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Diagnostics & LLRF system optimized for medical accelerators

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Content

- Accelerators
- Medical accelerators - specifics
- Instruments and applications
  - BPMs in linacs
  - BPMs in synchrotrons
  - LLRF applications
- Conclusion

Instrumentation Technologies

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Accelerators

Three main applications

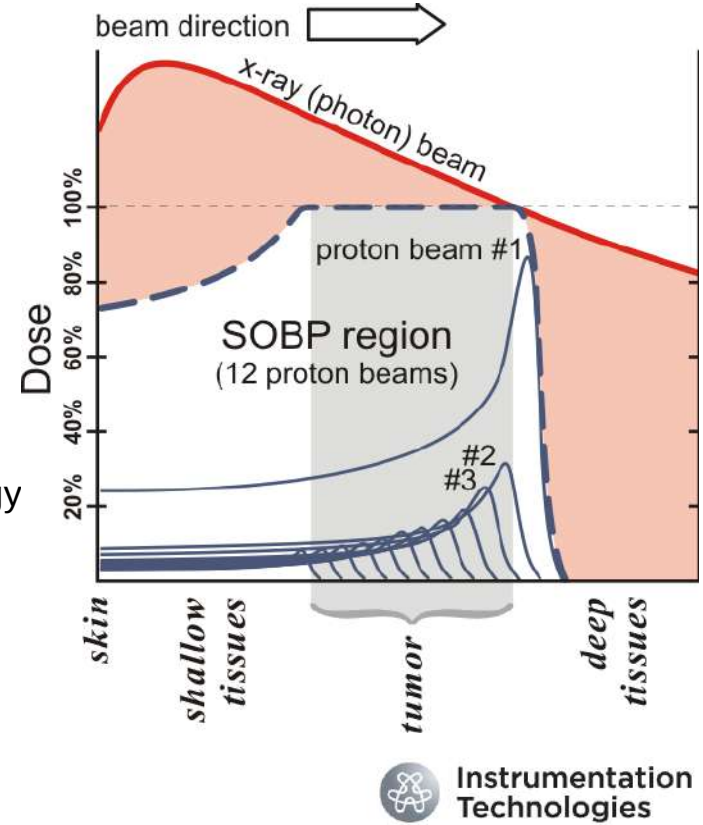
- Scientific research
- Medical applications (radioisotope production, electron accelerators, heavy particles accelerators ...)
- Industrial uses

Proton/carbon radiation therapy machines

Heavy particles have the advantage to selectively deposit a radiation dose at a specific depth by controlling particle energy (Bragg peak)

Need for accurate control and monitoring

- Particle energy
- Particle position



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Medical accelerators - specifics

Standards
- Medical regulations in patient treatment area

Instrumentation
- Control system - LabView, Custom, ..
- Quiet instrumentation
- Maintenance – short service time
- Simple to use
- Usually slow monitoring needed

Working together
- Projects under NDA
- Usually there is no direct contact with the technical people
- Working together with other providers
  - Pickup providers
  - CS providers
  - Installation equipment providers

Machine area

Treatment area

Instrumentation Technologies

Instruments

Similarities with scientific machines...

Adaptations toward medical applications:
- **Control system integration**
- **Hardware adaptations**
- **DSP adaptations**

Libera LLRF
- Linacs, Synchrotrons

Libera Spark
- Linacs, Synchrotrons, Beam transfers

Libera Hadron
- Synchrotrons

ADAM – Libera Spark HL

LIGHT is the first commercial linear proton therapy system

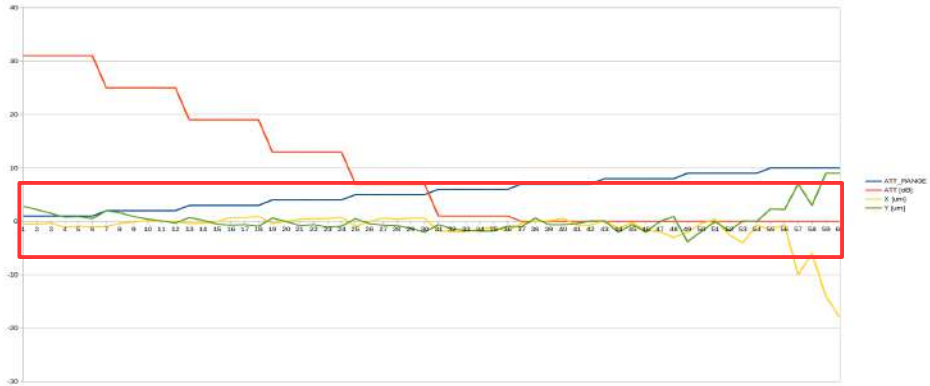
- COMPACT: Accelerator length 24m (designed for max 230MeV)
- Presently RFQ under commissioning at CERN (5MeV)

Libera Spark HL:

- Position RMS requirement: ~ 20 um
- No beam current dependence – 60 dB
- Operation at 750 MHz
- Evaluate remote attenuation setting at 200 Hz

- 4 Spark units evaluated
  at the ”ADAM” test-bench

BCD - 60 dB range (Spark HL)



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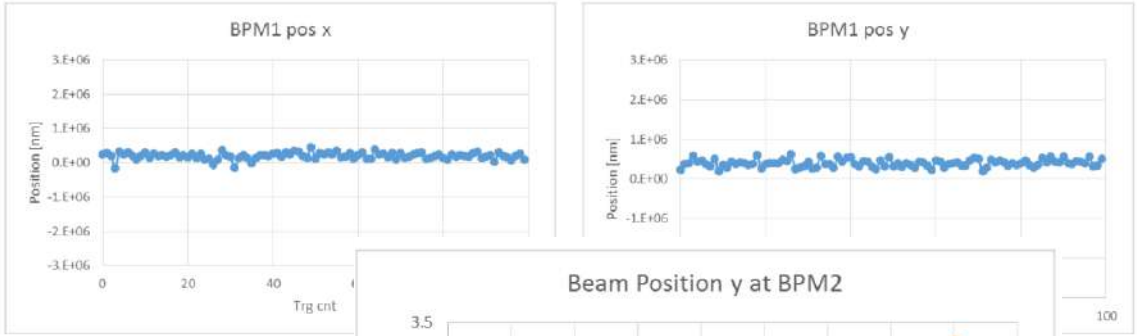
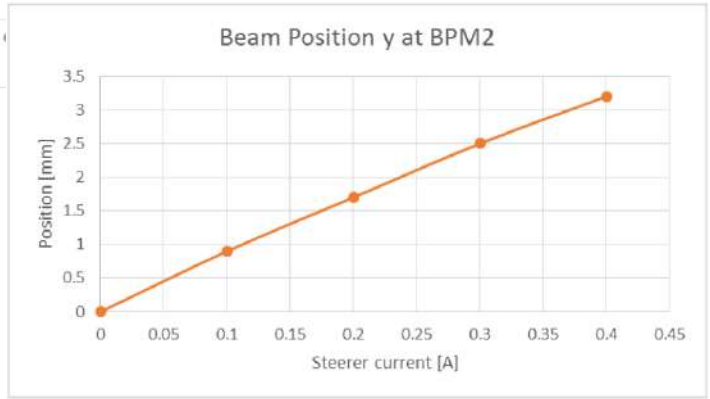
ADAM

100 positions x and y at the first BPM after RFQ with 10uA 5MeV beam, 5us pulse at 200Hz





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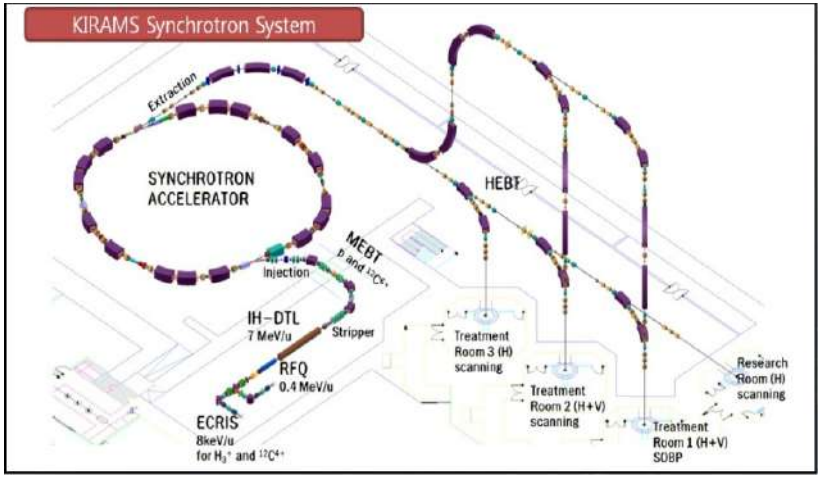
KIRAMS, Other Asian labs (NDA) - Libera Hadron

Libera Hadron

- SOCKET IO interface
- Quiet fans
- Settable SA data stream – Slow monitoring (from 10 Hz to 1 kHz)
- Modification of the DSP algorithm (Up to 11 MHz bunch repetition)



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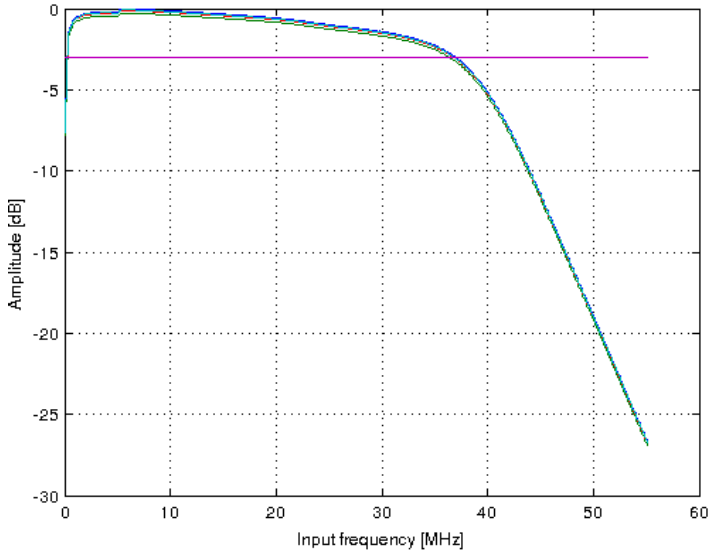
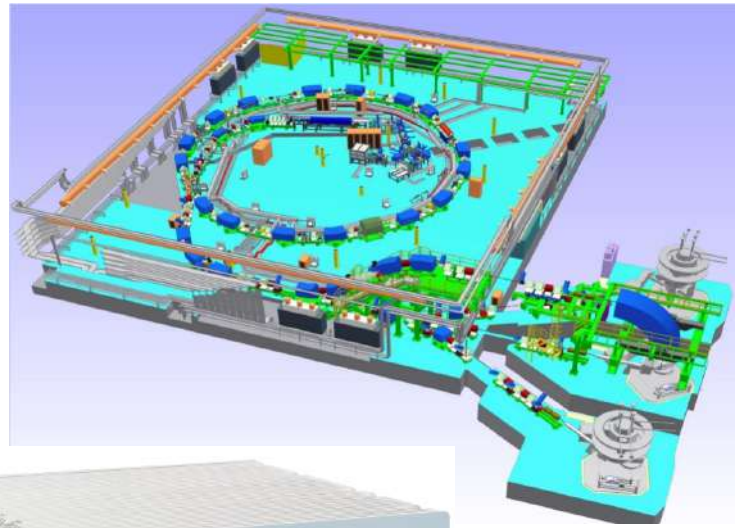
CNAO, IMP, Hitachi – Libera Spark “HR”

Libera Spark “HR”

- Hardware ready
  - 35 MHz LP filtering
  - 125 MHz sampling rate





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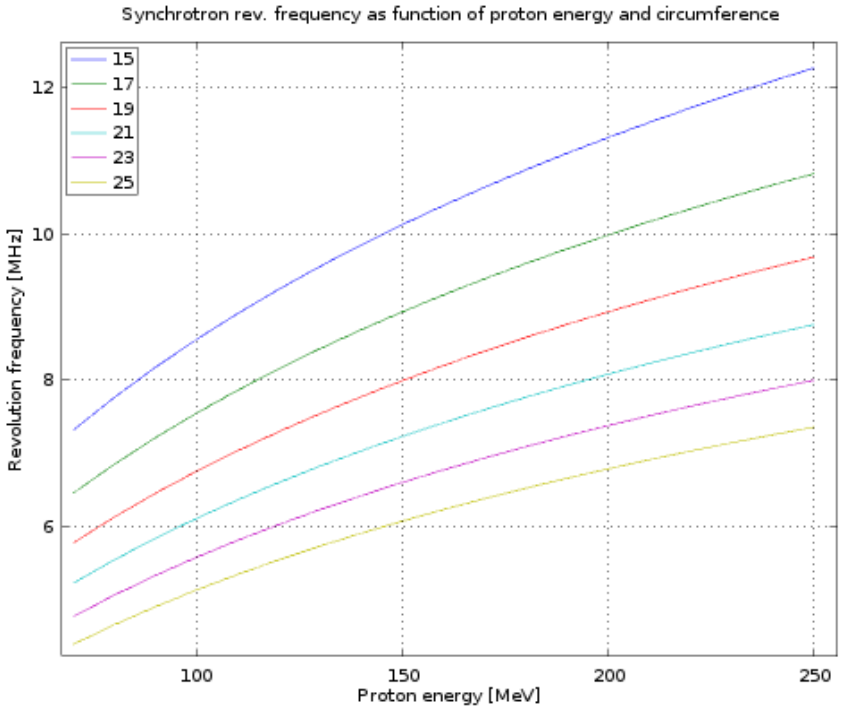
LLRF applications

Synchrotron design constraints

- Robust industrial design in a space constrained environment
- Energy range required by the synchrotron applications implies a frequency ramping in the range of 10 MHz
- RF system technologies
  - Ferrite loaded cavities (require dynamic tuning)
  - Magnetic alloy loaded cavities (broadband design, harmonics and frequency response normalization need to be addressed within LLRF)



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LLRF requirements

Energy ramping

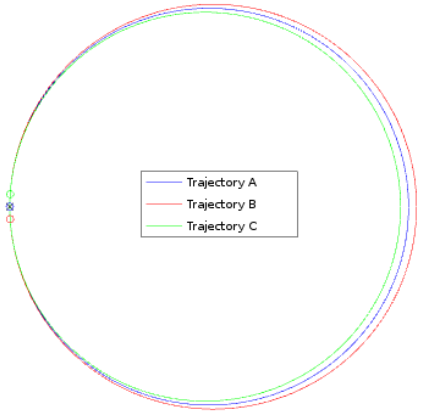
- RF cavity amplitude, phase and frequency must be consistently applied through arbitrary functions of time during the ramping cycles
- Bending magnet ramping must be synchronized with RF system ramping

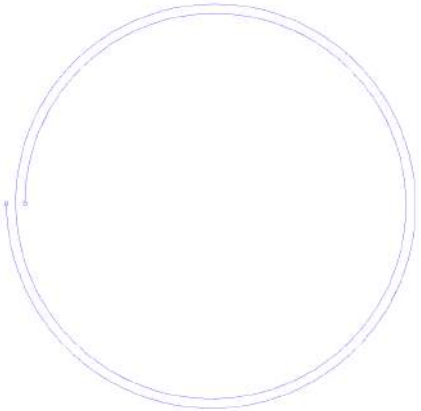
LLRF feedback requirements

- Beam phase based feedback (longitudinal feedback acting on phase)
- Orbit feedback (transverse BPM feedback acting on frequency)
- Dynamic cavity tuning (narrowband designs)

Protection system must react to unwanted working conditions and may require specific features

It may be required that treatment data is logged for archiving purposes





Conclusion

- Proton therapy beam energy needs to be configured and automatically applied as a treatment plan programmed sequence.
- Beam diagnostics tools are essential during commissioning phase, are required to prevent unwanted working conditions and in some applications may be necessary for the implementation of additional feedback loops.
- Digital LLRF systems are required for controlling accurately proton therapy beam energy.