



# First Experience with Slow Extraction Commissioning at Fermilab Delivery Ring

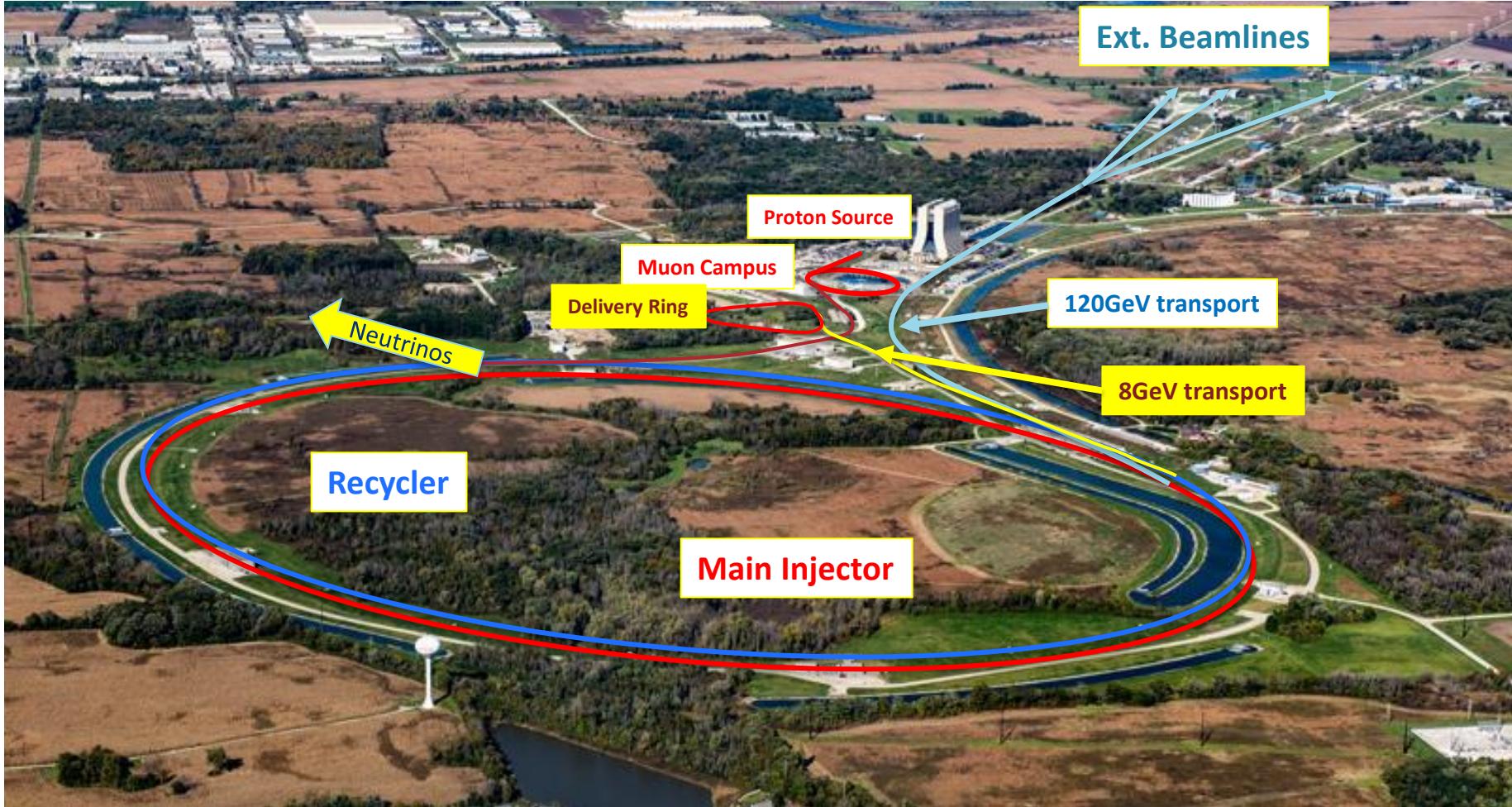
V.Nagaslaev

5<sup>th</sup> SX Workshop, Wiener Neustadt

February 11, 2024

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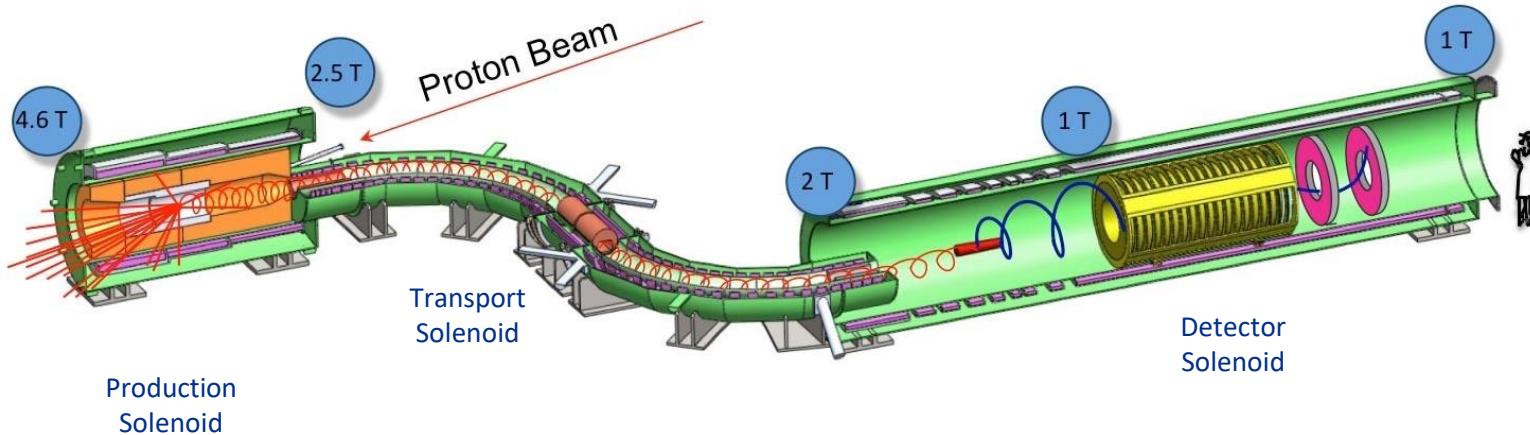
# Beam Facilities at Fermilab (SX Workshop-2022)



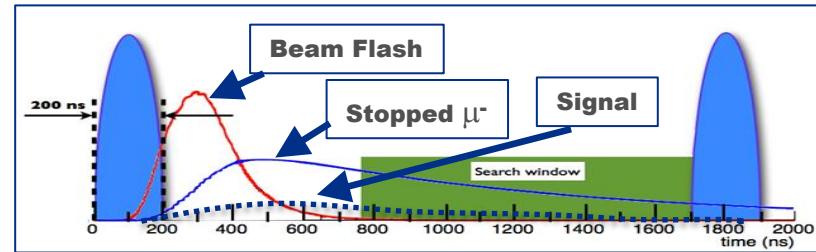
Muon Campus delivers beams for g-2 until Shutdown-2023  
Mu2e commissioning will follow

# The Muon to Electron conversion experiment (Mu2e)

Separate the background both in space and time



- CLFV discovery would indicate the BSM physics
- Sensitivity 10000 times below the previous experimental limits
- Slow spill beam delivery is required



Timing diagram: quiet time between bunches is crucial

# The Muon to Electron conversion experiment

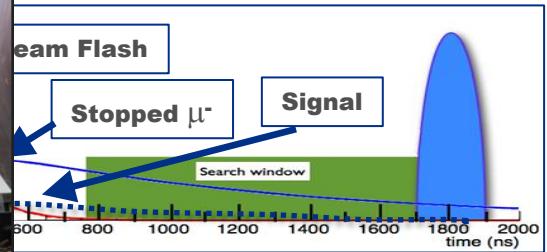
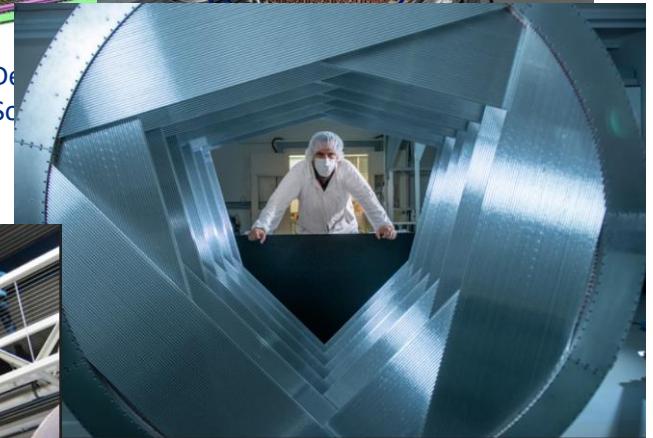
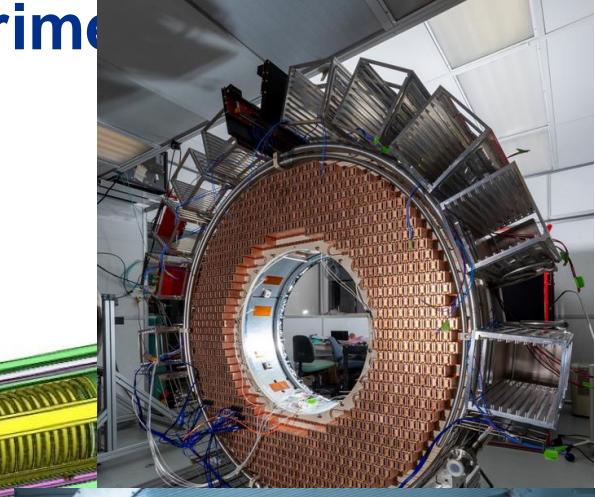
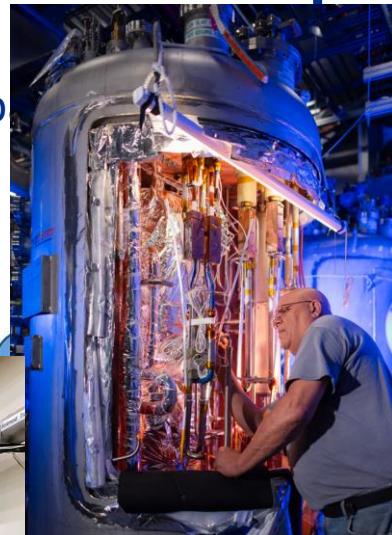
Separation

length in space

4.6 T



- Slow spill beam



long enough quiet time between bunches is crucial

# Mu2e SX characteristics

- Main design parameters:

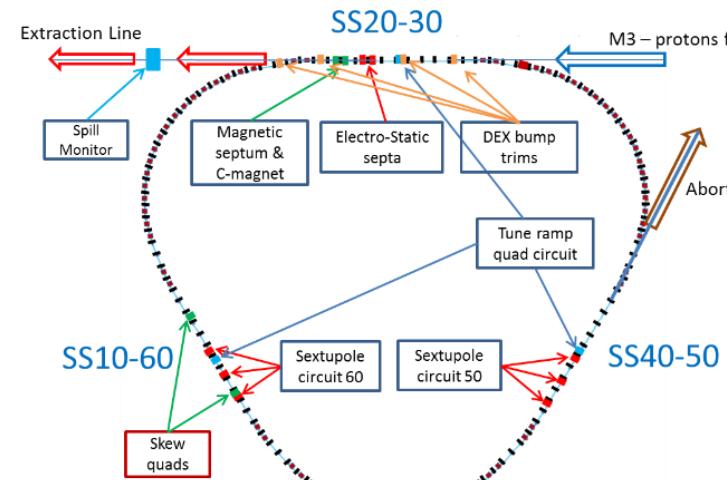
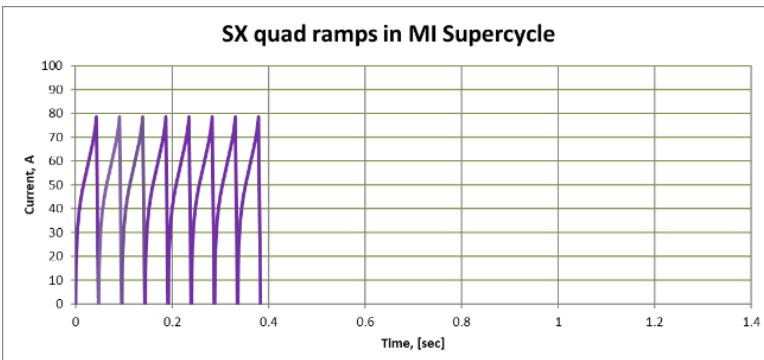
- Beam power 8kW
- Spill intensity  $1e12 p$
- Efficiency  $>98\%$
- Spill duration 43ms

- Delivery Ring:

- Circumference 505m ( $T_r=1.7\text{ usec}$ )
- FODO lattice,  $\beta_{\max}=15\text{ m}$
- Dispersion suppressed in SS
- Bunched beam, single bunch  $H=4$

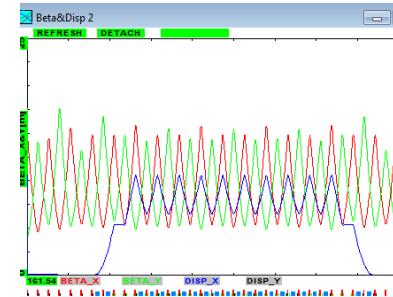
- Extraction:

- 3<sup>rd</sup> integer,  $Q_x=29/3$
- Quad driven squeeze
- Spill corrections: Quads + RFKO
- Beam abort in the end of spill



- Beam emittance:

- Unnorm., 95%  $E_{x,y}=1.6 \pi \text{ mm*mr}$
- Acceptance  $A_{x,y}=36 \pi \text{ mm*mr}$



# Mu2e SX characteristics

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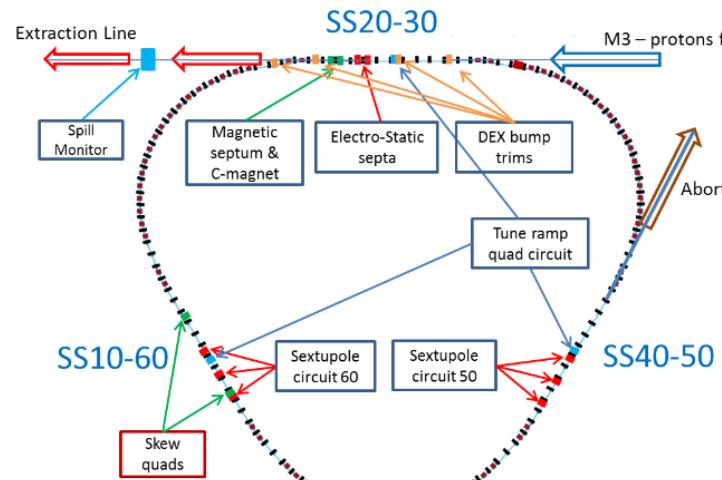
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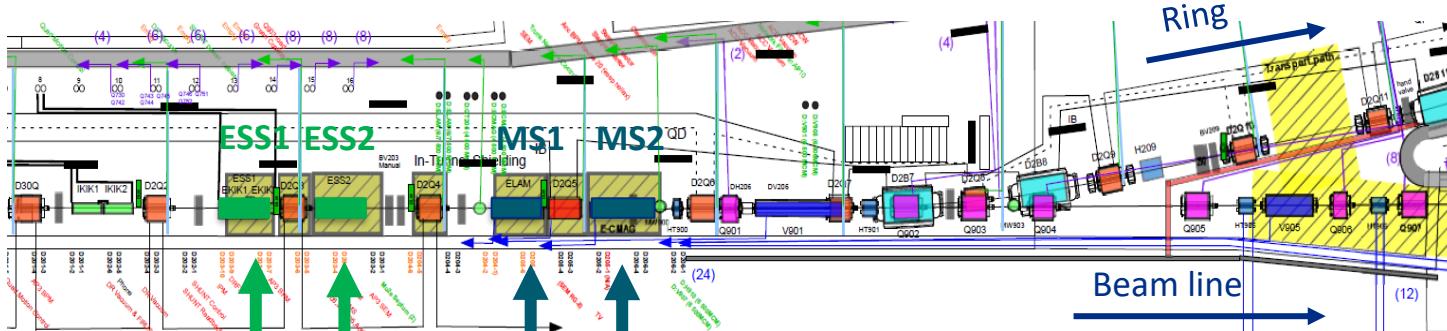
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# Slow Extraction (SX) operation planning for Mu2e

- Electrostatic Septa (ESS) are the last pieces needed for SX commissioning
  - Full scale ESS Prototype commissioned in 2020
  - Production ESS1 and ESS2 are in preparation
- SX schedule:
  - G-2 experiment scheduled to stop by the end of FY23 (shutdown)
  - Install 2 septa in the tunnel during the FY23 shutdown
  - Mu2e schedule assumed beginning SX operations in FY24

- Plan change:
  - Decision made in 2022 to install the septum prototype in the tunnel
  - **Limited commissioning of SX before the 2023 shutdown**
- The F23 summer shutdown at Fermilab extended to March 2024

# Experience with the ESS Full Scale Prototype (FSP)

Septum installed in the DR in the end of November 2022



# Main issues:

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1. Septum internal issues limited available HV to 75%
2. HV PS not available until available by Mar-01-2023
3. Slow Extraction studies started by Mar-24-2023
4. Instrumentation issues with SEM beam profile monitors in M4
5. Slow emittance blow up (~1 sec) – due to poor vacuum
6. Fast emittance blow up (~1 msec) – not yet understood
7. M4 spill monitors not fully available until July 2023
8. Beam Position monitors (BPMs) not available until July 2023
9. Operations stopped in July 2023 for the summer shutdown

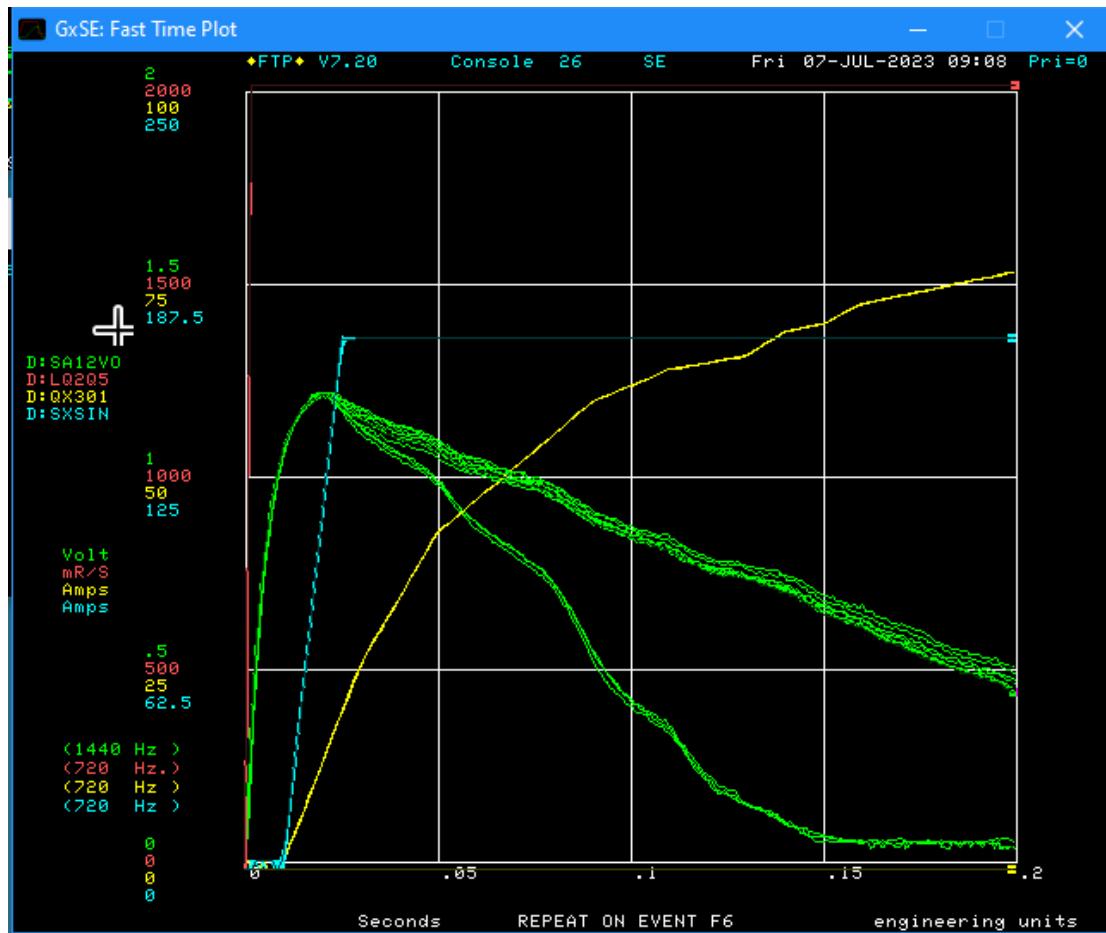
Only a few days for full studies available!

# Resonant Extraction studies:

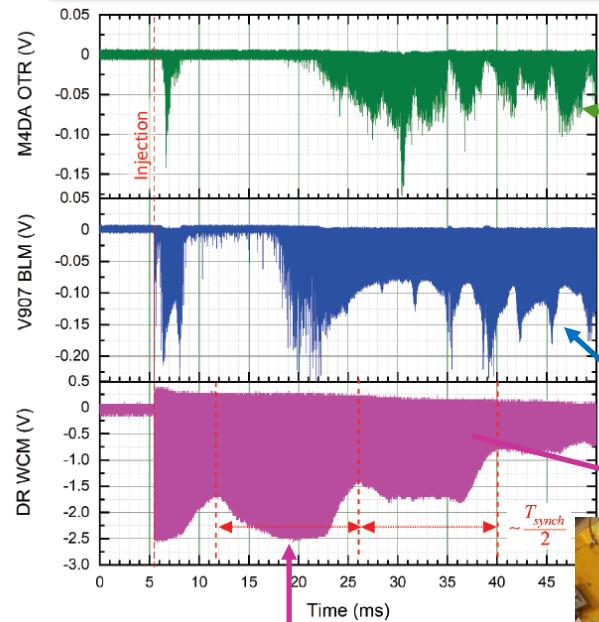
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1. Ramping up the resonance and extract
2. Experience with optimizing the orbits
3. Resonance TBT orbits

# Ramping up and Extracting



# Spill Monitoring:



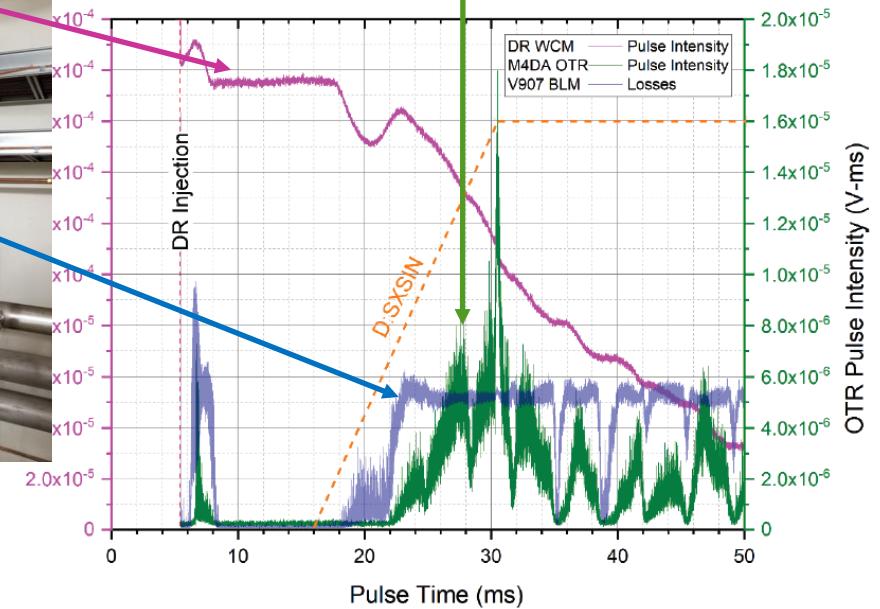
## OTR style monitor at the beam absorber



## Wall-Current Monitor

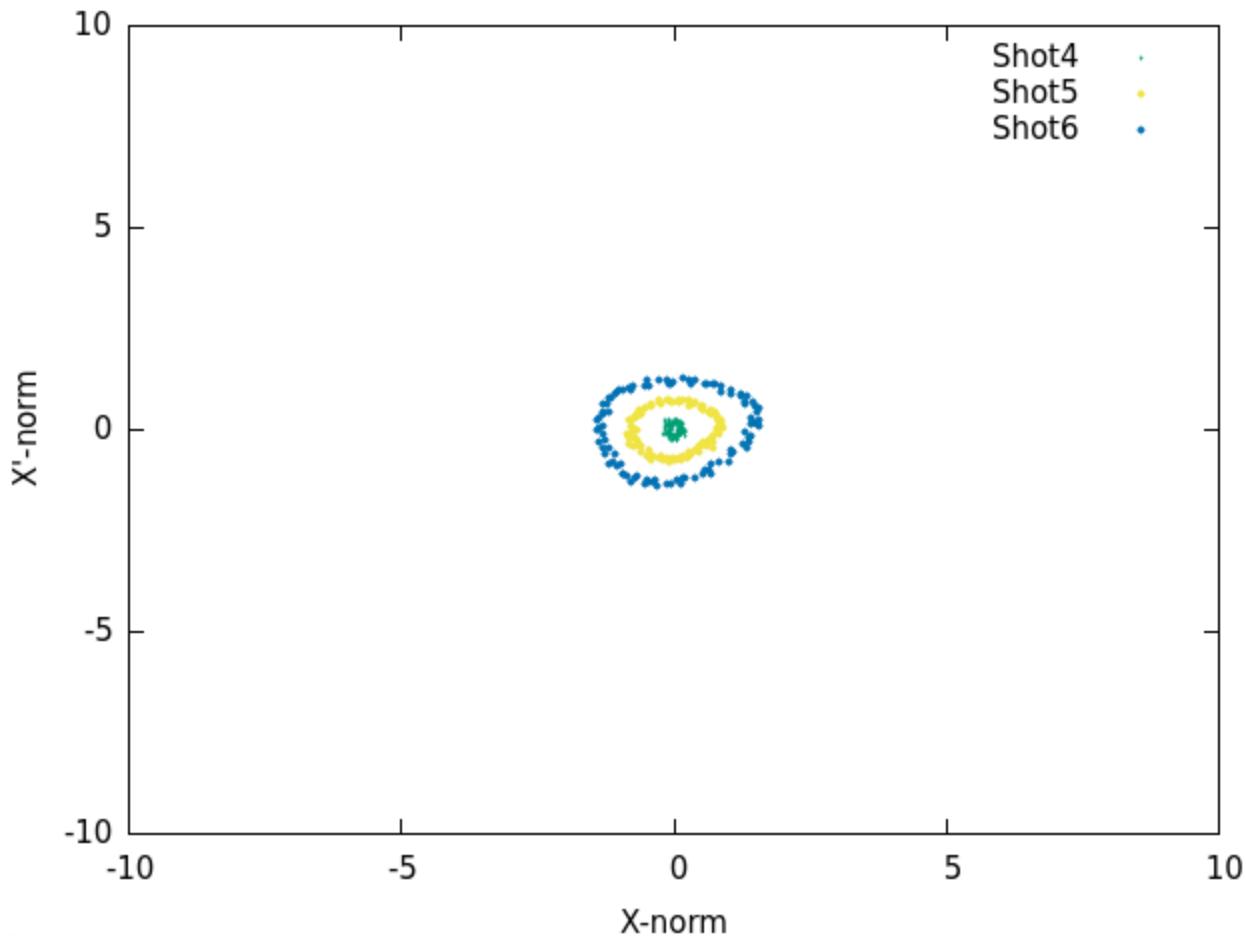


## SC-counter at 907



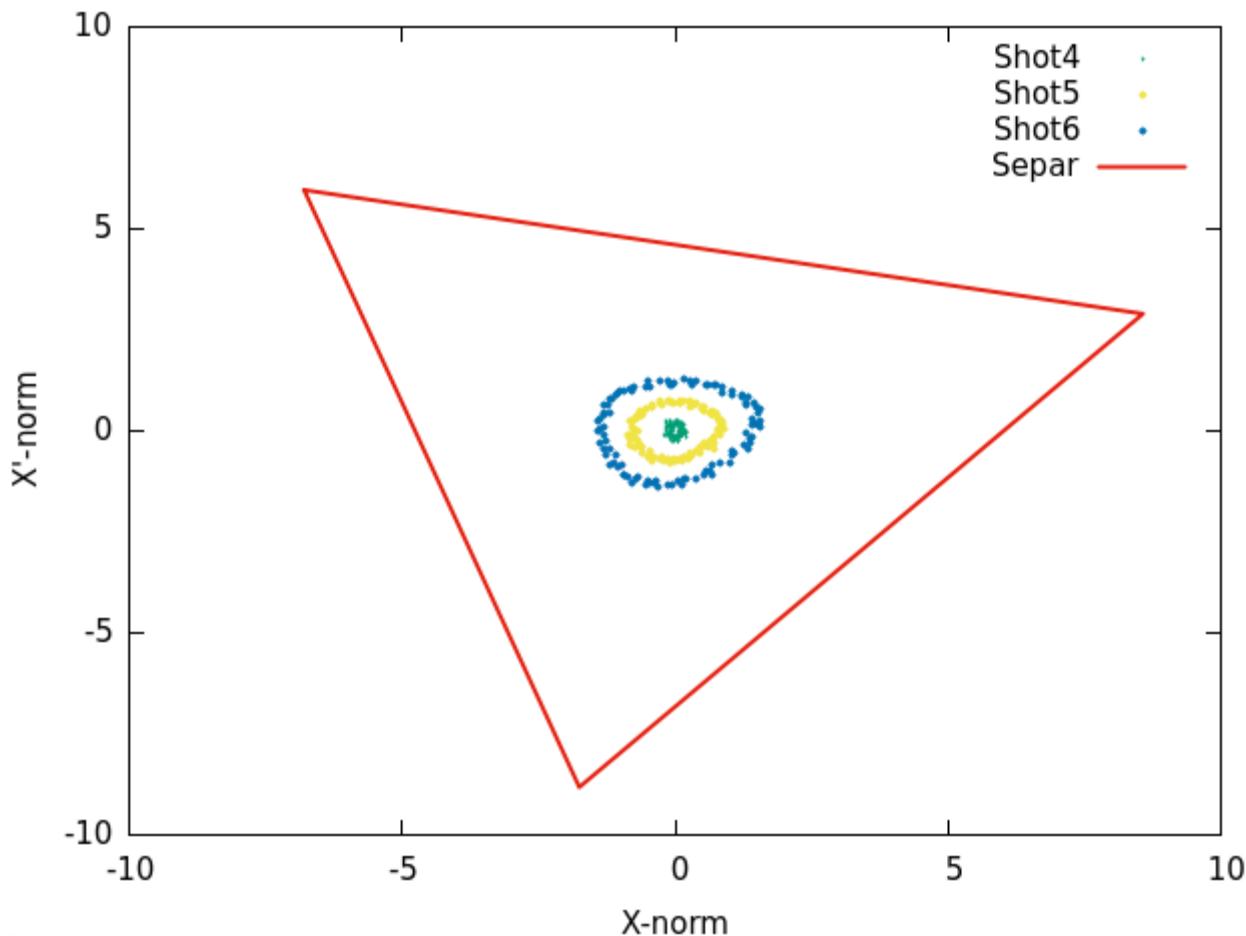
# Resonant TBT orbits:

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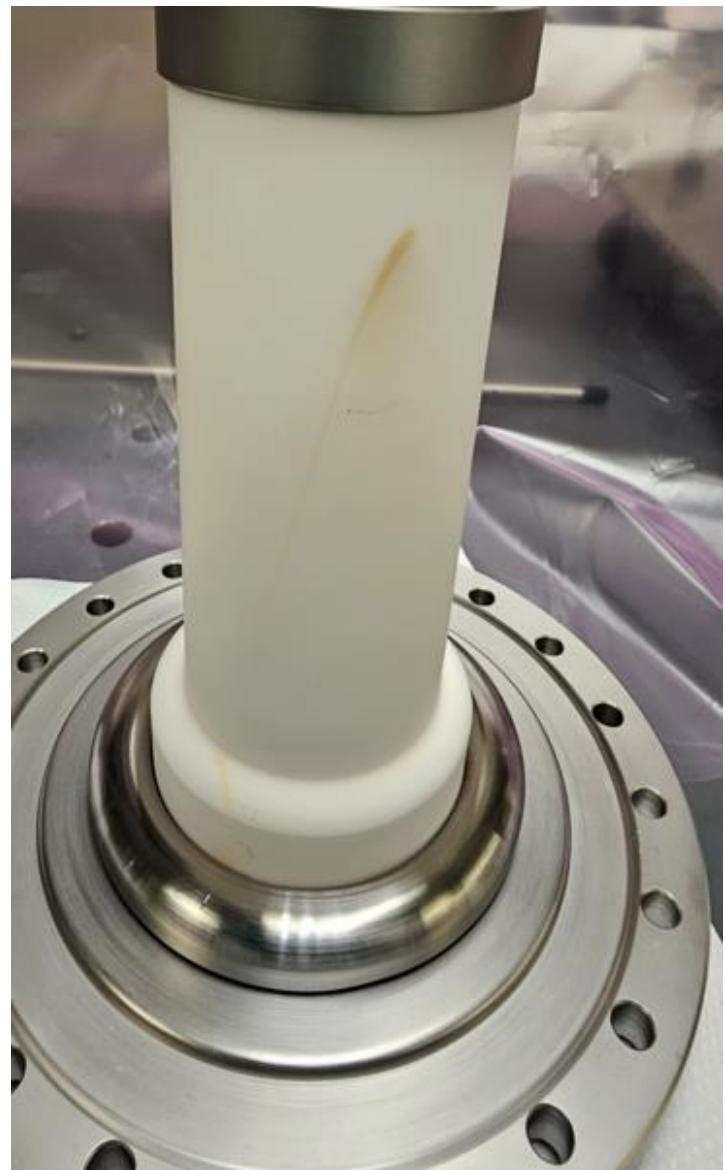
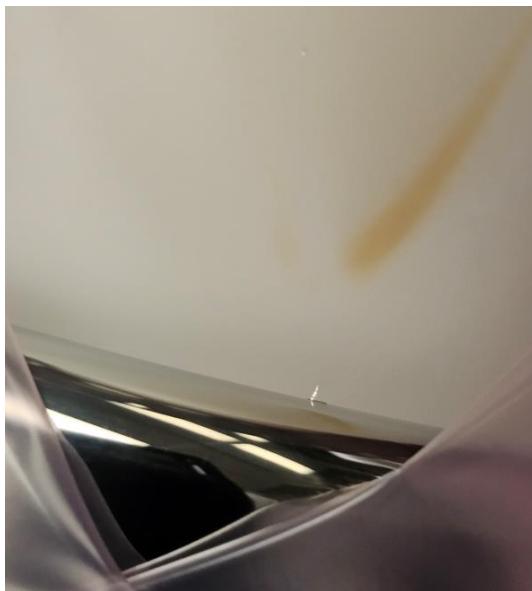


# Summary - What's accomplished

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1. Experience with driving the resonance extraction
2. Initial experience with tuning the extraction orbits
3. Observation of the resonance phase
4. Completion of the vacuum system
5. Completion of the 1<sup>st</sup> phase HVPS
6. Completion of the TBT BPM system
7. Experience with the installation design/implementation
8. Establishing the spill monitoring devices (phase I)
9. Identification of the instrumentation issues
10. Identification of the beam dynamics issues

Looking forward to continue commissioning in FY24



# Backup slides