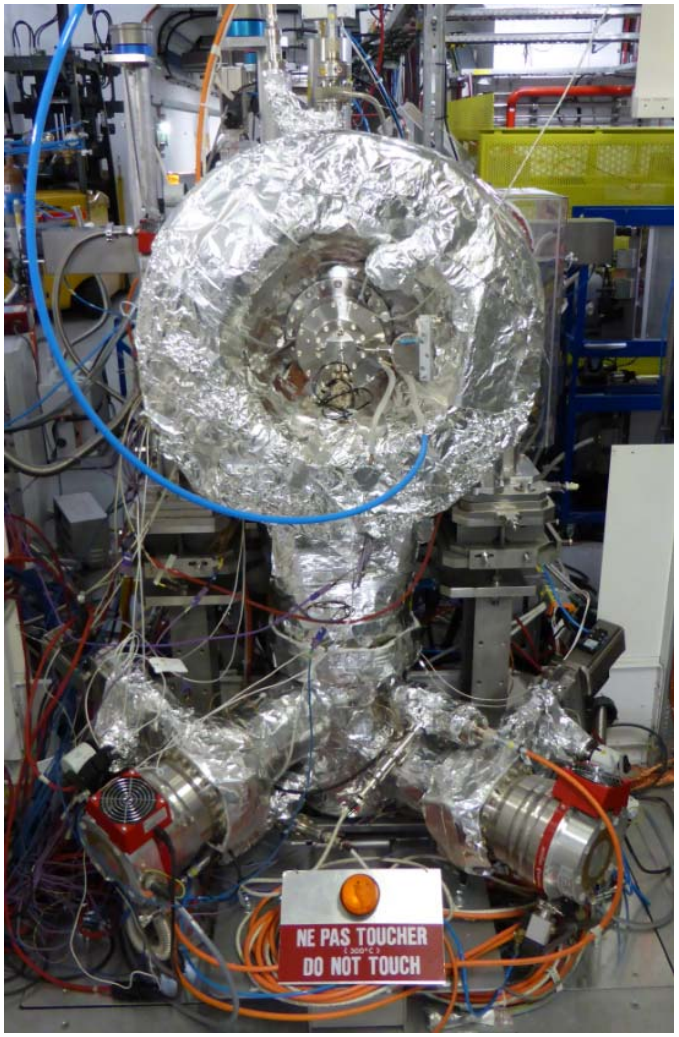
New Front end installation & bake-out

- ✓ Pumping port and valves 140°
- ✓ Ceramics 90° Cusp
- ✓ Magnets kept below 60°



Glazed Al_2O_3
Ceramic insulator





Pre-aligned support,
IS-position within 0.3 mm

IS03a B-Op, B-ll optics

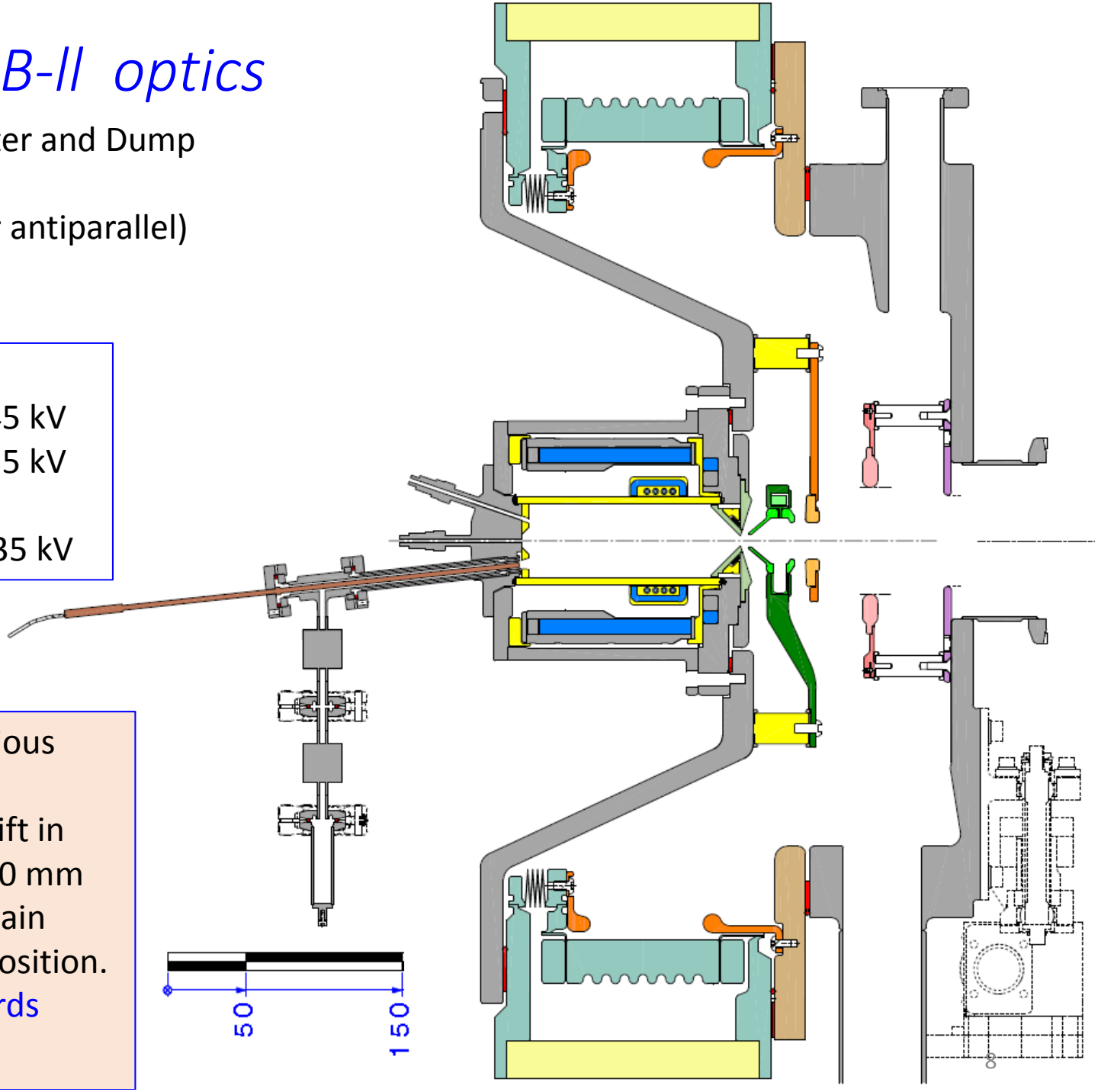
Orientation of the Filter and Dump magnetic dipoles:

B-Op := Opposite (or antiparallel)

B-ll := Parallel

Beam optics:

Source	-45 kV
Puller / Dump	-35 kV
Gnd. El.	
Einzel lens	+35 kV

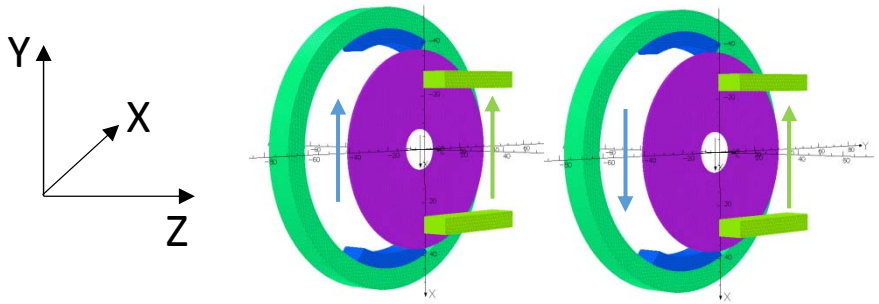


- ✓ Compatible to previous flanges & PGs
- ✓ Reduction of the drift in the front-end by 100 mm
- ✓ Protection of the Main insulator vs. Cs-deposition.
- ➢ Improvement towards nominal emittance.

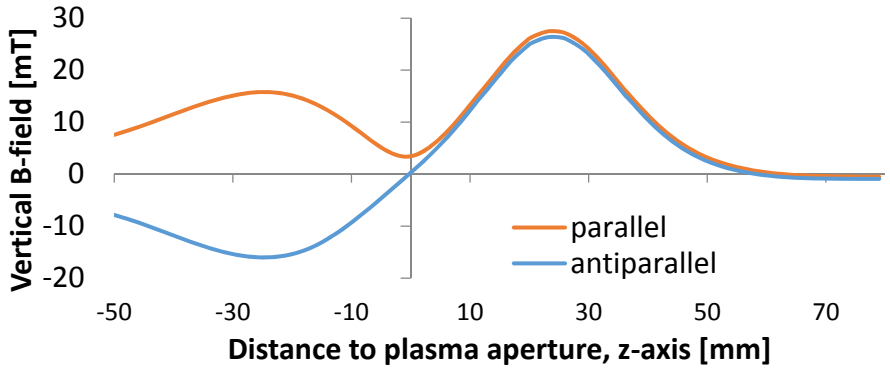
IS03a Op & II beam optics: Opera & IBSimu simulation

Magnets configurations:

a) parallel b) Antiparallel (Op)



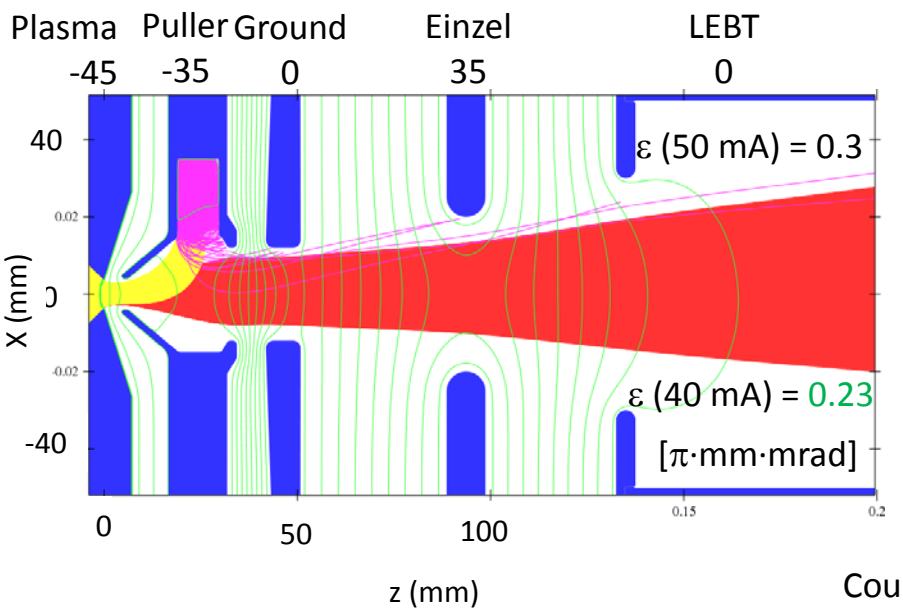
Vertical B-field along longitudinal axis:



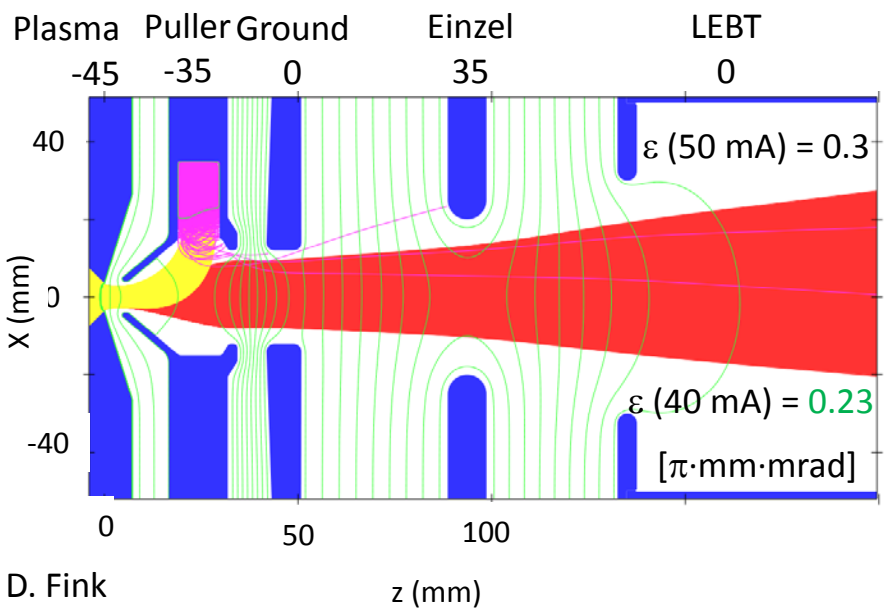
Filter + magnetic shield + dipole magnets:

H^- Beam: 50 mA,
e^- beam 150 mA e^-
$e/H^- = 3$

a) parallel

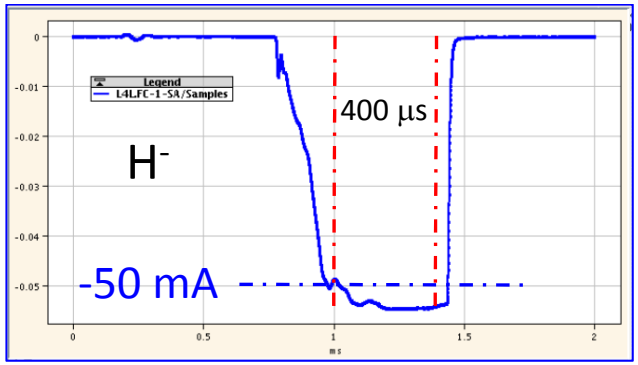


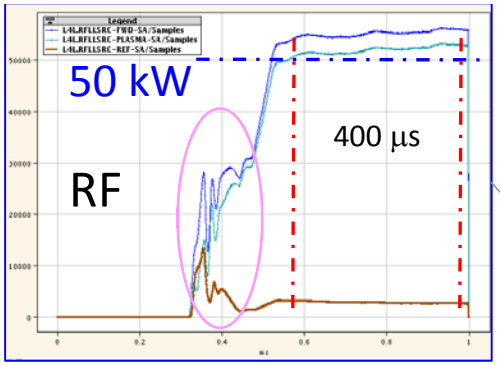
b) antiparallel



Courtesy: D. Fink

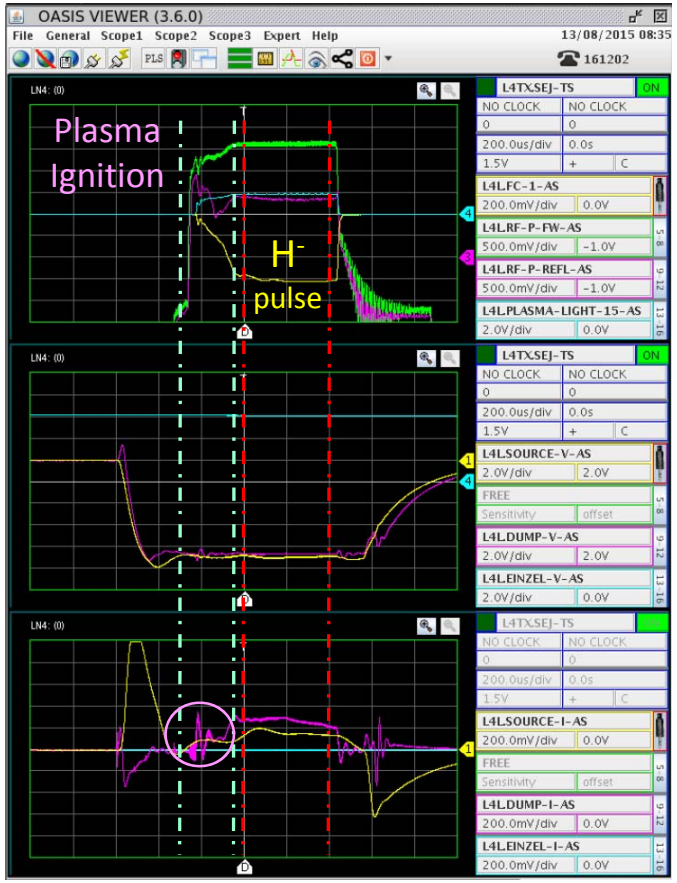
IS03a-II Operation

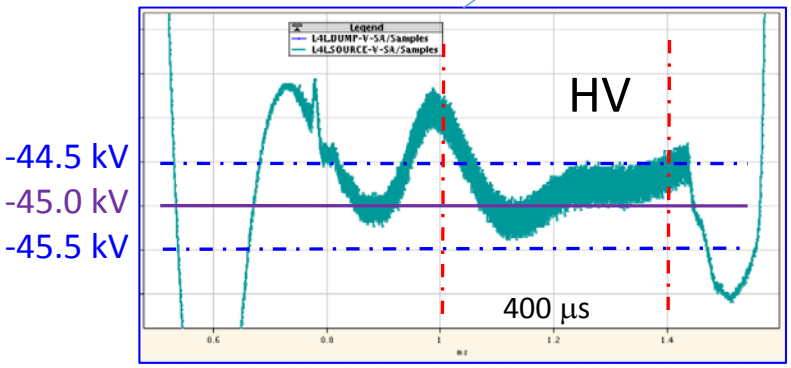




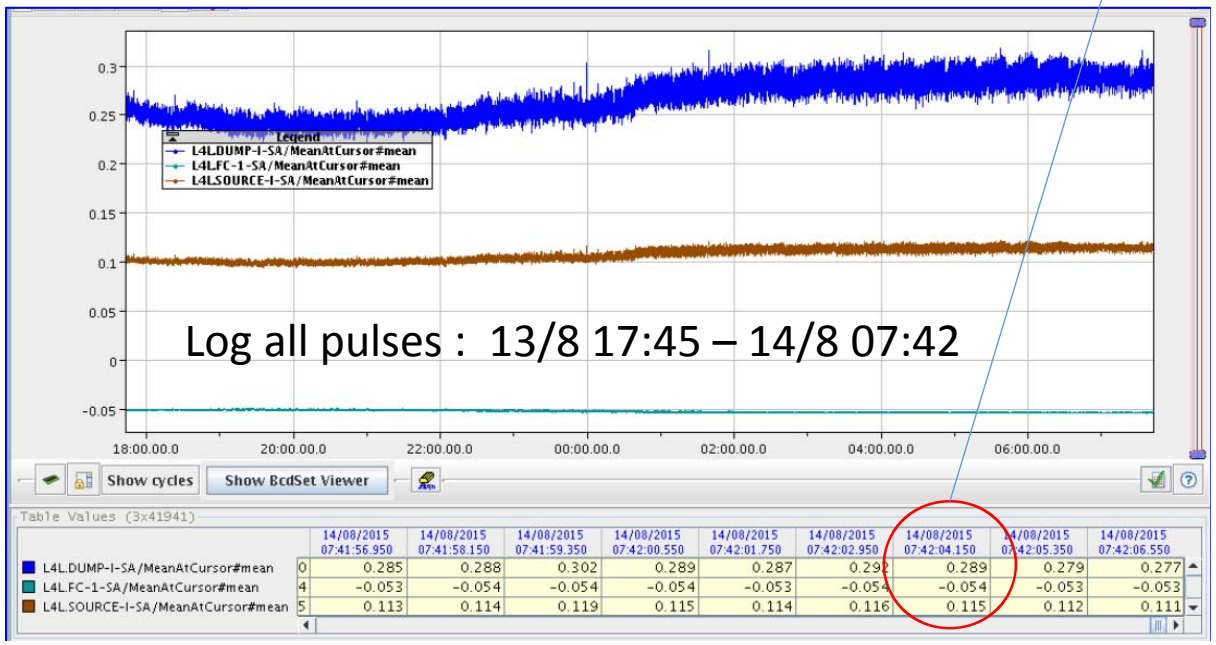
IS-Figures of merit:

Beam formation:	6.33 [e/H-ion]
RF-coupling:	94.1 %
RF-yield:	1.05 [mA/kW]
e-dump leakage:	15.5 %
Beam energy std. dev:	[V]





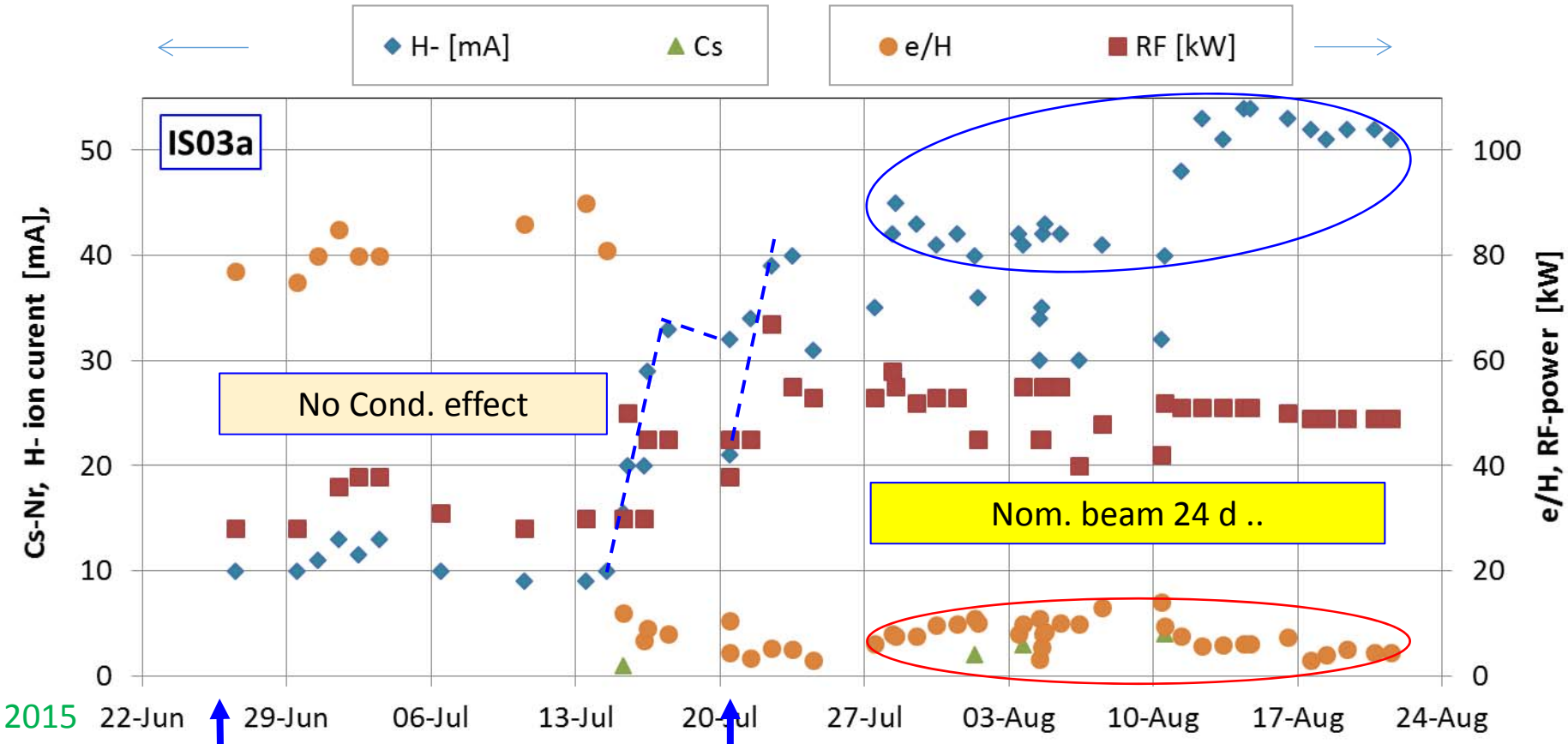
[A]	14/08/2015 07:42:04.150
e-dump	0.289
H- beam	-0.054
I-Source	0.115



		14/08/2015 07:41:56.950	14/08/2015 07:41:58.150	14/08/2015 07:41:59.350	14/08/2015 07:42:00.550	14/08/2015 07:42:01.750	14/08/2015 07:42:02.950	14/08/2015 07:42:04.150	14/08/2015 07:42:05.350	14/08/2015 07:42:06.550
L4LDUMP-I-SA/MeanAtCursor#mean	0	0.285	0.288	0.302	0.289	0.287	0.292	0.289	0.279	0.277
L4LFC-1-SA/MeanAtCursor#mean	4	-0.053	-0.054	-0.054	-0.054	-0.053	-0.054	-0.054	-0.053	-0.053
L4LSOURCE-I-SA/MeanAtCursor#mean	5	0.113	0.114	0.119	0.115	0.114	0.116	0.115	0.112	0.111

IS03a Linac4

Cs: 16.5 mg



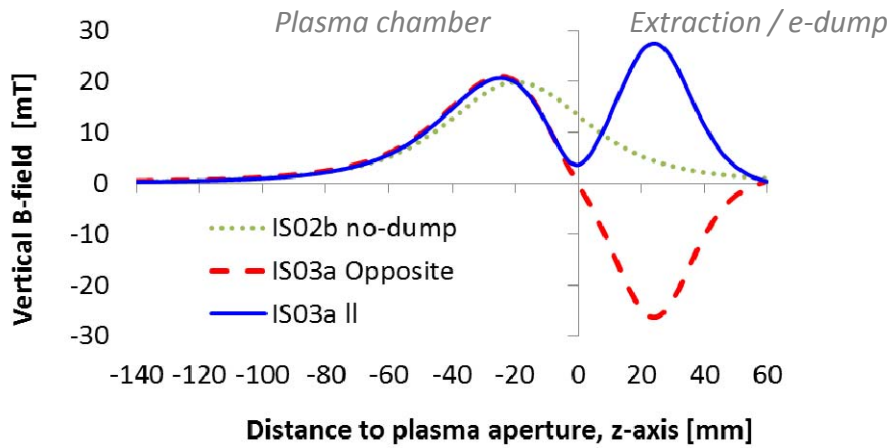
- Inst. FE + leak test
- Inst. B-O
- Bake-out.
- Dismount B-O

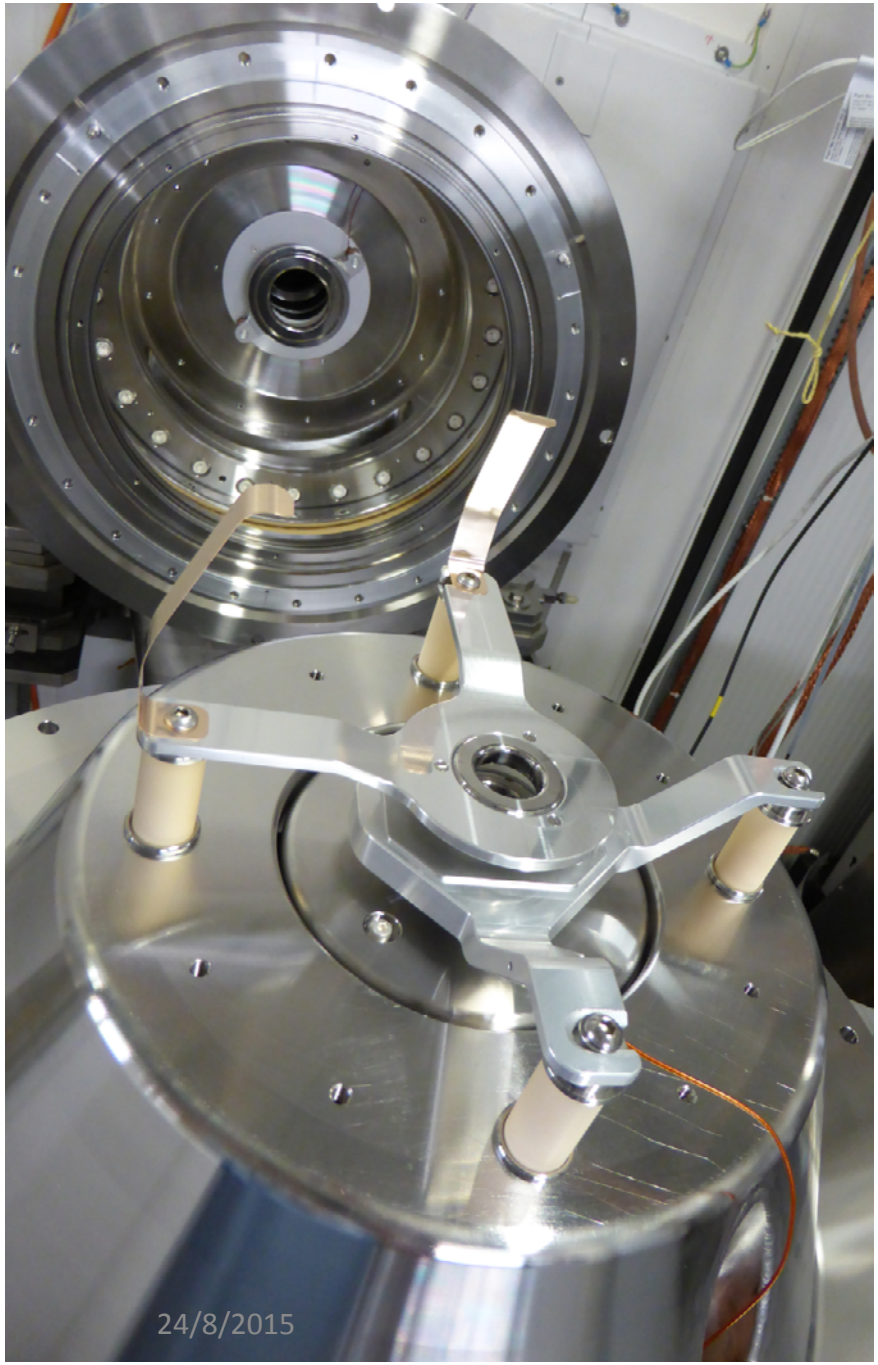
✓ 6 days

Opposite

Filter and dump Field.

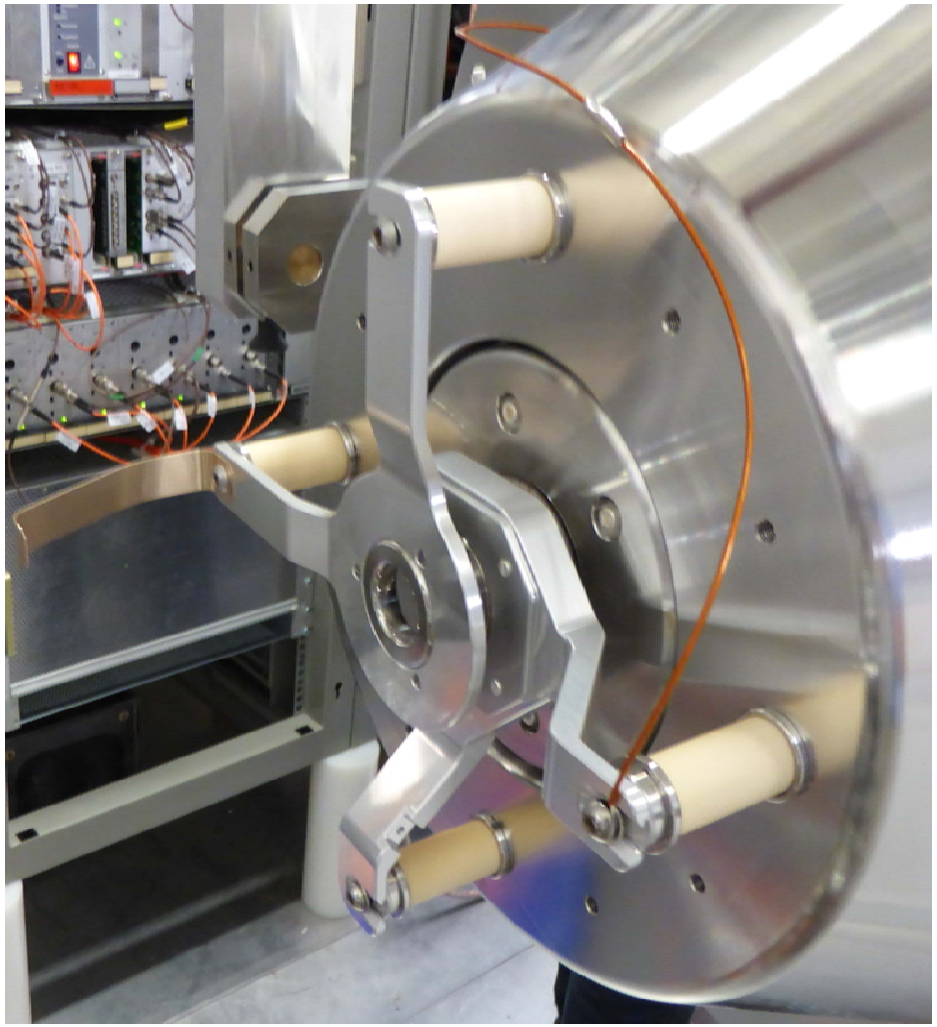
Switch to Parallel filter and dump Field.





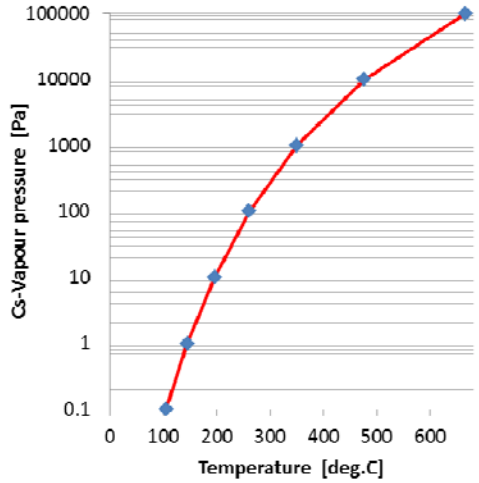
Inversion of the IS03a dump field

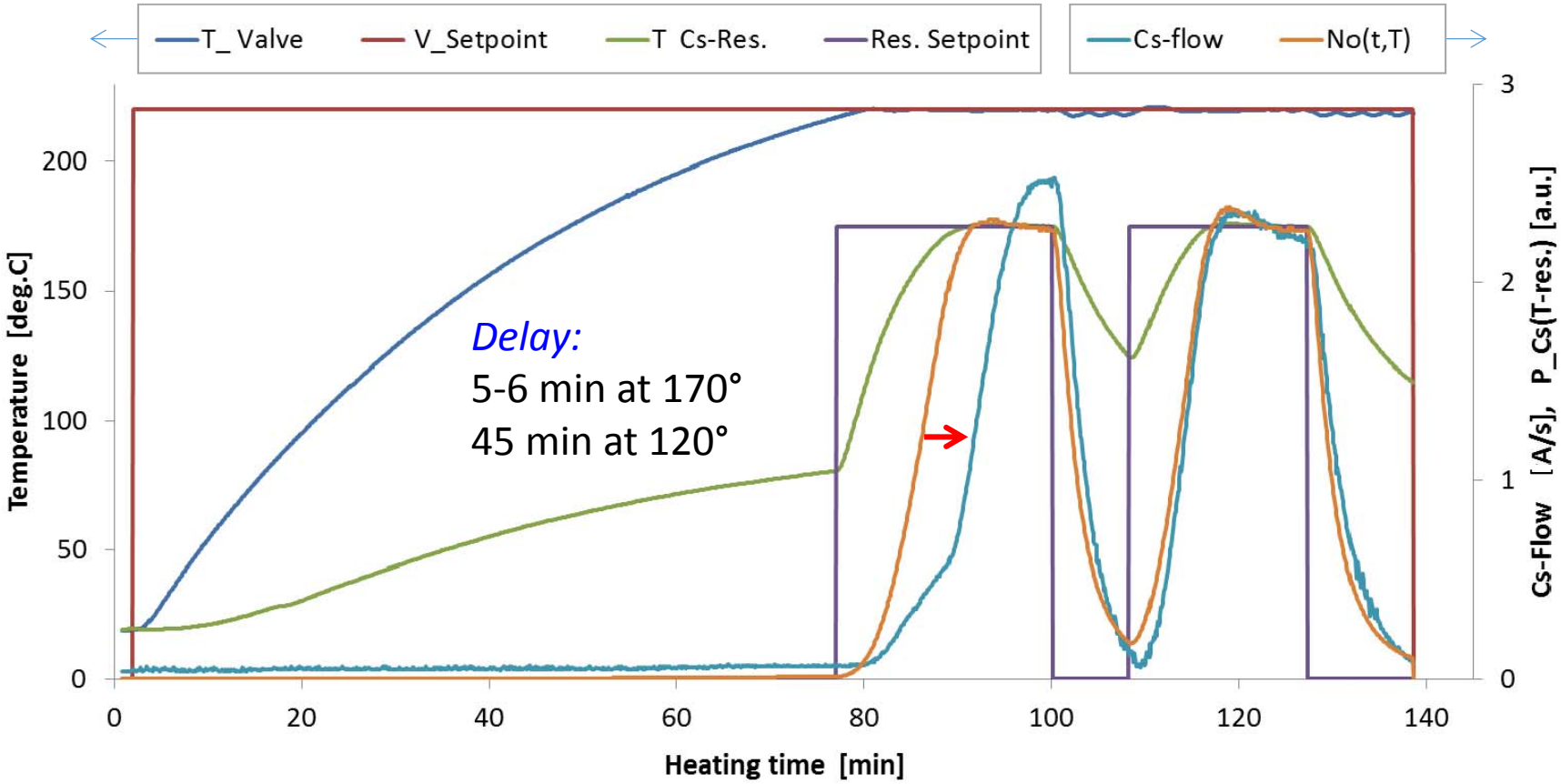
Rotation of the puller/dump
and ground electrodes by 180°



Cs studies

- ✓ Cs-flow Calibration
- ✓ Calibrated X-ray spectroscopy detection down to µg of Cs
- ✓ Sampling via solution in water → suitable for low surface concentrations of Cs



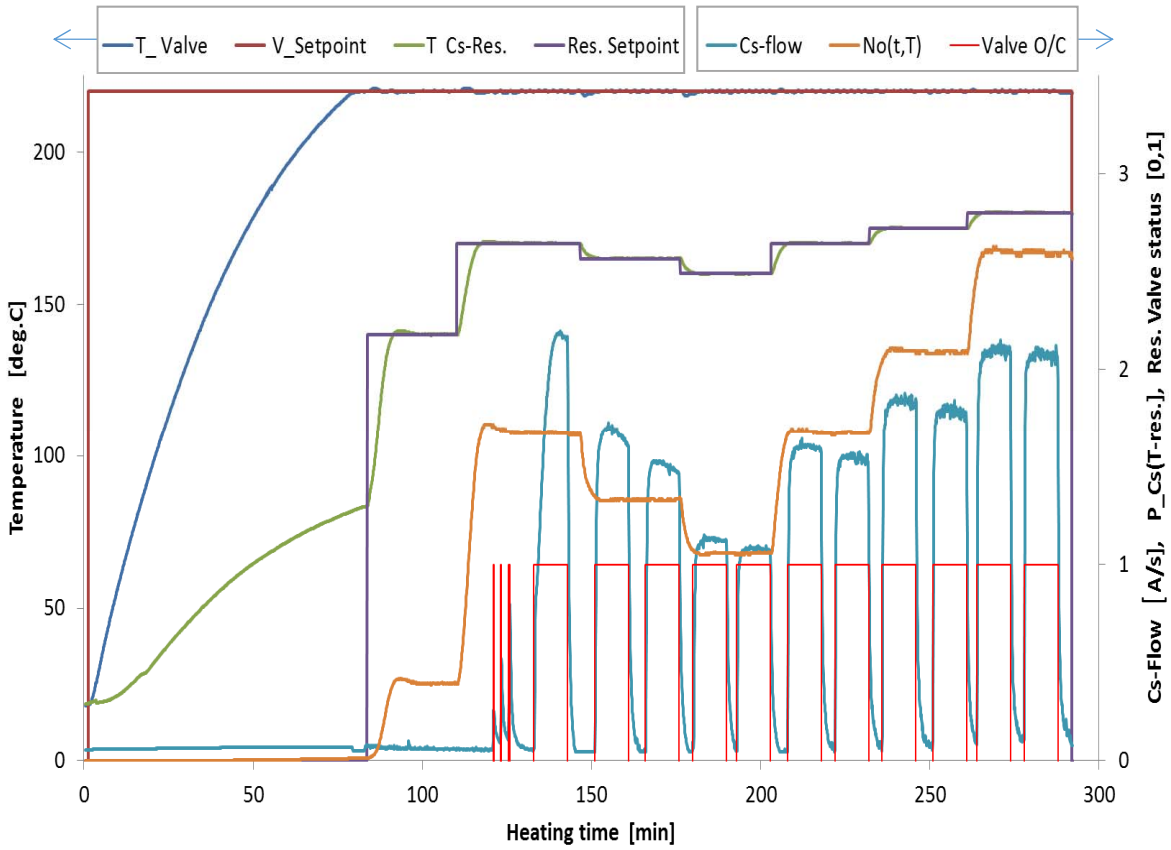


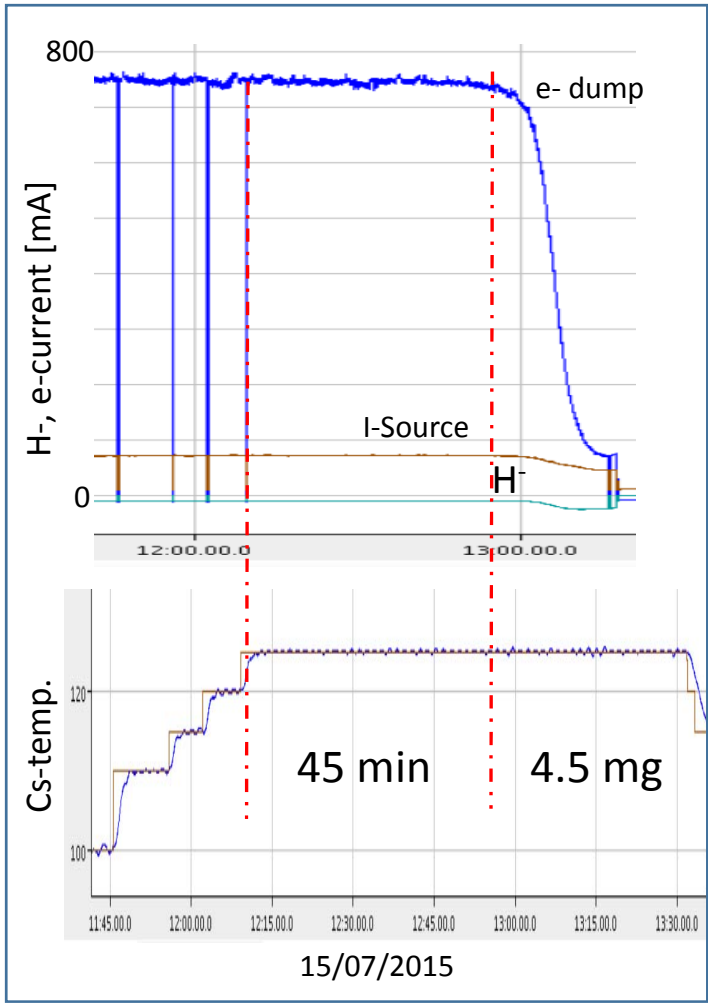
Valve & Temp. controlled cesiation (UHV vs. H2-plasma)

- ✓ The Cs-reservoir valve is always closed to prevent reaction in the event of accidental venting of the source between cesiations.
- ➢ The Cs-Valve will be motorized, Access free & improved process control.
- ✓ Cesiation under UHV conditions (H2 injection stopped).
- ✓ *"Low" temperature slow cesiation with plasma and HV*

Alternative:

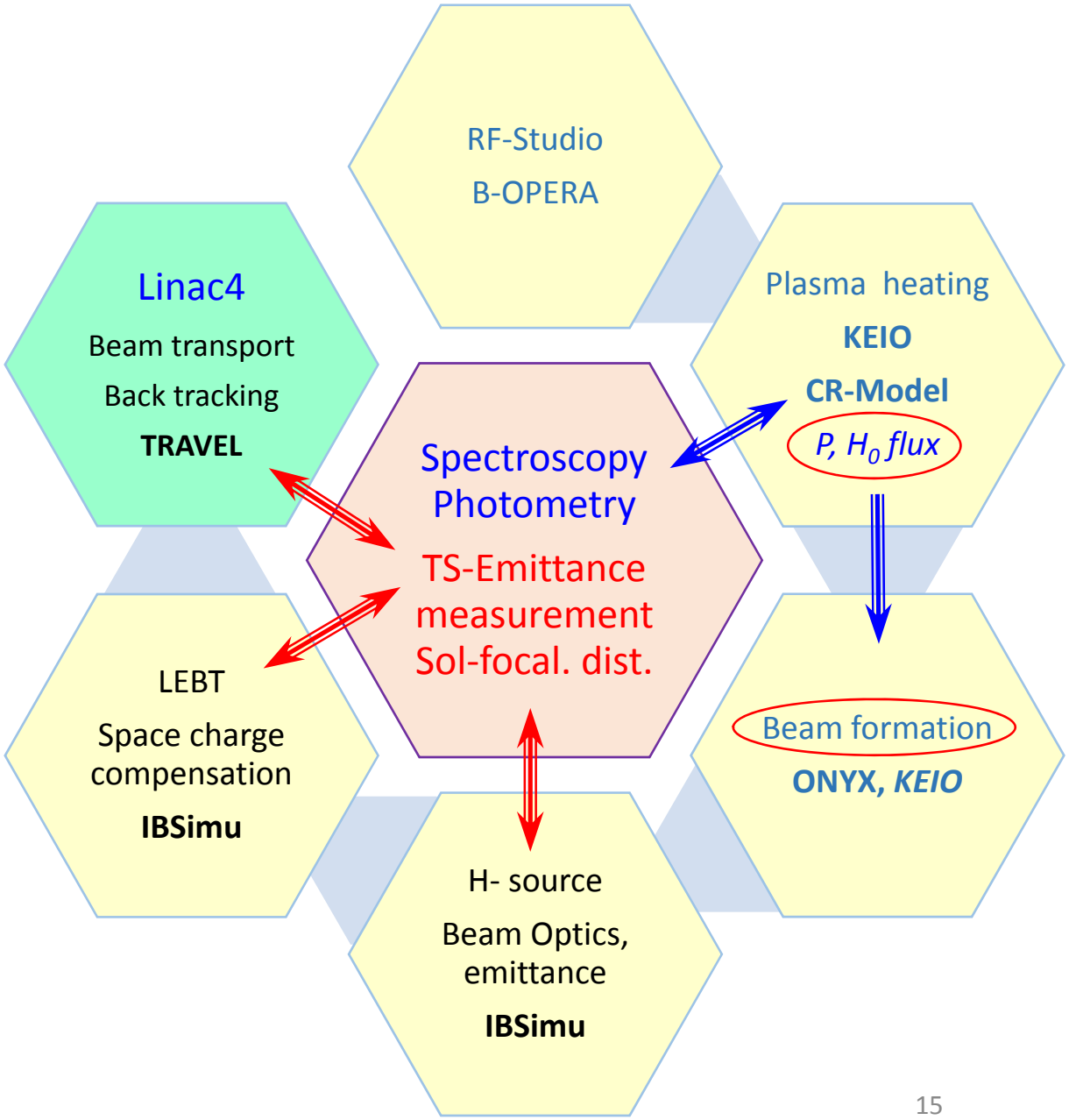
- ➢ *ionic cesium implantation (Aix-IPP coll.)*



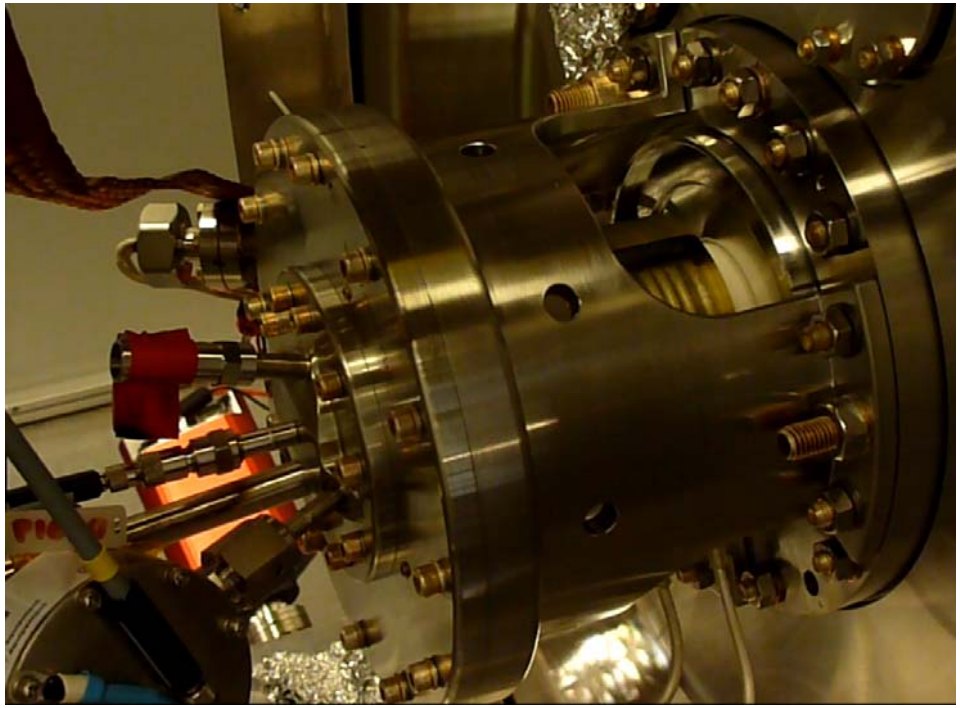


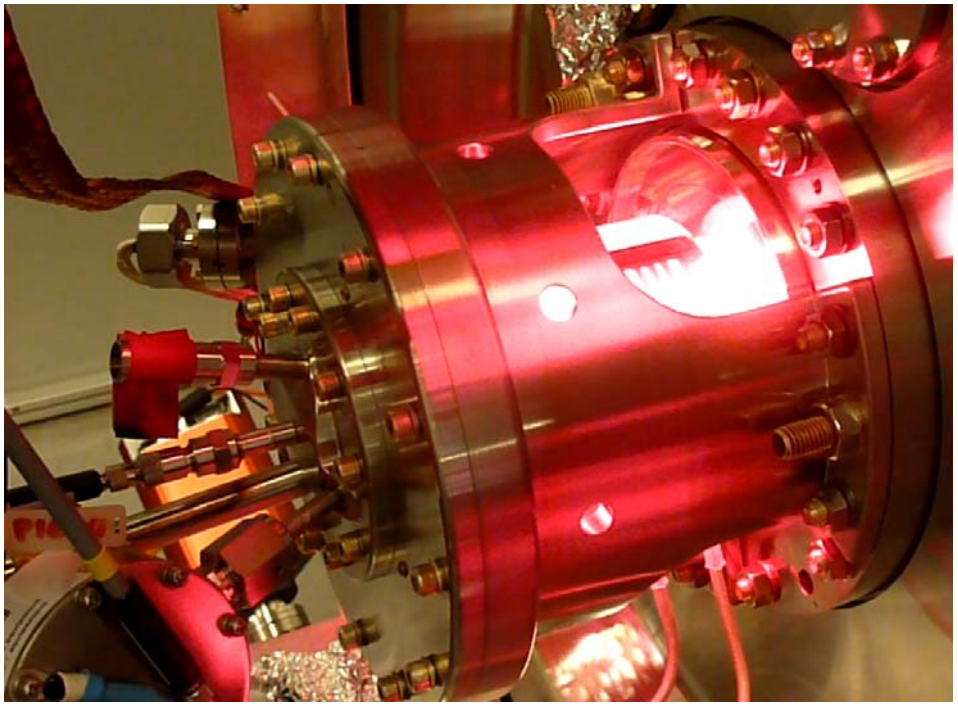
Emittance – Acceptance – Transmission / Beam formation

- ✓ Time dependent emittances measured at the IS-test stand
- ✓ Optimization of the space charge compensation with 2E-6 mbar H_2
- ✓ Time dependent 1st solenoid's focal point meas. (test stand)
- ✓ N-particle sampling from IBSimu, Travel vs. IBSimu Ok, Minimize volume mandatory for IBSimu.
- ✓ N-particles sampling from emittance x,y,x',y' distr. fed into Travel
- ➢ Back tracking
- ➢ Propagation through Linac4 → i.e. RFQ-transmission
- ➢ IS-operation status via 1st solenoid's focal point meas. in Linac4



Hydrogen Plasma studies:

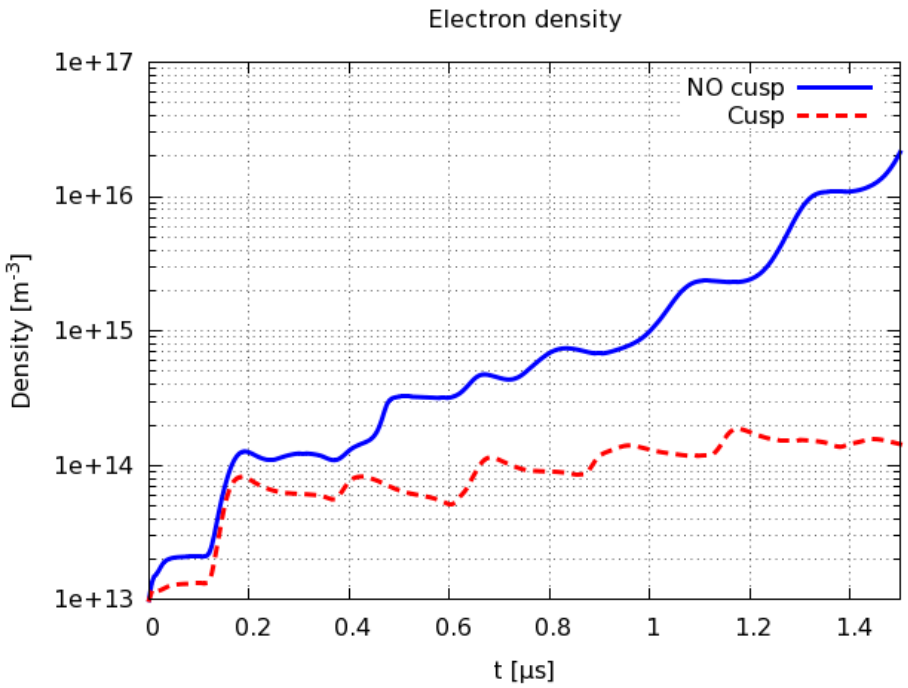




IS02-No-cusp tests 20/4/2015

Atomic: Balmer Photometry (Plasma ignition) & Spectroscopy
Molecular: Fulcher band Spectroscopy

Poster:
Determination of discharge parameters via OES at the Linac4 H^- ion source
S. Briefi, D. Fink, S. Mattei, J. Lettry, and U. Fantz

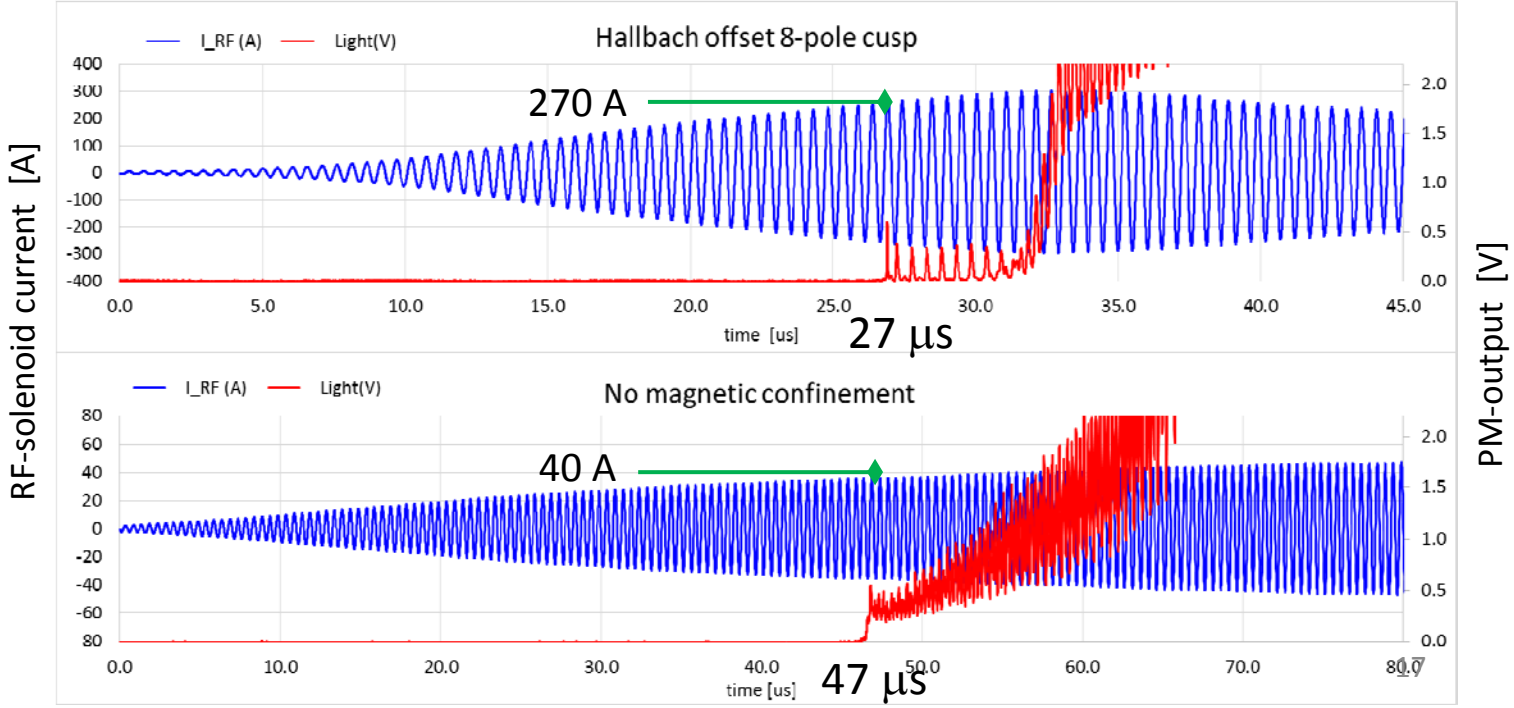


Plasma Ignition

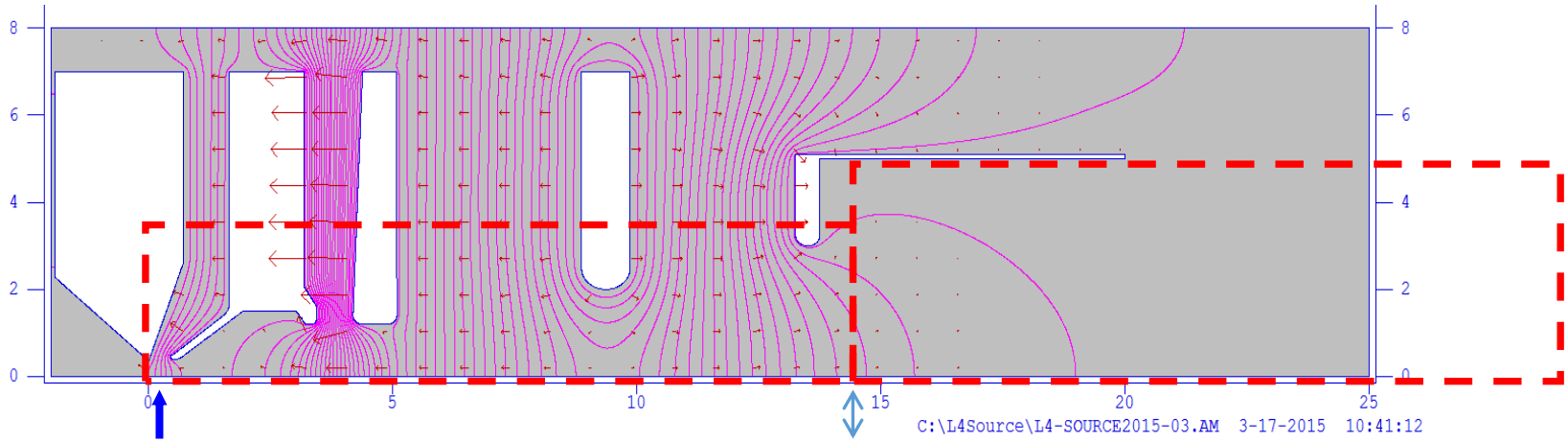
The effect of the L4-IS magnetic cusp was investigated in three ways

1) RF-heating Simulation shows very different heating behaviour, faster without cusp.
2) Photometry: A much lower RF-field ignition threshold is observed
3) Spectrometry: see S. Briefi's poster

➢ Ignition's e-burst may well be an easier deal, H^- yield to be measured.



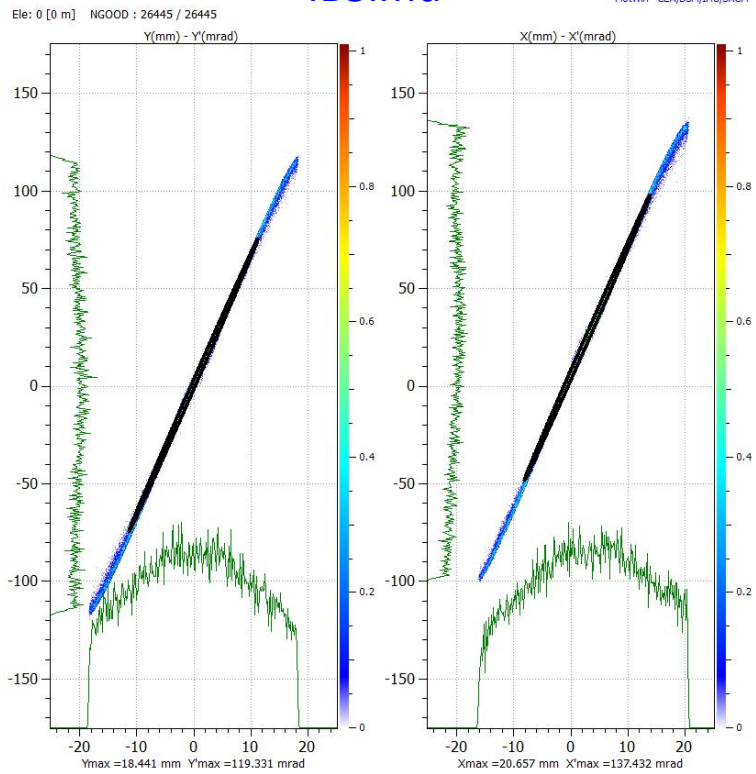
S. Mattei



IBSimu Input: 26k H^-, 16k e^-, $\mathcal{E}$ = 0.132 mm.mrad

Comparison

IBSimu



IBSimu / Travel

26k H^-

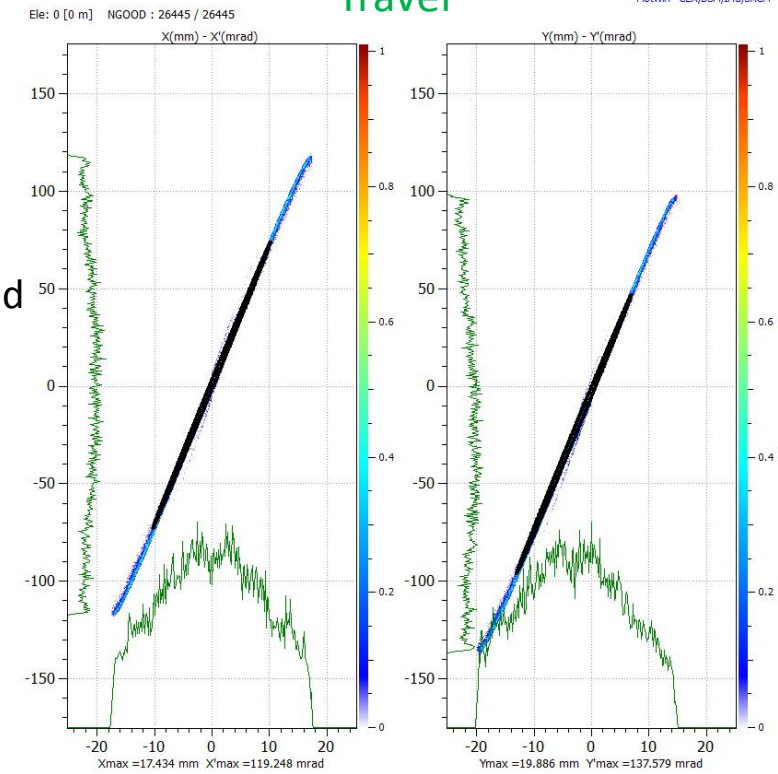
0.22 / 0.19 mm.mrad

2.97 / 2.99 mm

24.6 / 24.8 mrad

Courtesy: D. Fink & J.B. Lallement

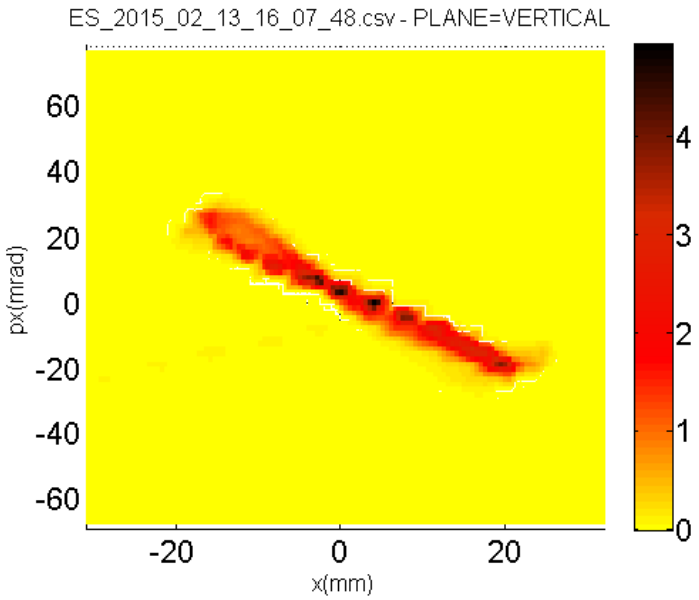
Travel



Emittance, Back Tracking

IS02$_b$ emittance meas.:

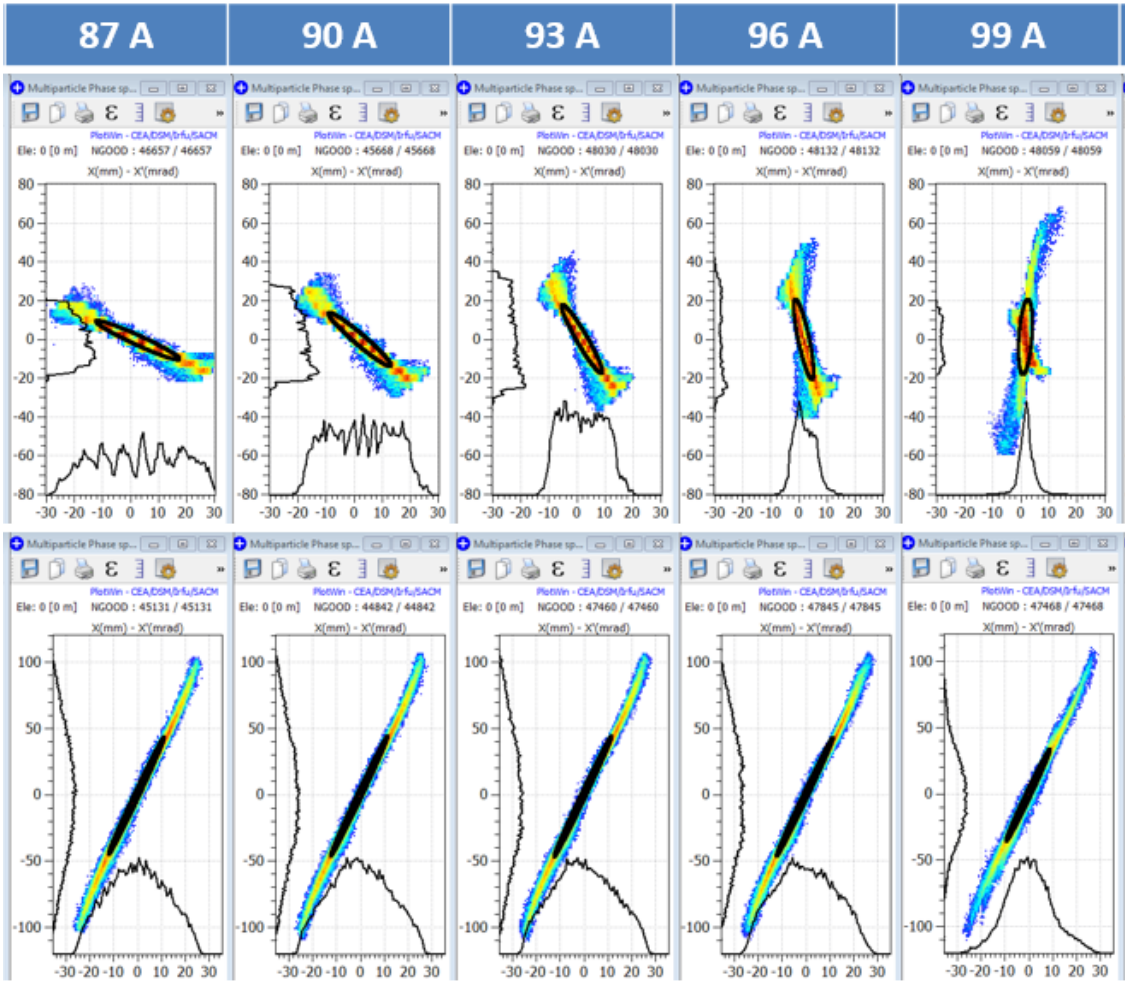
- ✓ H^- intensity [0-380 µs] 45 mA
- ✓ Electron to ion ratio: 1.3
- ➢ 90% within 0.3 π·mm·mrad $_{RMS}$
- ➢ Expected RFQ-transmission 83%



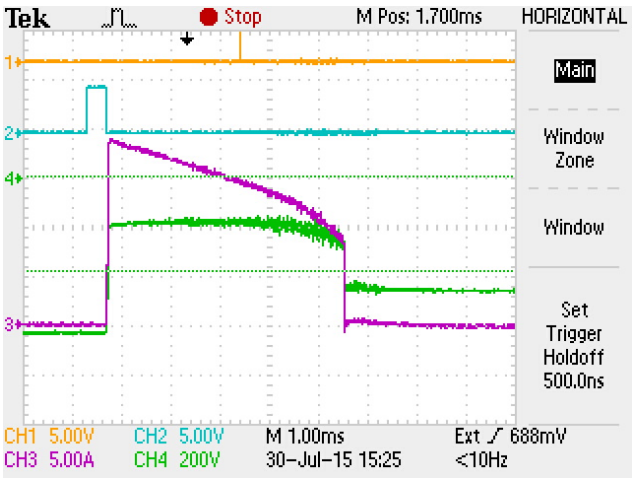
Courtesy: R. Scrivens,
D. Fink & J.B. Lallement

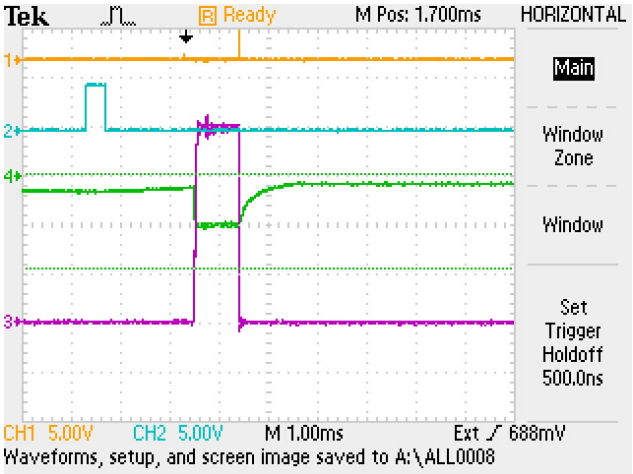
Back Tracking:

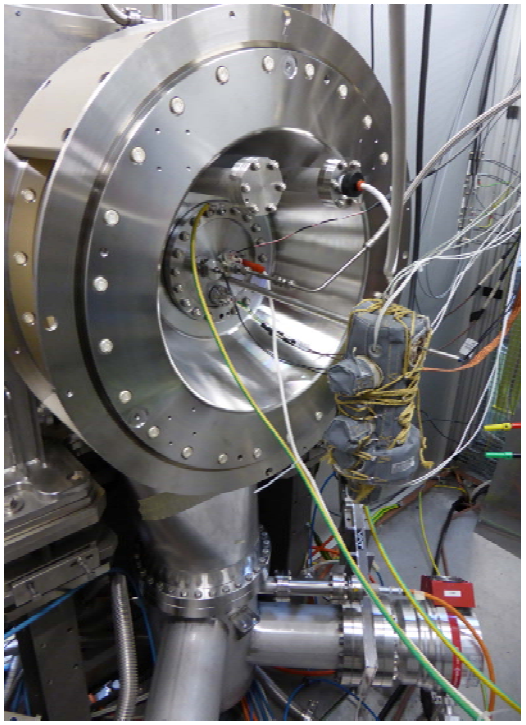
- ✓ Sampling from ε-meas. distributions.
- ✓ Back tracking to an arbitrary beam origin.
- ✓ Validate back tracking stability vs. optics setting
- ➢ Transport from this origin through the Linac4



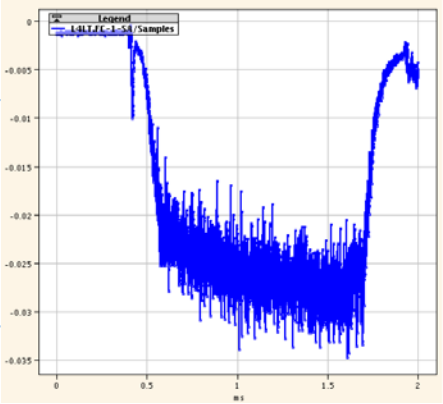
Magnetron discharges & H- beam







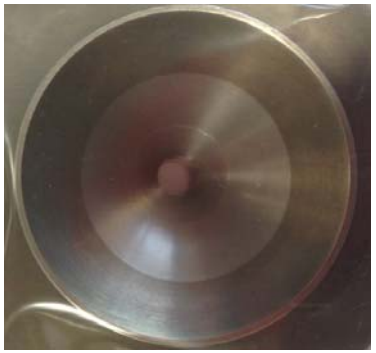
- A close to cw voltage is applied and a discharge takes place during the H_2 gas pulse, this contribute to the cathode and anode heating , the timing of the gas is derived form the "gas discharge"
- The impedance of the discharge starts close to 100 Ohms, once the temperature and Cs-flux are suitable it drops down to 15-20 Ohms
- The "low" impedance pulser can then be started and delivers a clean 20 A discharge of 1 ms duration under an impedance of 10 Ohms.



Rocky test conditions with few sparks and damaged power supplies, Cs-Oven stopped before H- beam meas. (2-4 mA seen), test ended on a last spark.
Major Help from RAL-D. Faircloth is aknowledged

Conclusion, Outlook

- ✓ Cesiated ion source prototypes reached the nominal beam current during multi week operation.
- ✓ Steady improvement of the emittance, for IS02b, 90% of a 45 mA beam is within the acceptance of the RFQ.
- Simulation shows that, for e/H < 3, the emittance of IS03 should match the acceptance of the RFQ.
- The IS03a is operating fine (40-50 mA) but with an e/H of 5 to 10. The origin is likely a low filter field strength.
- Operation of a low impedance discharge at 0.8 Hz was demonstrated on BNL's heated magnetron.



- *Simulation*:
  - Design a 15 mT filter field beam optics for IS03b
  - Simulate time-dependant proton and H_0 fluxes and beam formation.
  - Derive IS-regulation algorithms for CERN's control system
- *Experiment*:
  - Transport of a 45 mA beam through the RFQ and DTLs
  - Towards reliability and stability; Test regulation algorithms and implement preventive maintenance schemes during "IS-technical stops" at regular intervals.
  - IS03b *i.e.* Cusp free H^- source (easier ignition), Ion-Cs-implanted Mo-plasma electrode, AlN plasma chamber (oxygen free).
  - Proton source test.
  - Would be great to complete the heated magnetron tests, requires design and prod of dedicated discharge power supply.

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Thank you all ☺

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