MedAustron

Status of Proton Beam Commissioning of the MedAustron Particle Therapy Accelerator

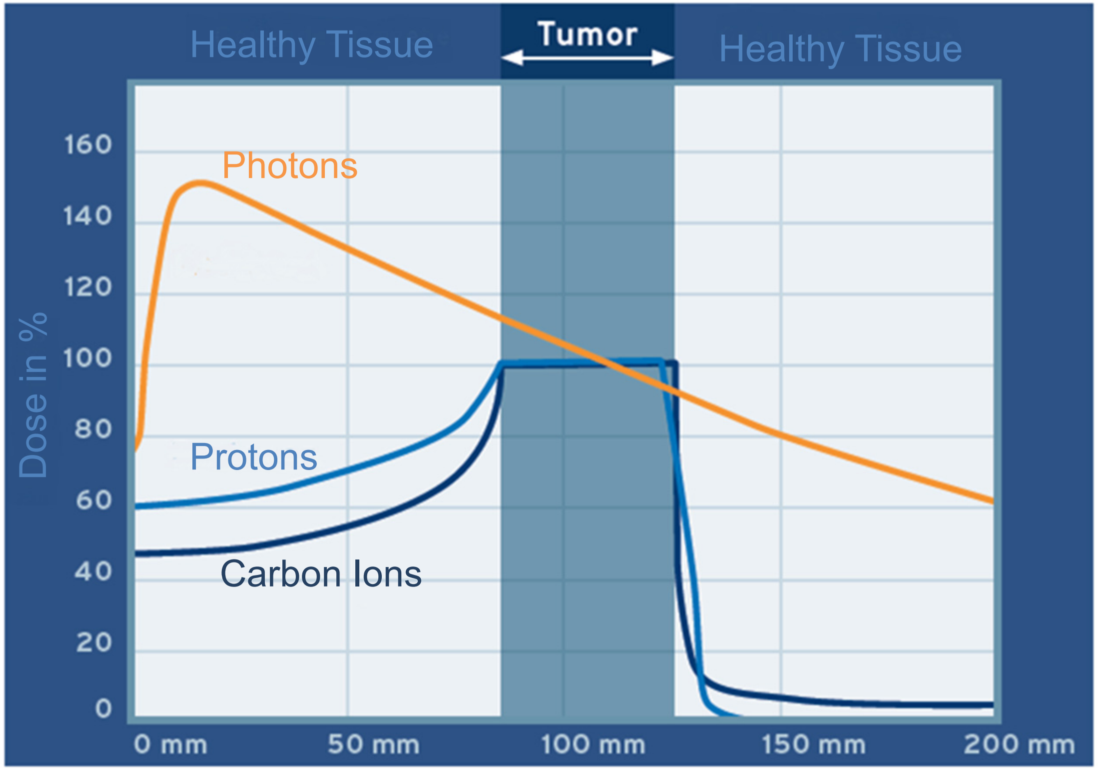
A. Garonna, F. Farinon, M. Kronberger, T. Kulenkampff, C. Kurfürst, S. Myalski, S. Nowak, L. Penescu, M. Pivi, C. Schmitzer, A. Wastl, F. Osmic, P. Urschütz

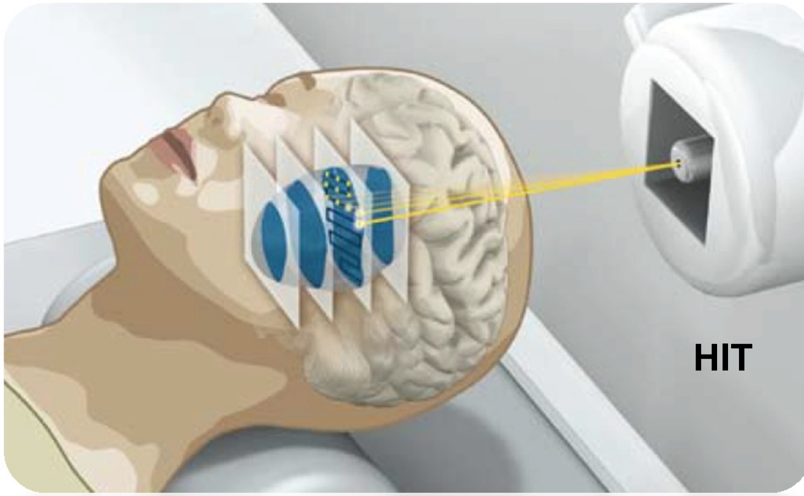
On behalf of the MedAustron Therapy Accelerator Division

Adriano.garonna@medaustron.at
http://www.medaustron.at

Proton Therapy

MedAustron





MedAustron

Based on Proton Ion Medical Machine Study (1990) and CNAO (Italy) designs, with important contribution of CERN (Switzerland) and PSI (Switzerland)

Proton Beam Parameters

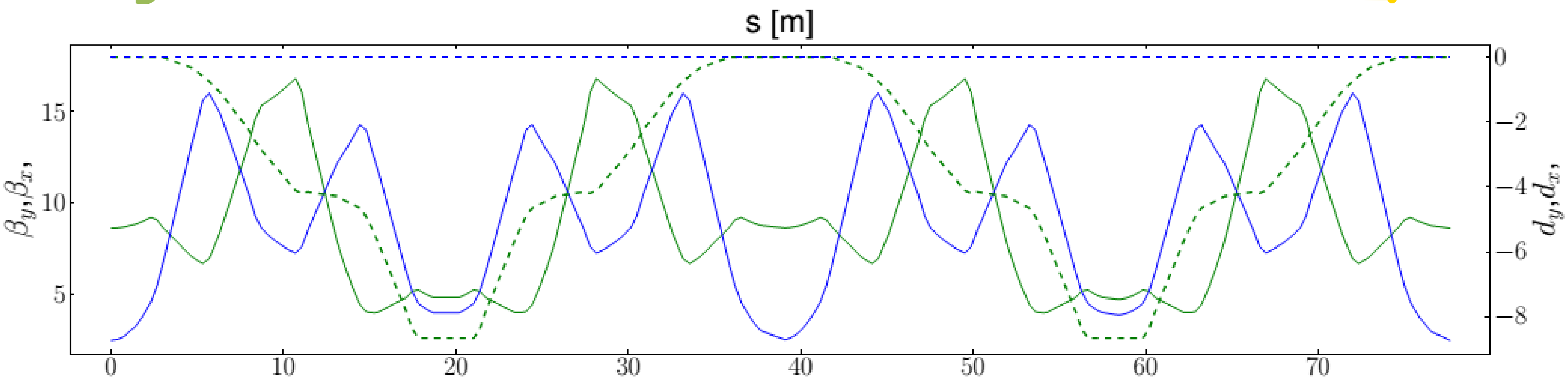
MedAustron

Intensity	**10^{10}** over **5 s** constant spills with **4 different intensity** levels
Transverse Position	0 ± 0.5 mm
Transverse Size	**Minimum Spot Size** in air (depends on scattering, defined as 4 mm FWHM in vacuum) **Round beam** with asymmetry < 10%
Penetration Depth	[30-380 mm] in **255 steps**, within ± 0.3 mm
Variation within spill	± 0.15 mm in range, ± 0.25 mm in position and ± 5 % in width

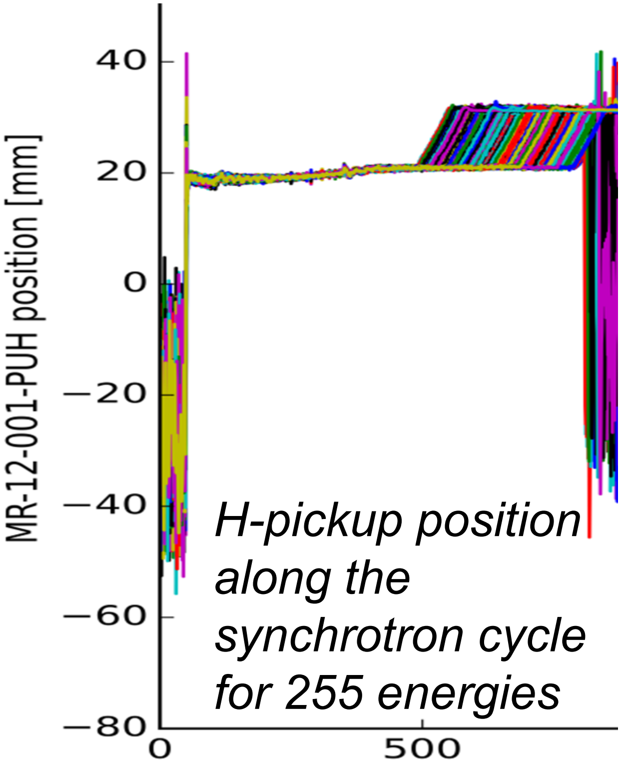
Multi-energy commissioning

- Machine fine-tuning for 4 `main´ energies (62, 136, 198, 253 MeV)
- Interpolation of the main energies´ normalized parameters to obtain settings for remaining 251 energies

Injection & Acceleration



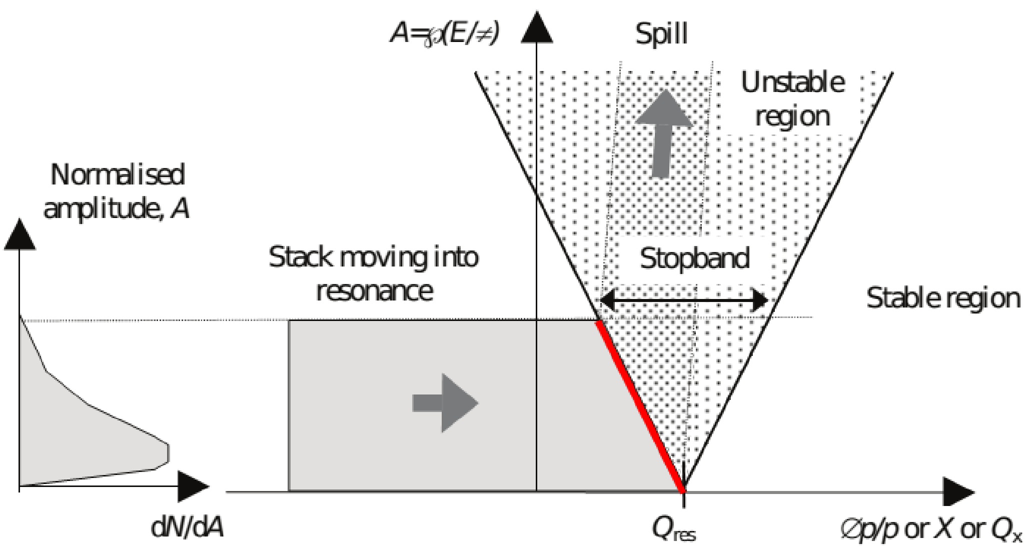
- Injector provides 800 μA at 7 MeV with dp/p = $5 \cdot 10^{-4}$ rms in 30 us
- H-painting with π-orbit bump: 6 effective turns
- Max achieved momentum increase x 13, max 3 T/s (full frequency swing from 0.5 to 3.3 MHz)
- Dispersive orbit oscillations during ramp < 1 mm

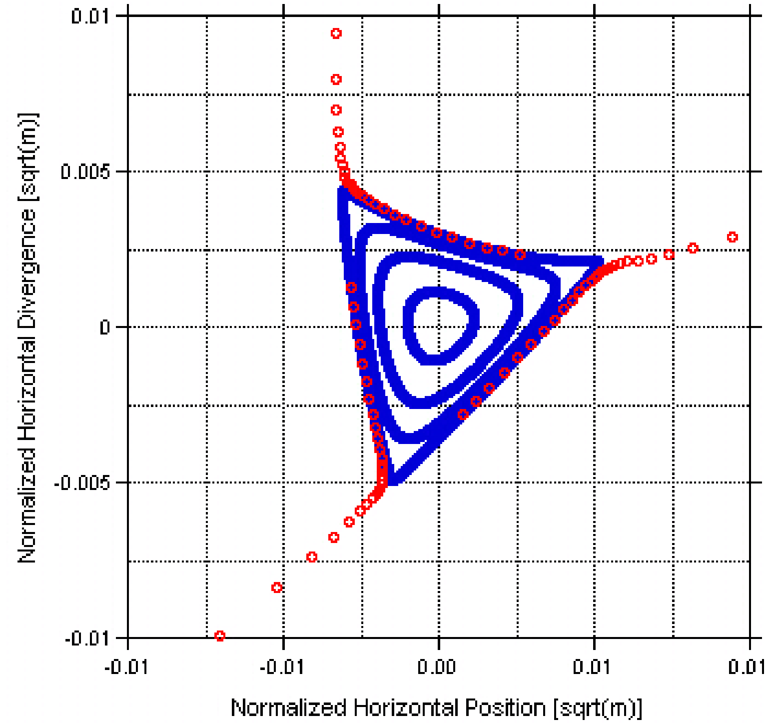


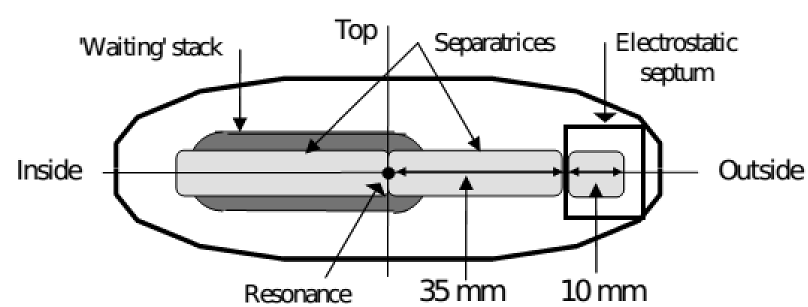
Slow Extraction

- Resonant sextupole enlarges the the horizontal third-integer resonance stopband

- Betatron core drives smoothly beam to instability (min 20 ms, clinical 1-10 s)

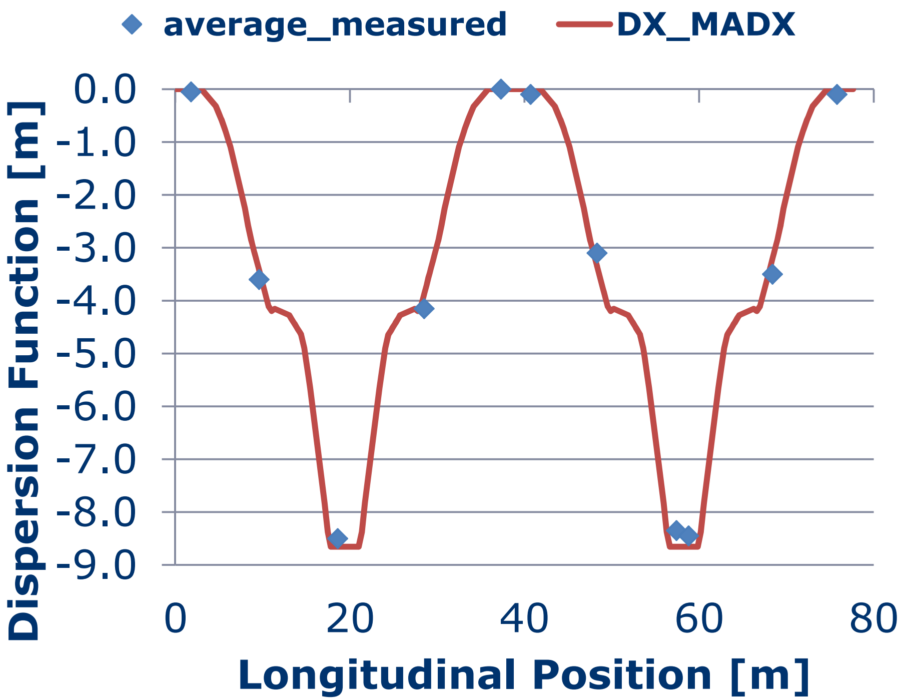


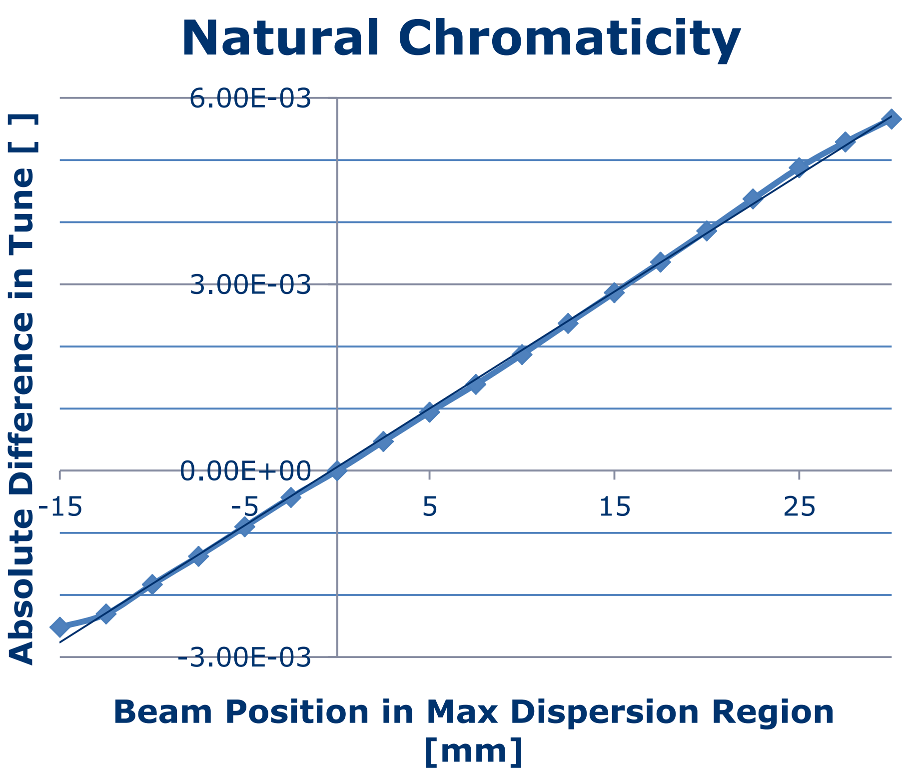




Flattop optics

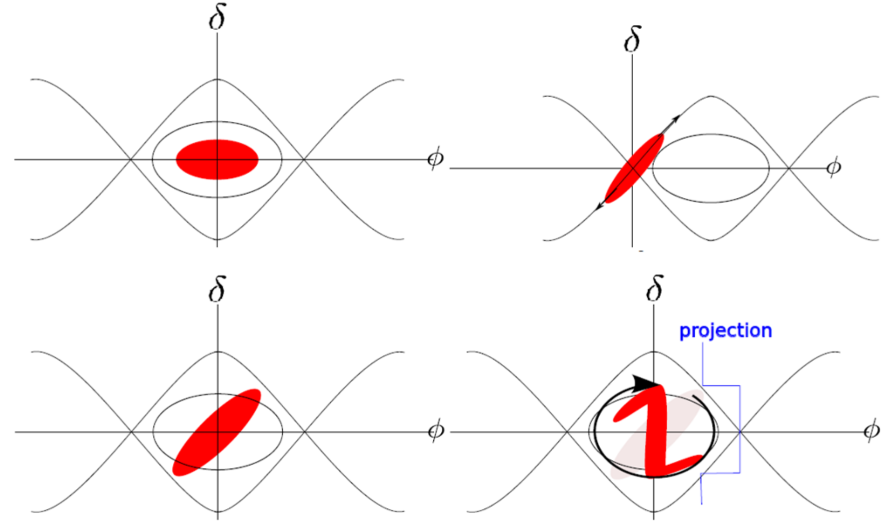
- closed-orbit error < 1 mm with max 0.4 mrad kicks
- Extraction optics adjustment (tunes and chromaticities) for 4 main energies





Design Parameter	Result over the 4 main energies
Q_H=1.667	1.667 ± 0.001
Q'_H = -4.0	-3.9 ± 0.2
Q_V=1.789	1.789± 0.004
Q'_V=-1.0	-1.2 ± 0.1

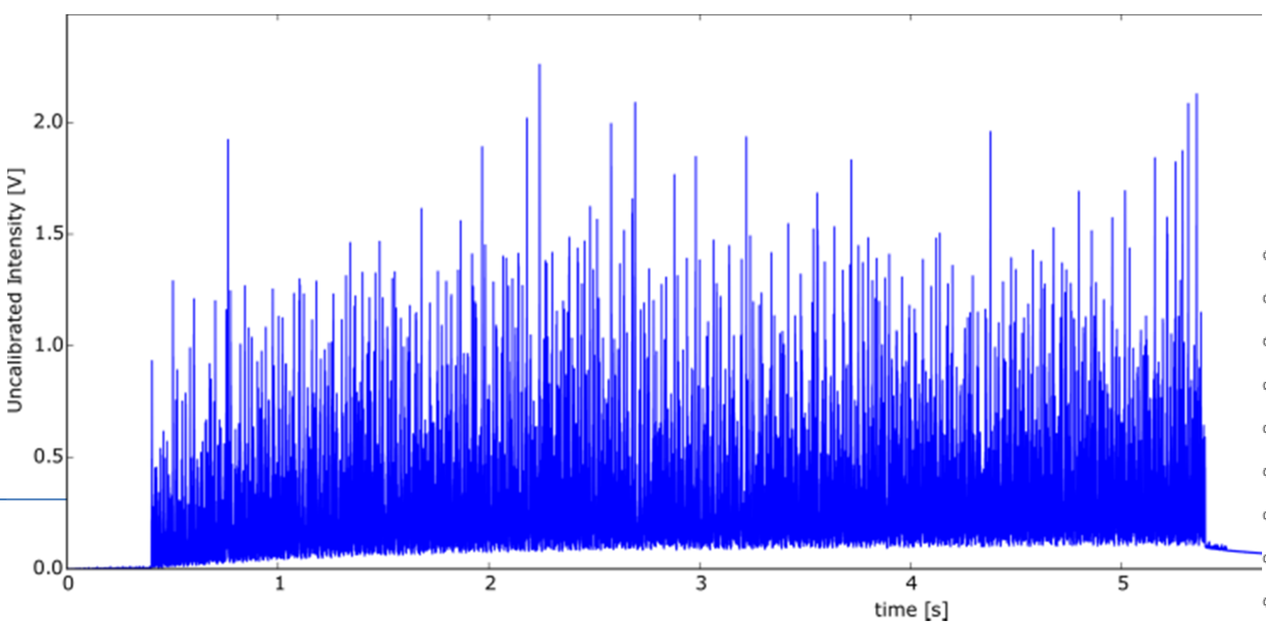
RF gymnastics for extraction

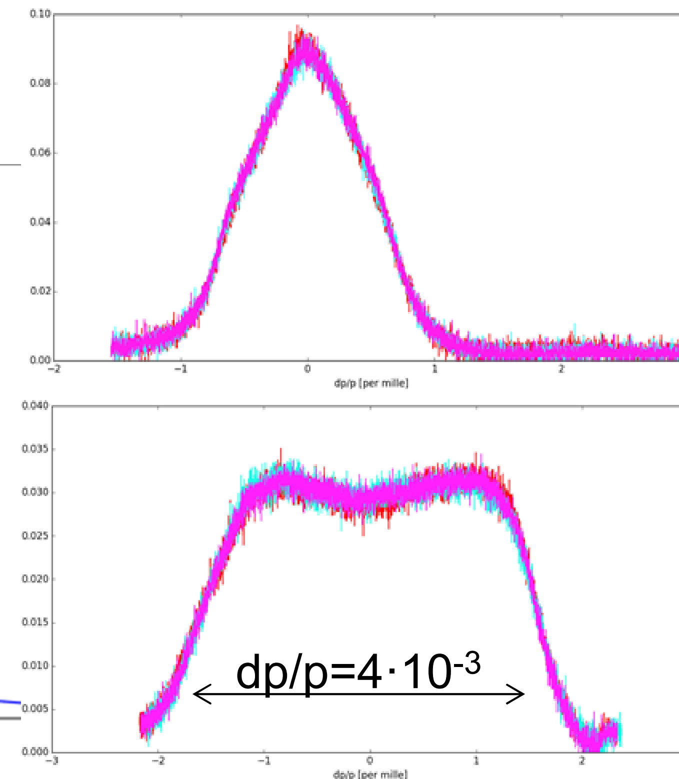


- RF phase jump via voltage inversion

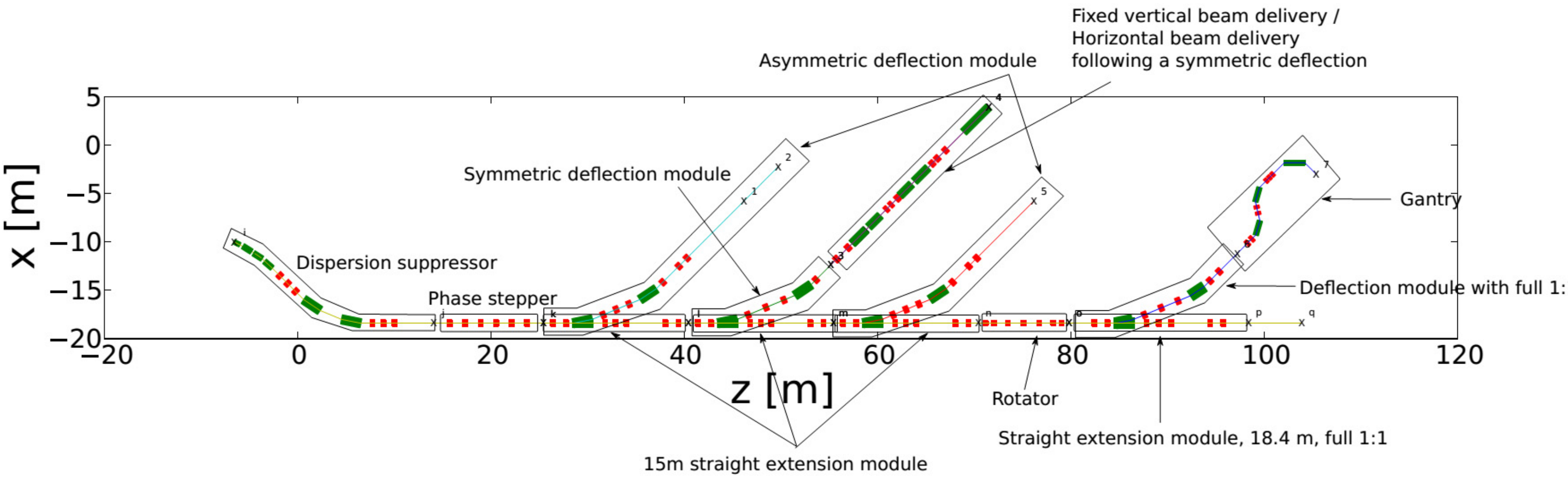
- $I_{max}/I_{mean} \approx 3.5 \pm 1$
  (10 kHz, 5 ms voxel time)

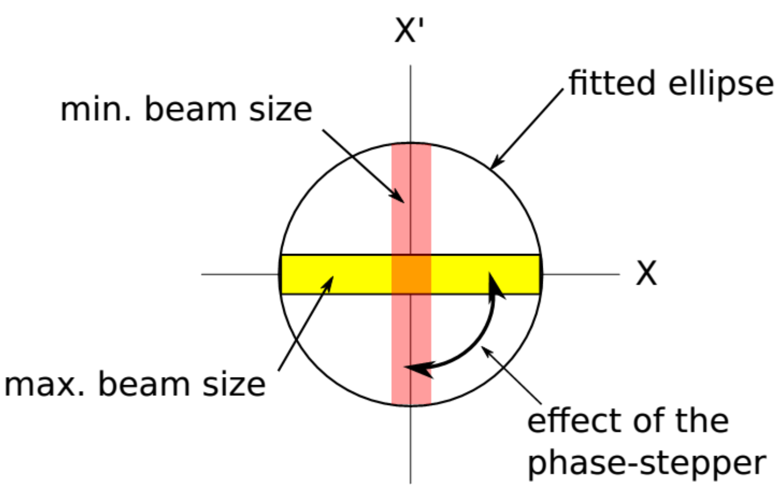
- Main ripple contribution at 4 khz, due to main bending magnet power supply

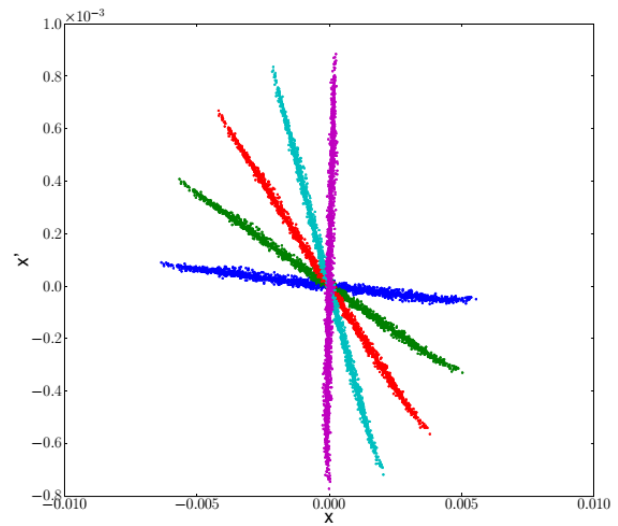




HEBT modules







Normalized H phase space: bar-of-charge rotation changes the projected beam size

HEBT

MedAustron

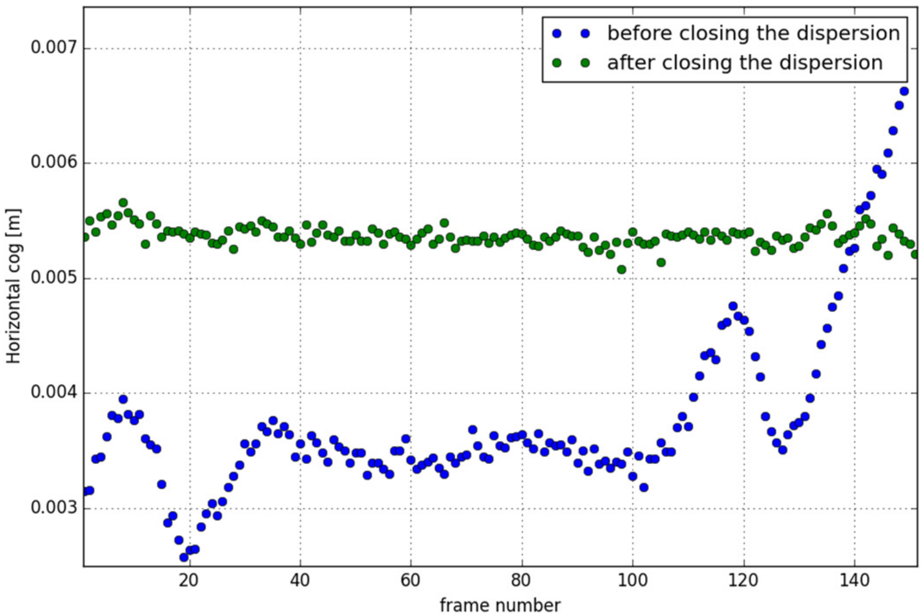
- Optics check: kick-response measurements and check of telescope properties

- Dispersion matching (Dx=-4.5 , D´x= -0.5 from extraction)

- Leading and trailing edges chopped (< 250 us ramp)

- Orbit correction:
  - k-modulation method at key positions
  - residual offset < 1 mm

- Magnet conditioning mechanisms (demagnetization of correctors and switching magnets, focusing/defocusing quadrupoles, …)



H-position along the spill

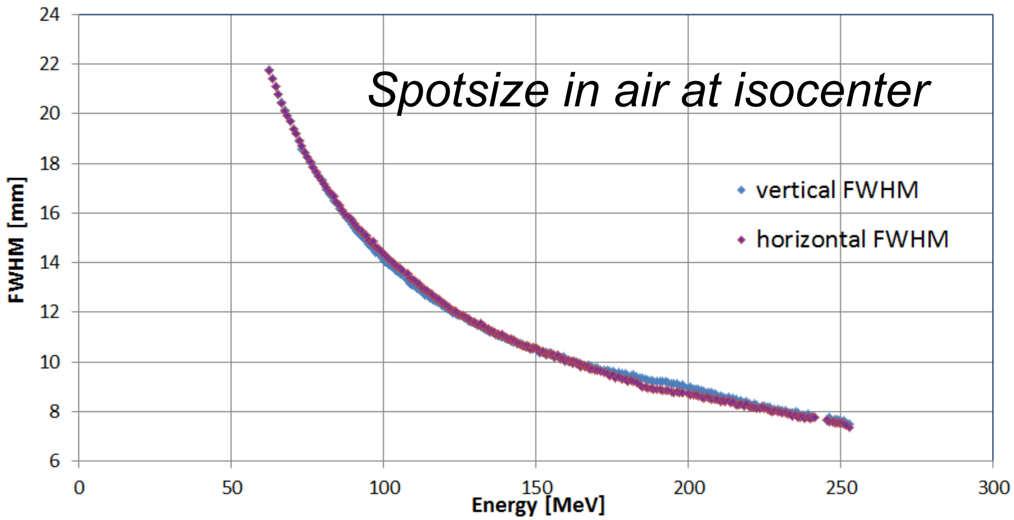
Accelerator Section	Transmission
Through LEBT, RFQ, Linac	45 %
Through MEBT	95 %
Through Synchrotron Injection	25 %
Through capture and acceleration	65 %
Through extraction and HEBT (max **1.8e10/spill**)	80 %

Spot Size Adjustment

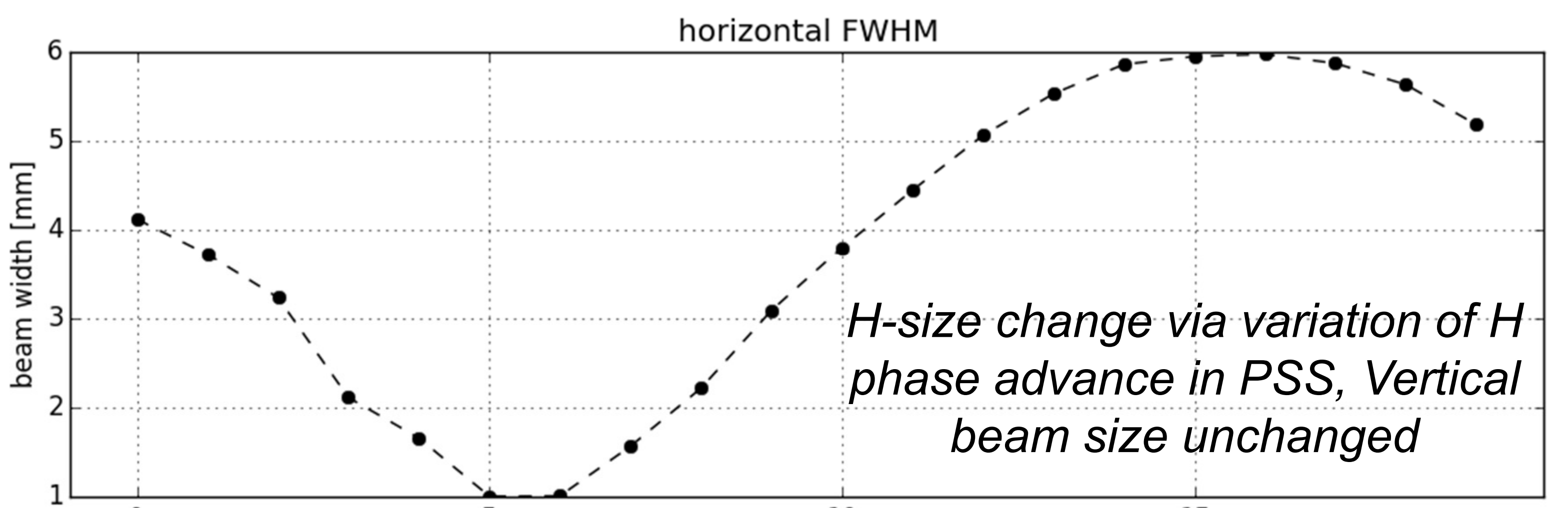
MedAustron

- Vertical optics matching at entrance of Phase-Stepper Shifter (PSS)

- Spot size adjustment via PSS and last quadrupole setting



- Intensity-related effect: lowered $Qv_{injection}$ for low intensities by 0.03 to obtain spot size asymmetry < 4 % for all energies and intensities



Proton Commissioning Status

MedAustron

IR3
- ´System Freeze´
- Medical commissioning and CE-label for Medical Device

IR1
- **Accelerator Commissioning**
- User Commissioning

IR2
- **Accelerator Commissioning of IR2-H**
- Accelerator Commissioning of IR2-V

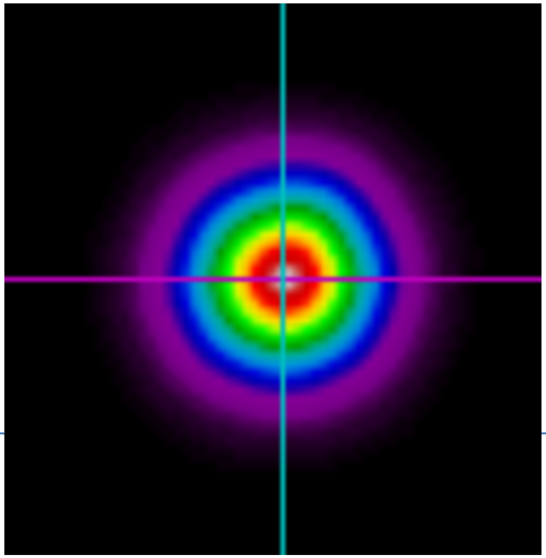
IR4
- **Tendering**

Commissioning is a technical, scientific and human endeavor possible only with strong team spirit

Thanks to V. Lazarev (**Siemens**), M. Pullia, L. Falbo (**CNAO**), R. Rossmanith (KIT) and **CERN** for the crucial support

Thank you for your interest

- MOPOY001: Synchrotron RF Commissioning, C. Schmitzer et al.
- TUPOY001: Beam QA procedure, L. Penescu et al.
- TUPMR037: Betatron-Core Driven Slow Extraction at CNAO and MedAustron, M. Pullia et al.
- TUPMR036: Extraction Commissioning, T. Kulenkampff et al.
- TUPMR035: High-Energy Beam Transfer Line Commissioning, C. Kurfürst et al.
- WEPOR045: Analysis Tools Framework, A. Wastl et al.



252.7 MeV beam measured at IR3-IC