3 & 12 MeV Linac4 commissioning

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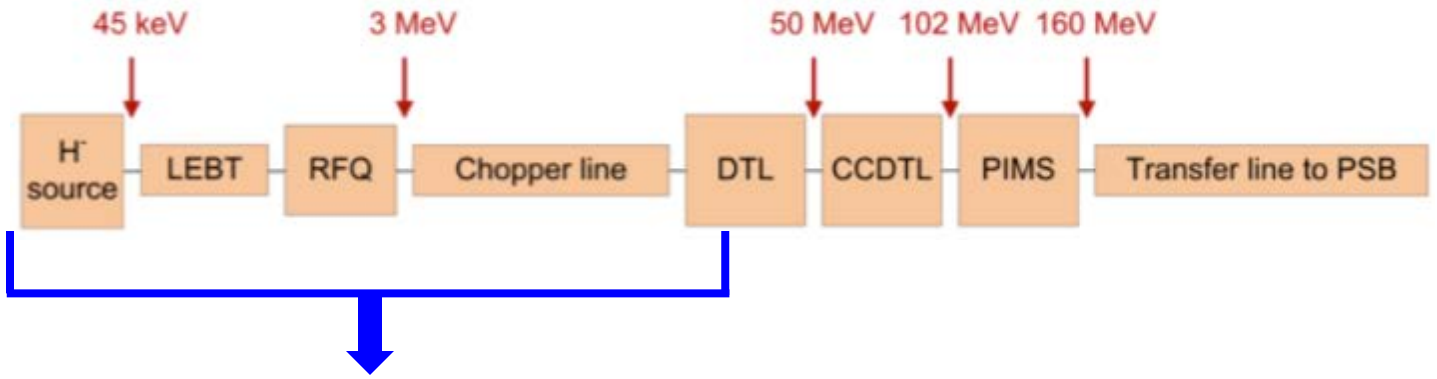
CERN - BE/BI

BI Day – Centre de conventions - Archamps, 16th Oct. 2014

Outline

- Linac4 commissioning status
- Beam instrumentation overview up to 12 MeV
- Beam intensity measurements (BCTs)
- Beam transverse profile measurements (WS and grids)
- 3 and 12 MeV slit-and-grid emittance meter
- Beam longitudinal measurements (BSM and spectrometer)
- Conclusions and outlook

Linac4 commissioning @ 3 and 12 MeV

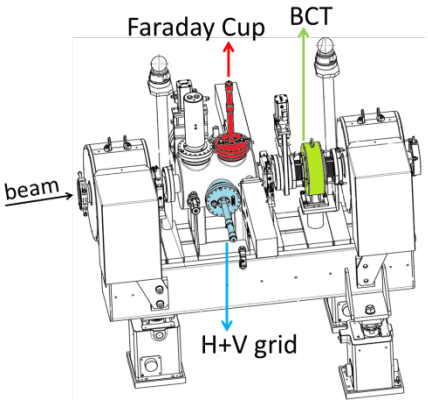


Commissioned up to 12 MeV (first DTL tank)

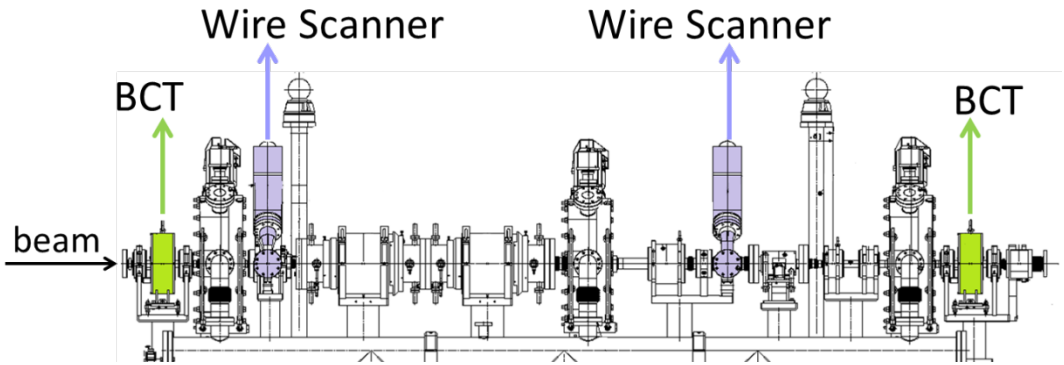
- March 2013 – June 2013 : 3 MeV commissioning at the dedicated Test Stand (RFQ and Chopper Line)
- Nov. 2013 – March 2014: 3 MeV commissioning in the tunnel
- August 2014 (2 weeks): 12 MeV commissioning (DTL1)
- Oct. 2014 – Nov. 2014: 12 MeV commissioning with the new H^- source

Beam instrumentation up to 12 MeV

LEBT @ 45 keV



MEBT (Chopper line) @ 3 MeV



Beam instrumentation up to 12 MeV

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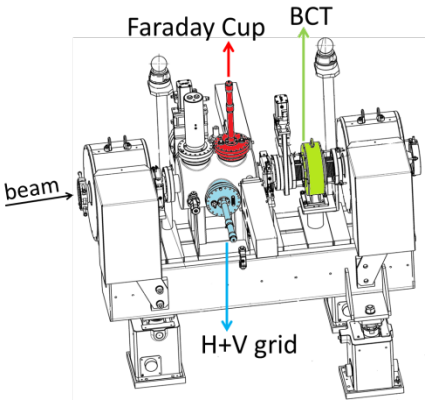

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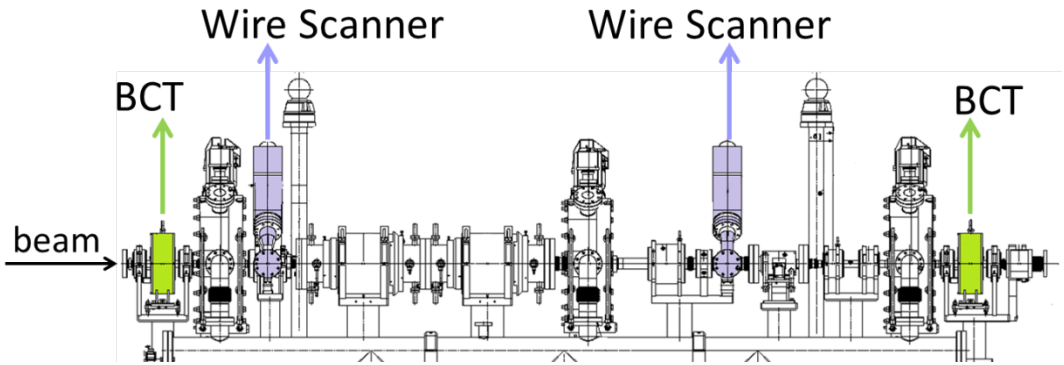
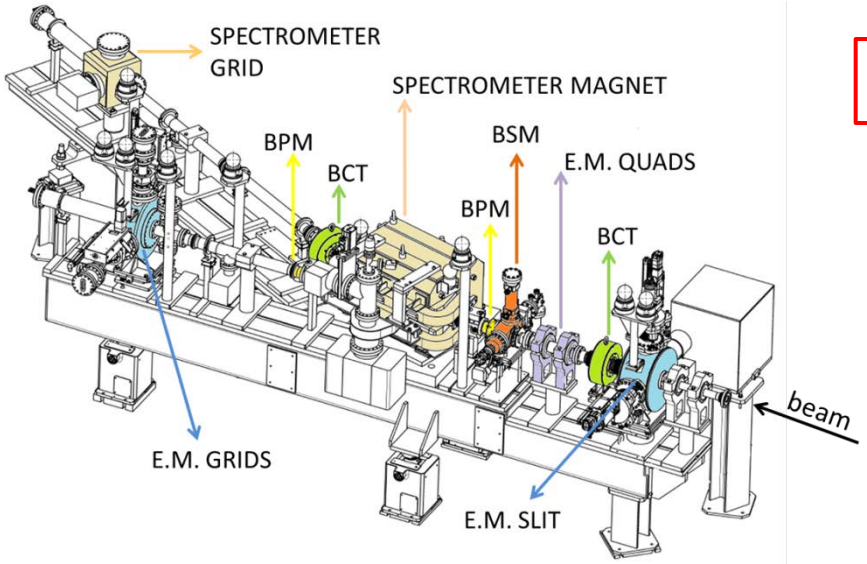




+ laser & diamond emittance meter (Thomas' talk)

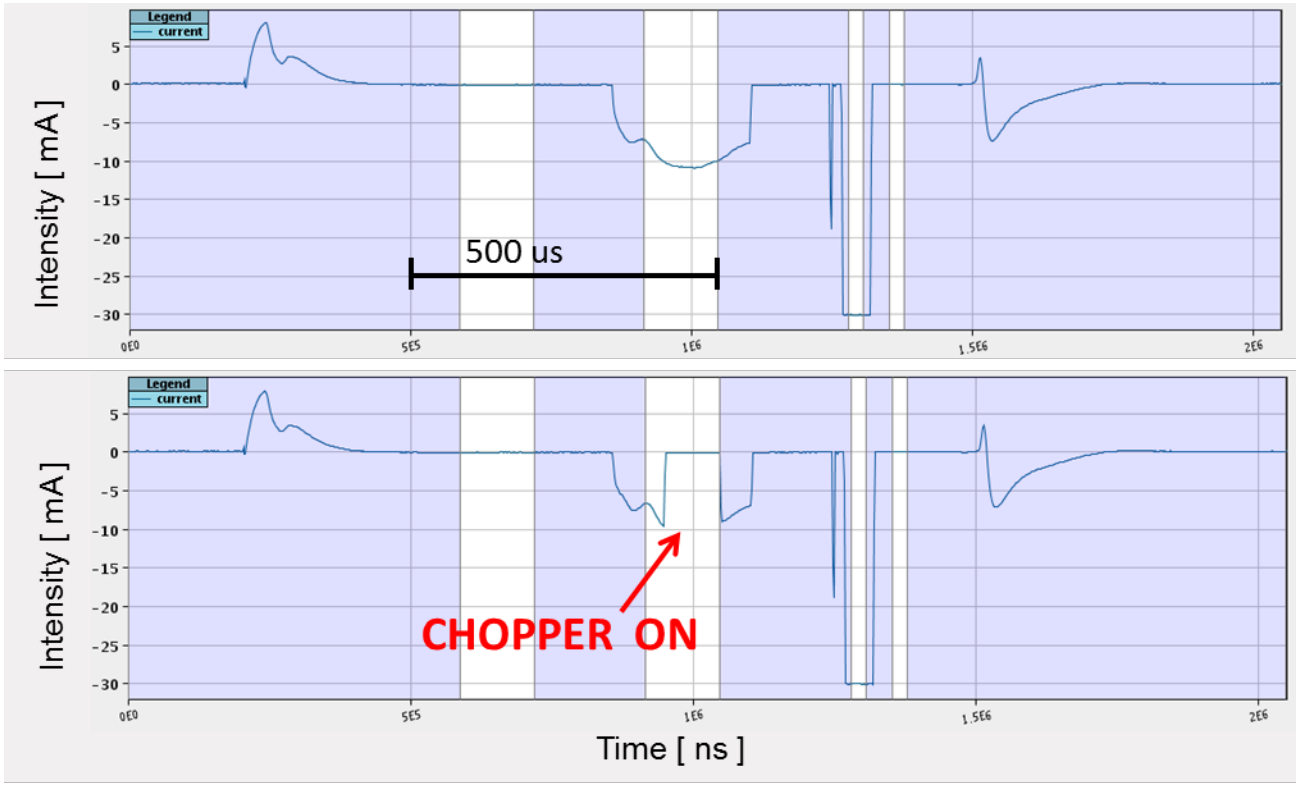
Movable Test Bench @ 3 & 12 MeV

Used for 3 commissioning stages, being plugged at:

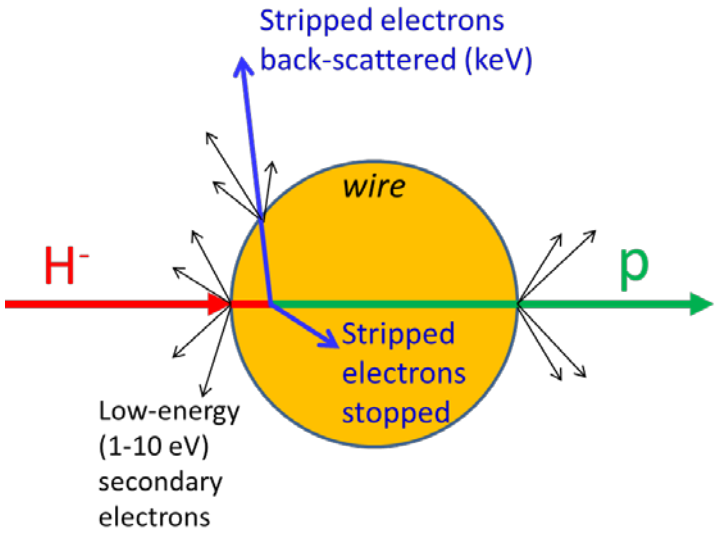
- RFQ exit @ 3 MeV
- MEBT exit @ 3 MeV
- DTL1 exit @ 12 MeV

Intensity measurements

- H^- source current = 15-20 mA (new H^- source ≈ 30-40 mA)
- BCT features : calibration pulse, magnetic shielding
- Fundamental to optimize transmissions through RFQ , MEBT and DTL1
- First evidence of the chopper operation (rise/fall time < 10 ns)

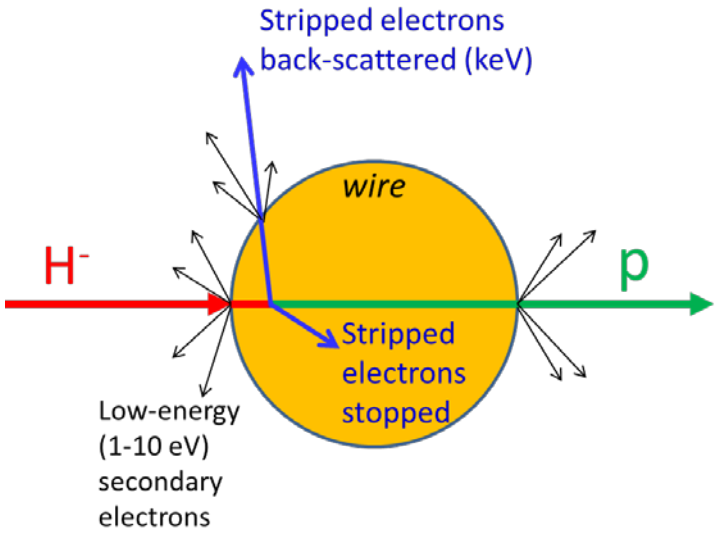


Transverse profile: wire detection



- Wire signal = balance between negative charge (stripped electrons stopped) and positive charge (secondary emission + p eventually stopped)
- **33 µm Carbon wires** preferred over 40 µm Tungsten wires, as Tungsten would cause :
  - unacceptable thermal load on 3 MeV WS
  - too small signal at 3 MeV, due to protons stopped in Tungsten wires

Transverse profile: wire detection



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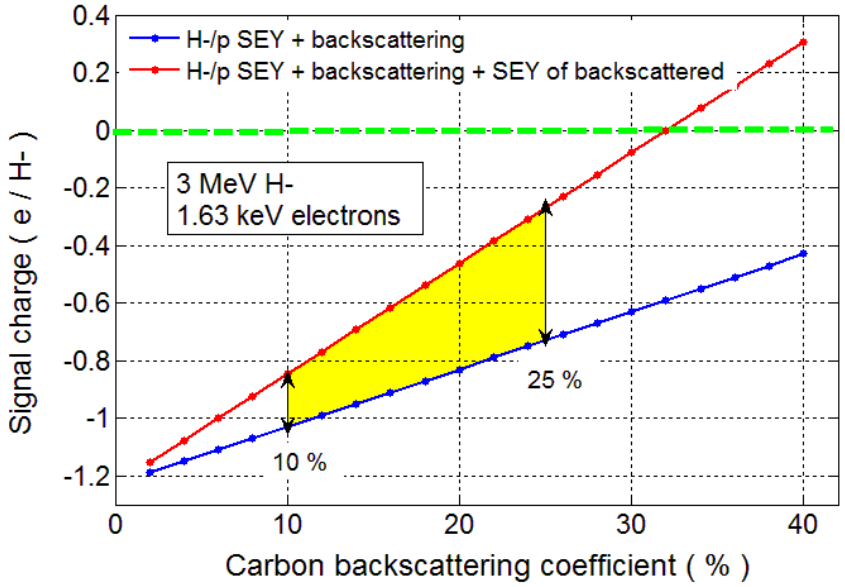
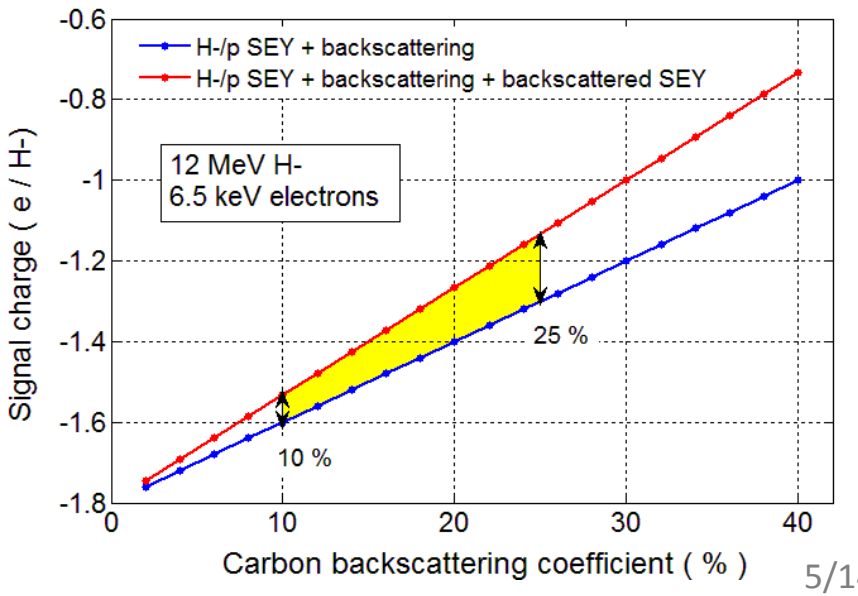
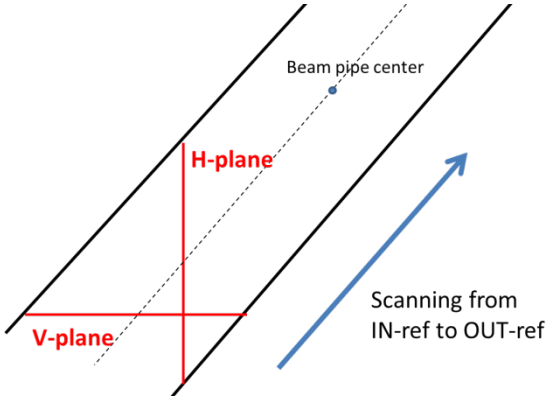
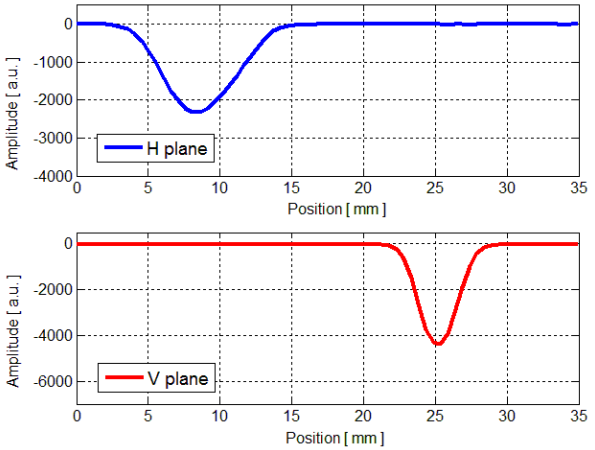




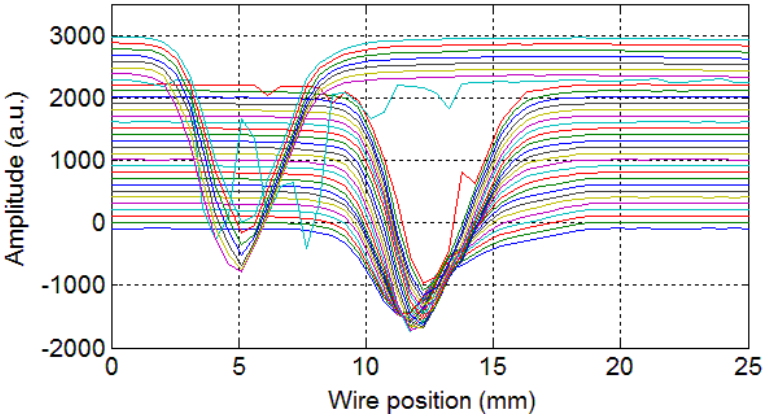
Wire scanners @ 3 MeV (1)

- 33 μm Carbon wires mounted in L-shape on the same fork support and scanning the beam at 45 degrees (one scanning position per pulse)





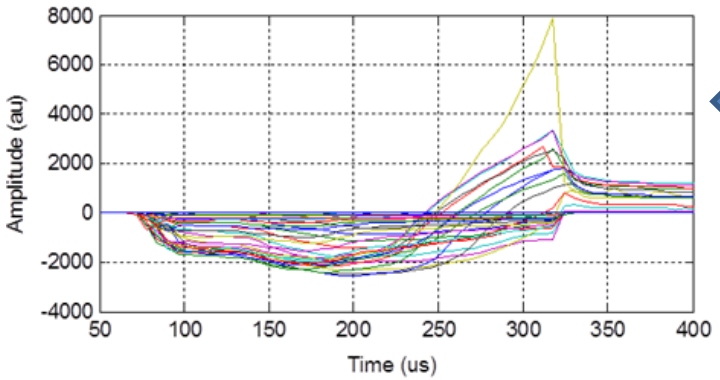
- Time resolution of 4 μs within the beam pulse (250 kHz ADC) → WS2 evidenced the vertical displacement of the chopped beam

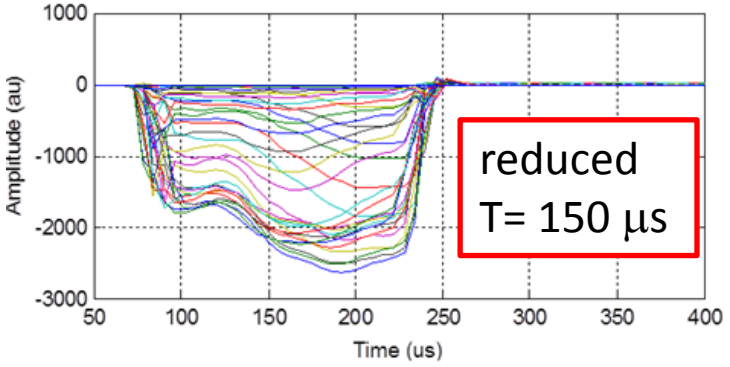


Vertical transverse profiles along the beam pulse with chopper ON

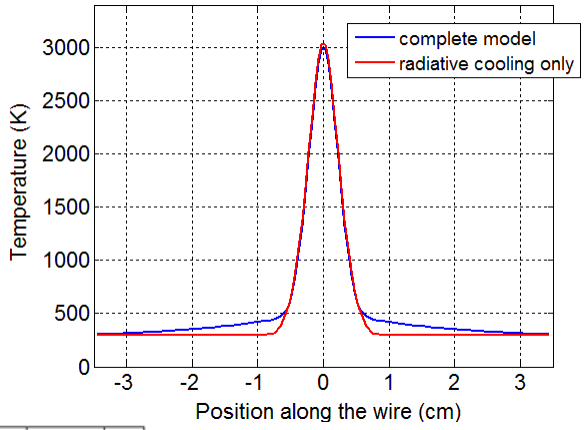
Wire scanners @ 3 MeV (2)

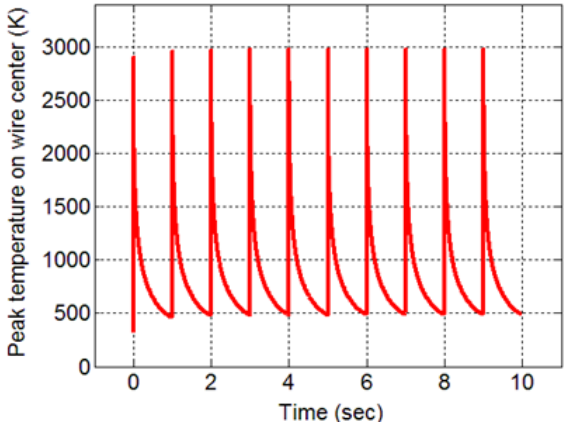
- Thermal load verified and wire heating simulation model validated:
  nominal Linac4 current of 40 mA → beam pulse must be reduced to 100 µs (Interlock)
  10 mA, nominal beam size → thermal load acceptable with 250 µs beam pulse
  10 mA, waist condition → beam pulse had to be reduced to 150 µs





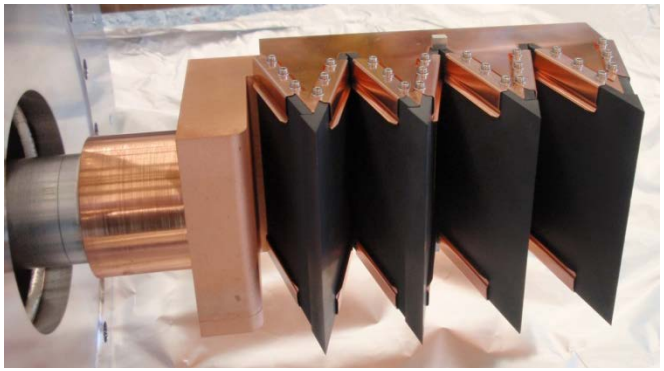
σ_x= 0.3mm
σ_y= 1.8 mm
T= 250 µs
Rep rate = 1Hz
I = 10 mA

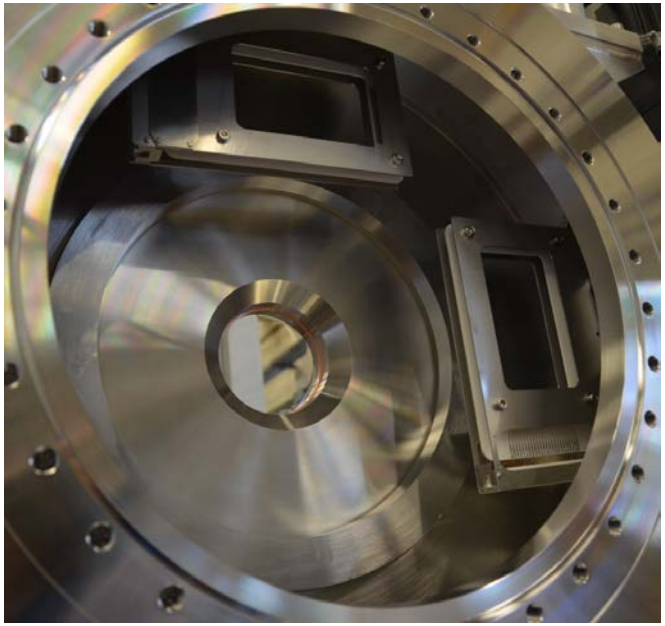


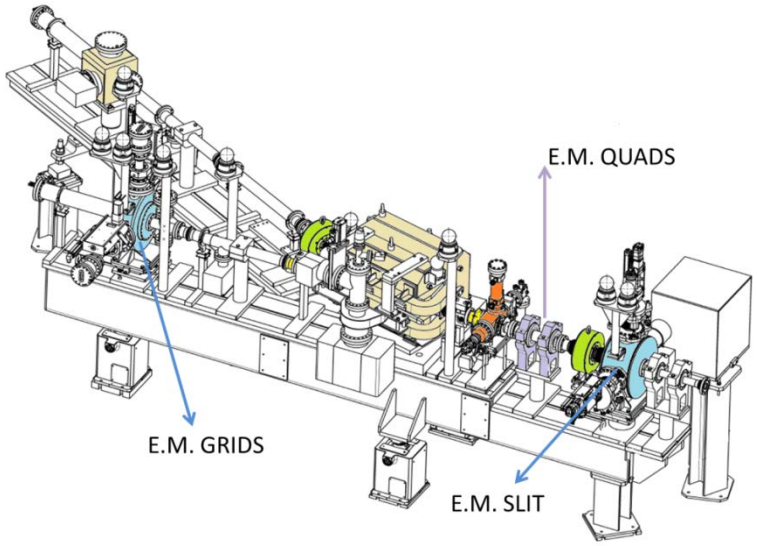


Slit-grid Emittance Meter @ 3 & 12 MeV

- Slits (H+V)= 2 blades system, each consisting of a harmonica shaped, water cooled copper structure covered by graphite plate, gap = 200-300 μm
- Wire grids (H+V) = 48 Carbon wires, pitch of 0.75 mm, metallic frames up- and down-stream at 5 mm distance





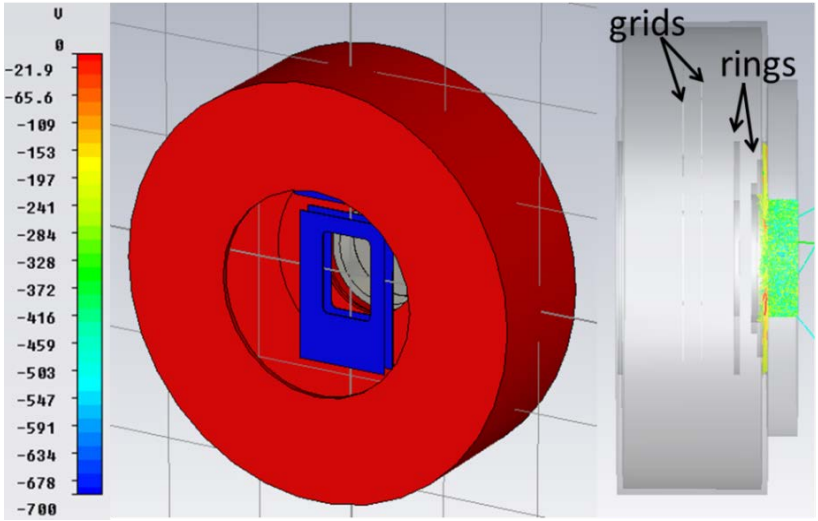


B.Cheymol, E.Bravin, D.Gerard, U.Raich, F.Roncarolo, "Design of the emittance meter for the 3 and 12 MeV Linac4 H^- beam" – IPAC 2010 conf proceed.

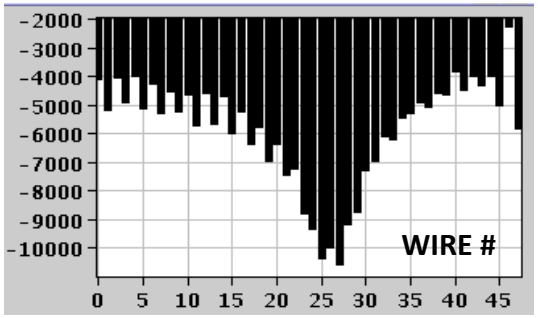
EM commissioning: biasing conditions

- @ 3 MeV : frame bias of – 700 V found to be essential to repel secondaries from the downstream dump and to enhance the wire signals by suppressing secondary emission from the wires.
- @ 12 MeV : less critical condition due to the lower secondary emission from both the dump and the wires → nevertheless same frame bias applied as it significantly enhances the wire signals.

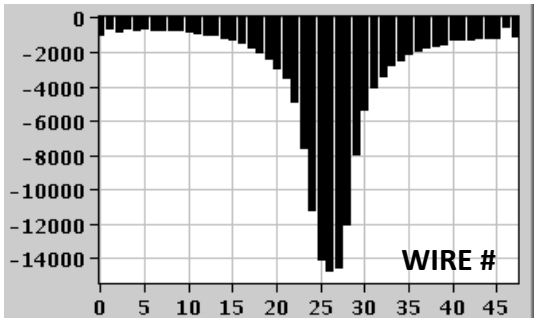
CST Particle Studio simulation : grid frame bias = -700 V



Beamlet profiles on the EM grid



NO bias



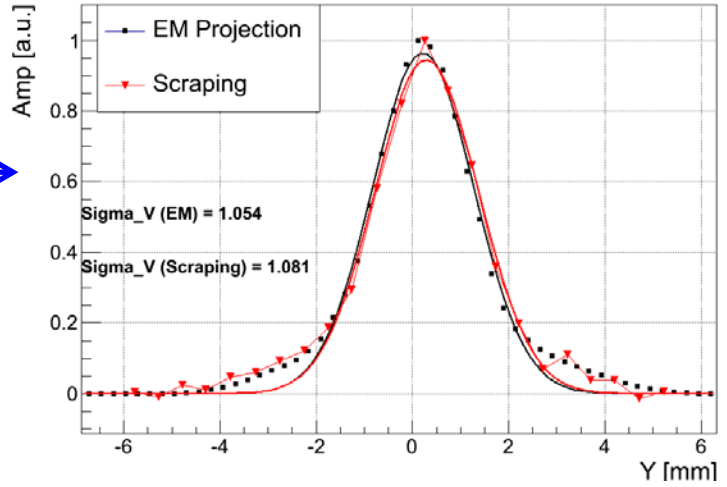
Frame = - 700 V

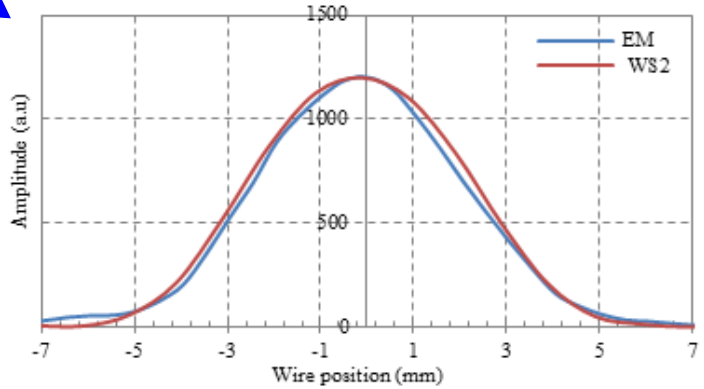
Emittance Meter validation

- Beam profile (EM projection) cross-checked with the beam profile obtained by using the slit as a scraper and by reading the remaining beam current on a downstream BCT.

- Beam profile measured by WS2 cross-checked with the profile obtained from emittance measurements (phase spaces) back-tracked (PATH) to the same location of WS2.

- Agreement with the emittance measurements by:
  - quad scanning + profile measurements
  - prototype laser emittance meter (Thomas' talk)





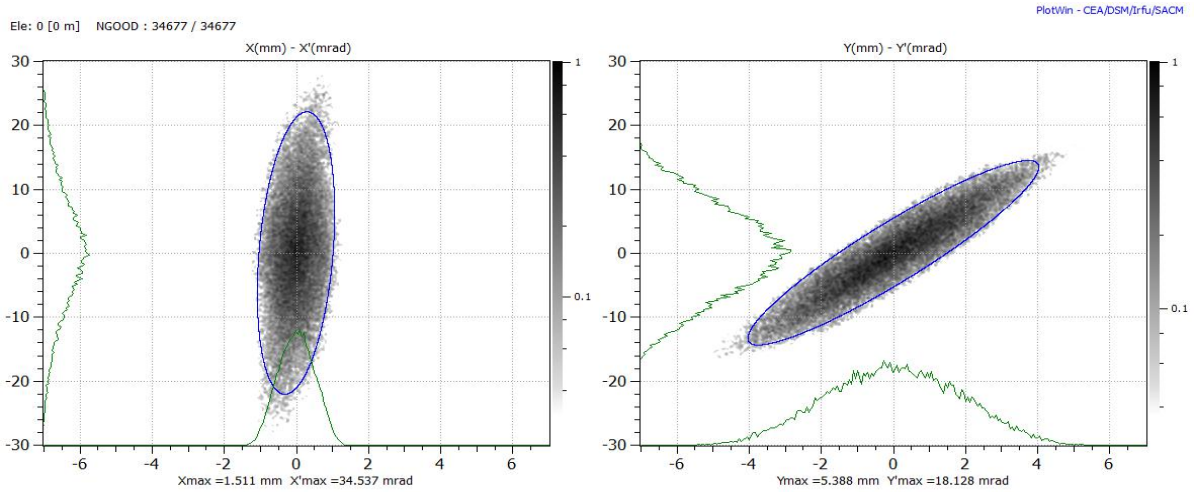
M.Y.Satri, et al. "Transverse beam profile measurements in the Linac4 MEBT" – Linac14 conf proceed.

Table 1: Transverse emittance

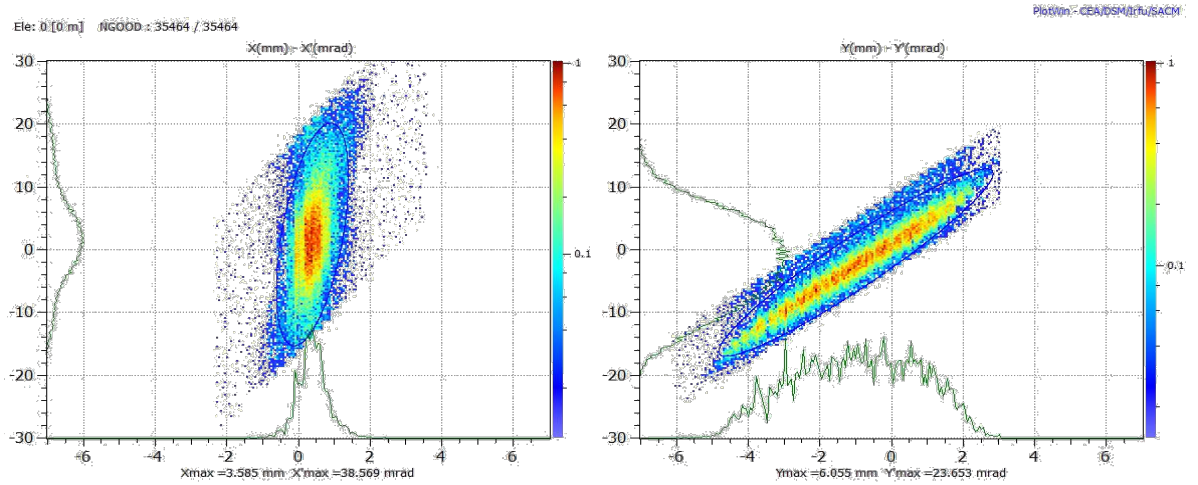
Method	Ex norm rms	Ey norm rms	Threshold
Slit-grid	0.27	0.24	1%
Laser-diamond		0.27	0.1%
From profiles	0.31	0.34	0.5%

A.M.Lombardi, "Commissioning of the low-energy part of Linac4" – Linac14 conf proceed.

3 MeV beam matched to DTL1



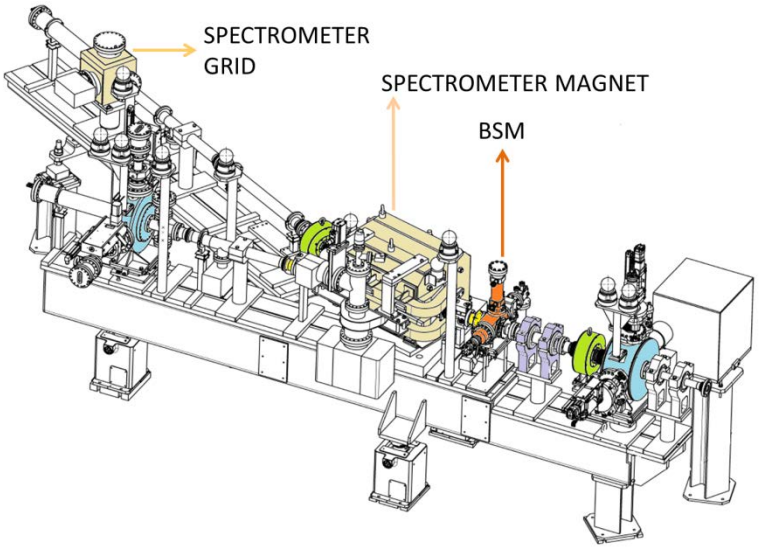
Expected matched beam



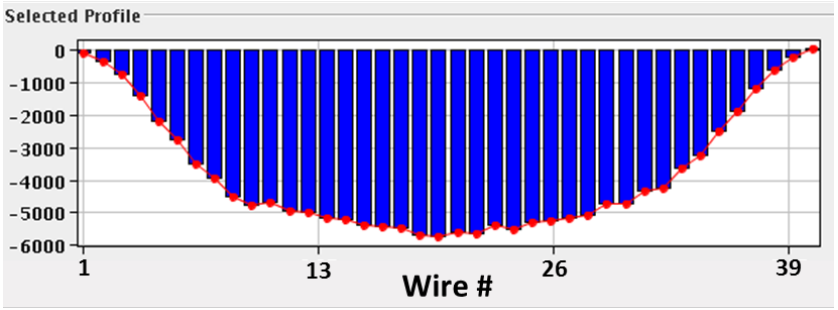
Measured matched beam

A.M.Lombardi, "Linac4 commissioning overview" – LIU-day, 11 April 2014

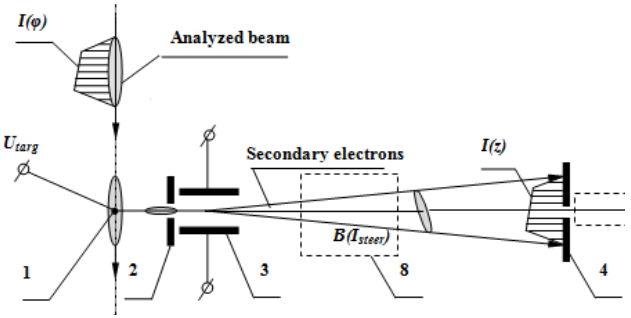
Longitudinal measurements

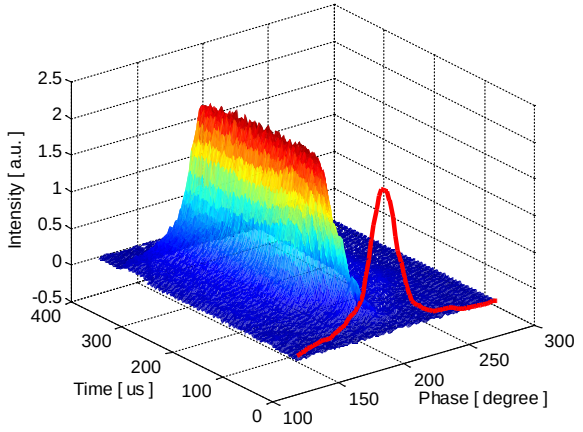


Spectrometer grid: 40 Carbon wires, 0.75 mm pitch, frame bias = -700V @ 3 MeV, same but less critical @ 12 MeV.



Bunch Shape Monitor: developed at INR (Russia) by A. Feshenko, measures the longitudinal distribution of a micro-bunch, phase resolution = 1 degree, time resolution = 1 µs.



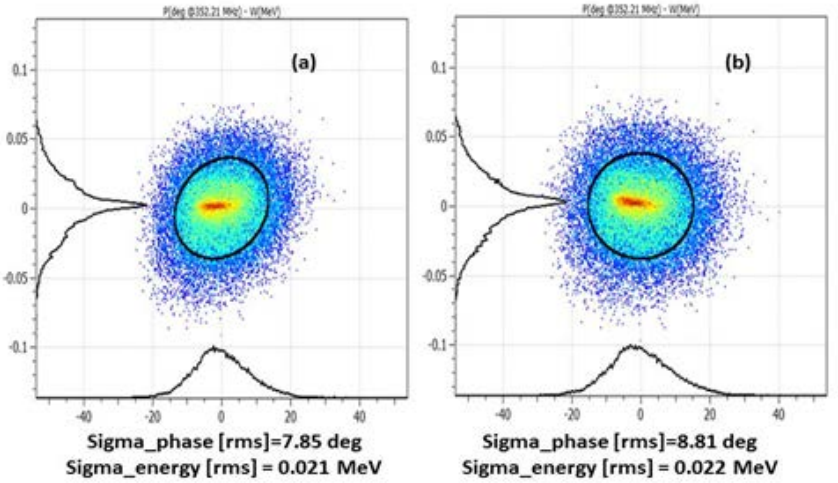


Longitudinal measurements

- Spectrometer successfully used for
  - phase tuning of the 3 MEBT bunchers
  - energy spread measurements

- BSM successfully used to
  - phase tune the 3 MEBT bunchers (spectrometer cross-check)
  - measure the micro-bunch longitudinal distribution
  - obtain indirect measure of the longitudinal emittance

Expected *Reconstructed*



@ 3 MeV:

Method	ε_{rms} deg MeV	ΔW MeV
simulations	0.19	0.022
From BSM phase profiles	0.16	0.021
spectrometer	-	0.019

A.M.Lombardi, "Commissioning of the low-energy part of Linac4", LINAC14 Conf.Proc.

G.Bellodi, V.A.Dimov, J.B.Lallement, A.M.Lombardi, U.Raich, F.Roncarolo, F.Zocca, M.Y.Satri, "Longitudinal beam profile measurements in Linac4 commissioning", LINAC14 Conf.Proc.

Conclusions & Outlook

- Linac4 commissioning @ 3 MeV ended successfully.
- Beam instrumentation performance proved to be very good and essential to validate the 3 MeV beam dynamics.
- 12 MeV commissioning started in August (2 weeks) with the old source and it restarted this week with the new source (until end of November).
- Beam instrumentation on the temporary bench has been successfully commissioned @ 12 MeV in August and we are confident to get same good performance we had @ 3 MeV.

Thank you for your attention !