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Slow Extraction with High Intensity Beams

V. Nagaslaev (Fermilab, US PI)

US/Japan Hawaii Symposium

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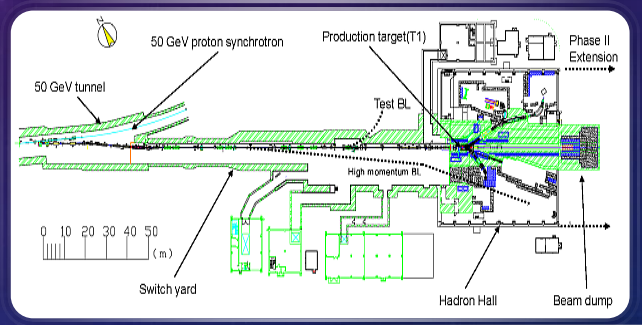
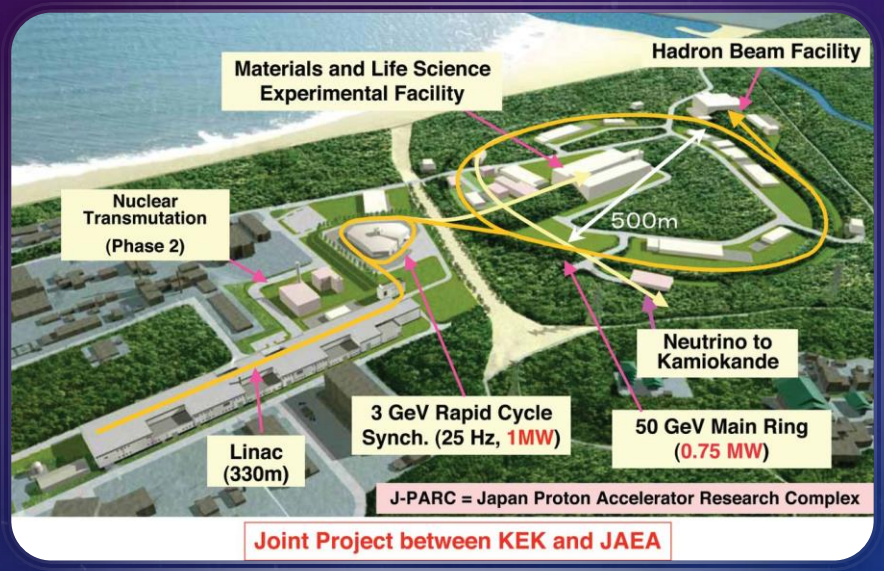
GENERAL FACTS AND TRENDS IN SLOW EXTRACTION (SX)

- Serves to deliver continuous beam
- AKA Resonant Extraction (RE)
- Many applications of SX
- Wide range of experimental needs
- Many fundamental discoveries in the past made in FT experiments
- New experiments coming; pushing the limits



Japan PI: Masahito Tomizawa, masahito.tomizawa@kek.jp

COLLABORATION: SLOW EXTRACTION AT J-PARC



- Beams for the Hadron Beam Facility
- Rich experimental program
- 30 GeV p from Main Ring
- 60kW beam power; growing
- Extraction efficiency = 99.5%

Collaboration: Slow Extraction at Fermilab

US PI: Vladimir Nagaslaev, *vnagasl@fnal.gov*

- 120 GeV protons from MI
  - 2 experimental sites
  - Wide range of secondaries and energies
- New SX facility at construction (Mu2e)
  - 8 GeV/8kW proton beam
  - Single bunch
  - Spill length - 43ms
  - Very high spill uniformity
  - Very low losses

Collaboration: Slow Extraction at BNL

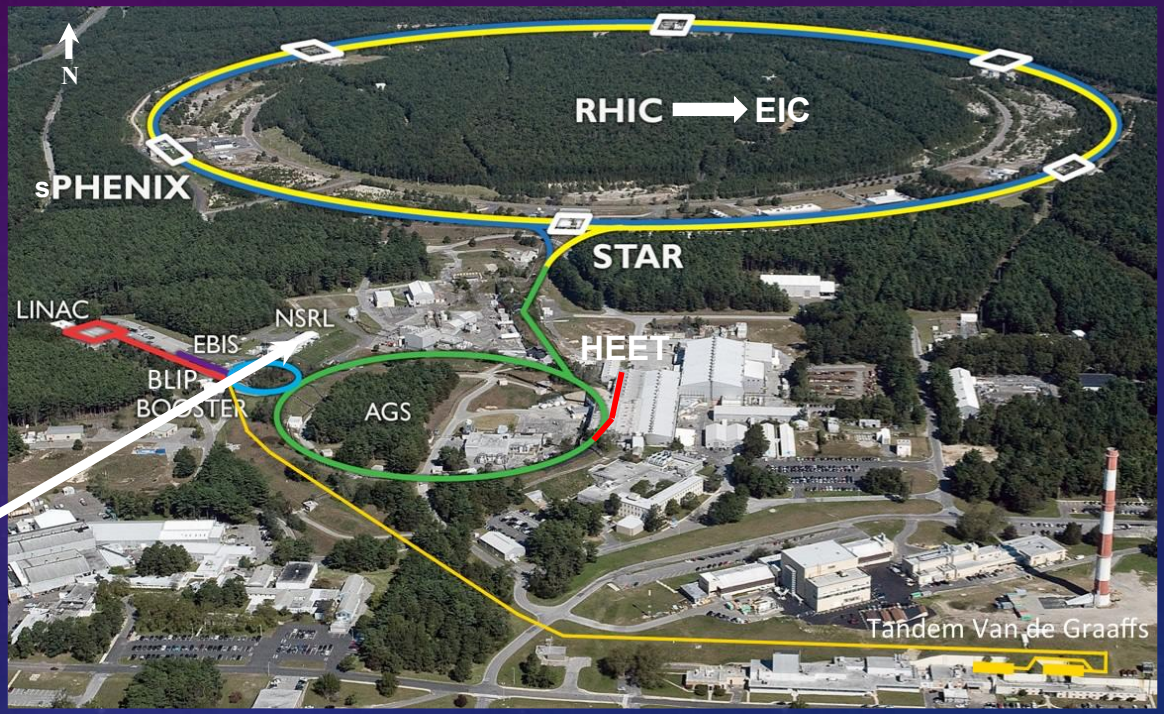
Co-Investigator: Kevin Brown, brownk@bnl.gov

High Intensity SX from AGS

- Max 7.2×10^{13} protons/spill
- 25 GeV/c
- 98% extraction efficiency
- Program ended in 2002

NASA Space Radiation Lab

- Extraction from Booster
- Solar Particle Events (SPE)
- Galactic Cosmic Ray (GCR) Spectra



Proposed Future Facilities: High Energy Effects Testing (HEET) Facility at the AGS

- Simulates SPE and GCR events with High quality 3D uniform beams

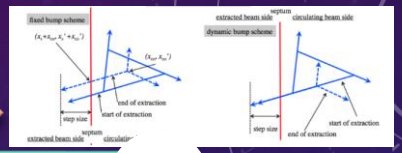
CHALLENGES OF THE SX AT HIGH INTENSITY

Beam losses	Spill quality	Machine protection
• Radiation protection • Equipment lifetime	• Spill regulation • Ripple detection	• Prevention • Early detection

BEAM LOSSES MITIGATION

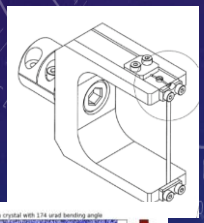
Dynamic ramping the beam conditions

- Ramp to resonance ✓
- Ramp orbit ✓
- Ramp the resonance ✓
- Constant Optics SE ✓

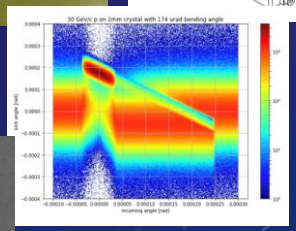


Shadowing the septum ✓

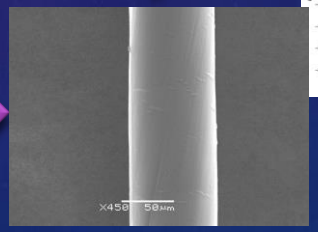
- Diffisers



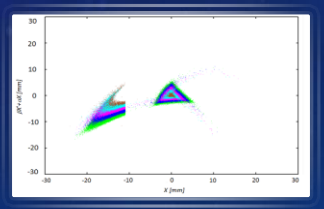
- Crystal collimation

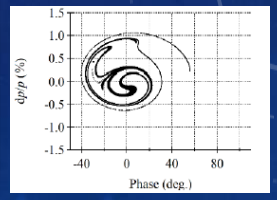


Search for new low-Z materials (CNT) ✓



Beam dynamics ✓



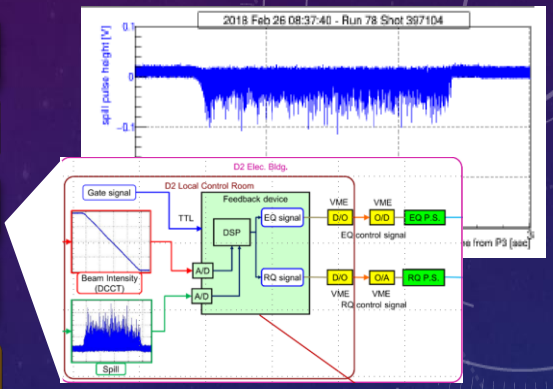


✓ complete ✓ active

SPILL QUALITY IMPROVEMENTS

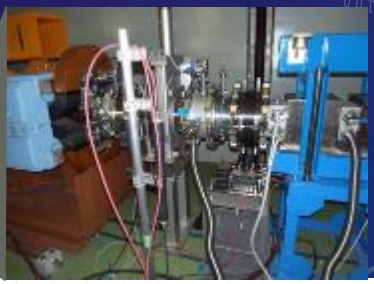
Spill Regulation Electronics

- Pushing the BW
- Fast data transfers
- Growing complexity
- Algorithms (ML)
- RF manipulations



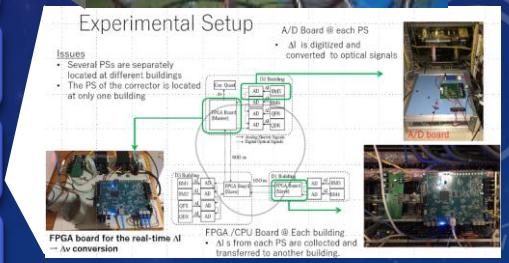
Spill Regulation Devices

- ML on harmonic sources regulation (feedforward)



Ripple Detection

- Spill Monitoring
- Ripple Source Monitoring (ex: CERN)
- Ripple Source Integration (ex: J-PARC)
- Active filtering (ex: BNL)



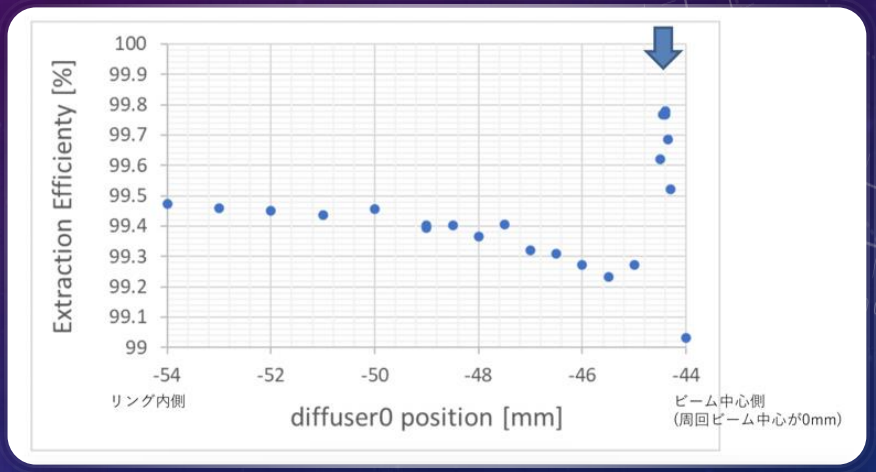
RECENT RESULTS FROM THE US-JAPAN SLOW EXTRACTION COLLABORATION

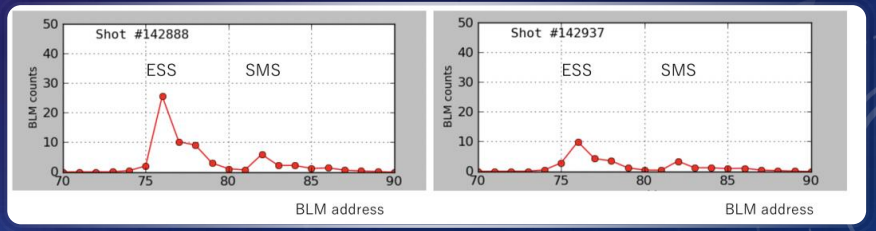
DIFFUSER TEST AT J-PARC

2/18 2021

- Two diffusers at two locations
- Preliminary efficiency 99.78%
- Low intensity only
- High intensity test to follow

10kW Diffuser Beam Test



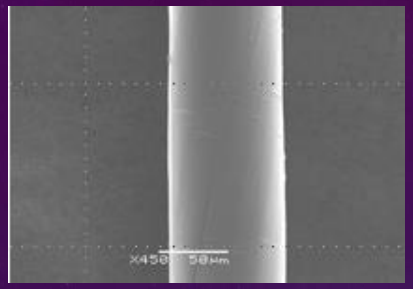


efficiency 99.53%

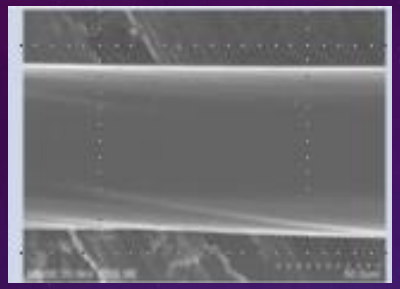
efficiency 99.78%

Courtesy: R.Muto and M.Tomizawa

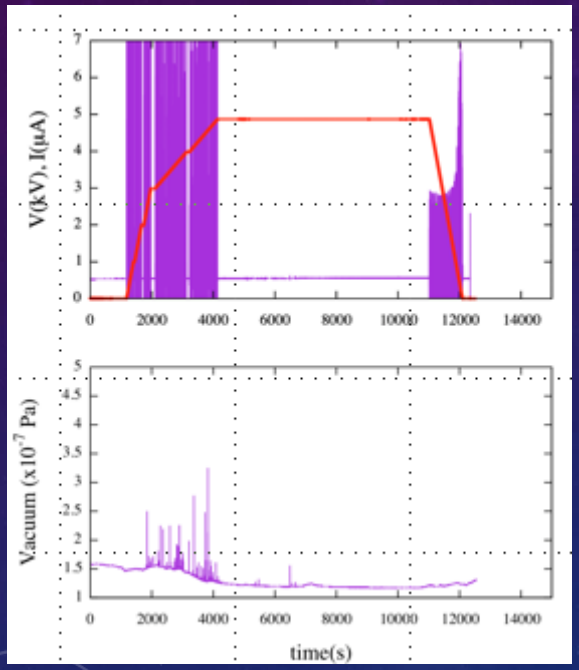
RECENT PROGRESS WITH THE CNT WIRES



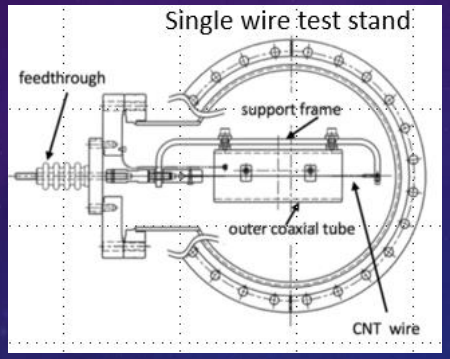
FNAL, SEM



J-PARC, SEM



M.Tomizawa

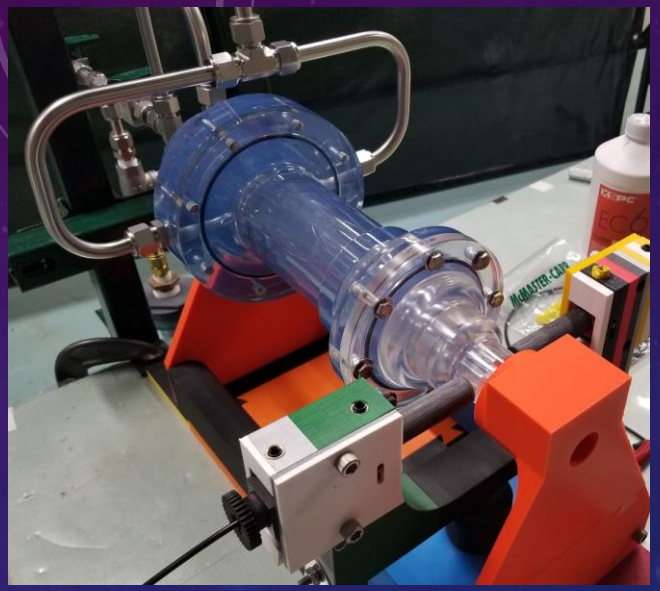


J-PARC, 2020:

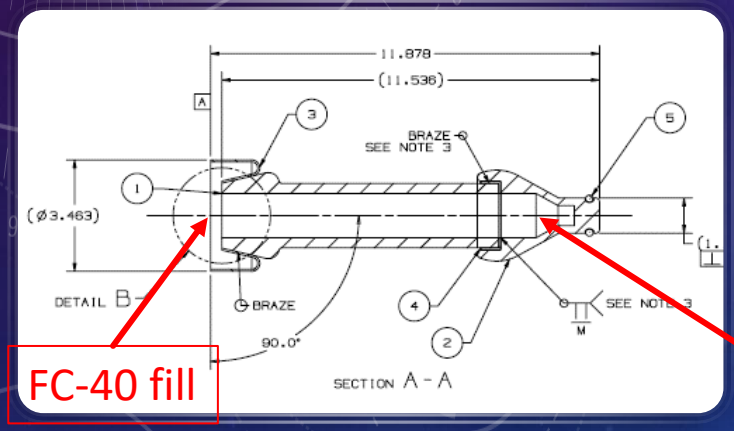
- Single wire in cylindrical cell
- Stable operation at 5kV
- Equivalent to 20MV/m
- New options

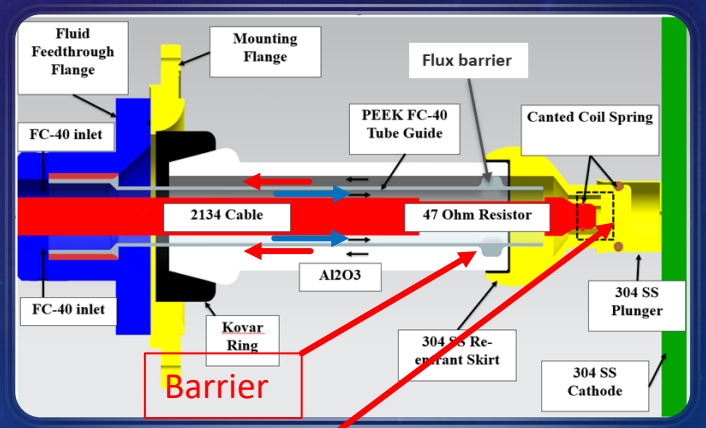
RADIATION HARDNESS

- Septum: activation up to 1R/hr
- Most vulnerable part: HV feedthrough
- New channel type FT developed
- Good results in lab testing
- Building the production unit



doi:10.18429/JACoW-IPAC2019-WEPMP044

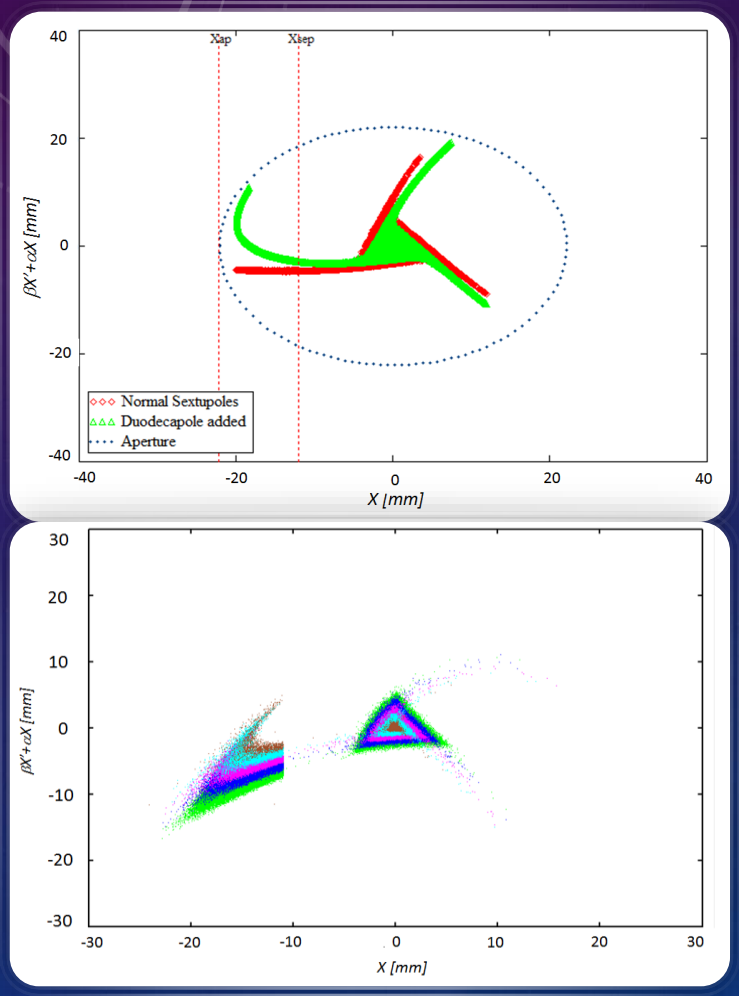




Critical area

BEAM DYNAMICS

- Second or third integer
- Higher order resonance
- Higher multipole fields
- Concept of integrable optics?
- Beam stability



PhysRevAccelBeams.22.043501

SUMMARY

The new demands for SX bring new challenges

The US/Japan Collaboration stays at the top of the new trends

There is a rich and vibrant program for new research

Active collaboration is the best way to stay successful

Many thanks to DOE and KEK for supporting this collaboration!