EAST BEAMS PRODUCTION AND DELIVERY IN 2022

Joint Accelerator Performance workshop 2022

Many thanks to the (several) involved equipment groups, the users representatives for their feedback (and continuous constructive communication) and the OP, RF and ABT colleagues working on the cycles settings, in **particular** : Eliott Johnson, Matthew Fraser, Alexandre Lasheen, Gil Imesch and Denis Cotte for the settings management, Alexander Huschauer for the High Level knobs, Marcel Coly for the UCAP devices

Outline

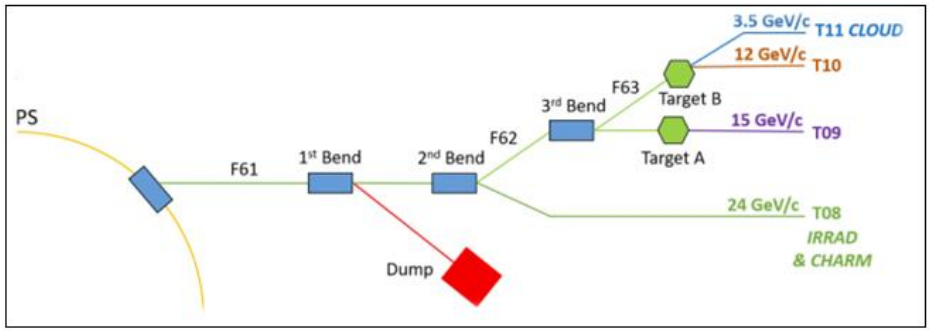
- **Reminders and recaps**
  - A reminder from 2021
  - 2022 run recap
- **24 GeV/c protons slow extraction from the PS**
  - Tune control during the slow extraction
  - Adjustements made in 2022
- **Tools**
  - Settings management and high level knobs
  - Beam instrumentation
  - Losses reduction
- **Drifts over time**
- **Transfer line optics (ABT) studies**
- **CHIMERA**
- **Plans for 2023 and conclusion**

A reminder from 2021

- **Pablo Arrutia** presented the **East Beams production** in **2021**
https://indico.cern.ch/event/1063281/contributions/4468575/attachments/2360034/4028438/IEF WS EAST(3).pdf

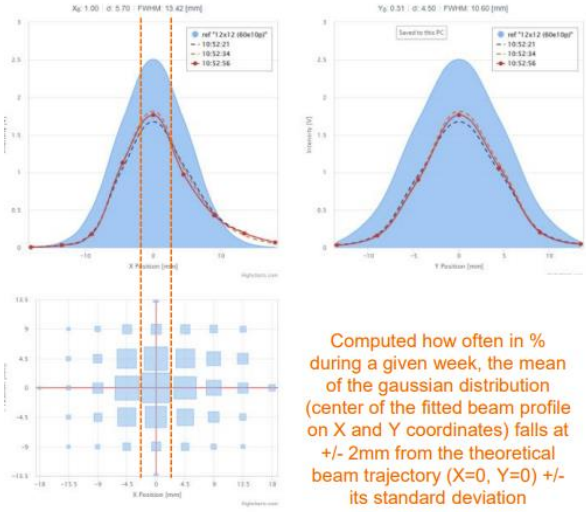
- The following **key points** had been identified and had to be adressed in 2022
  1) **Eddy currents** effects
     - In particular : **Figure-of-eight loop (W8L) inducing transient phenomenon**
  2) **Spill quality : bursts** of particles extracted **before**
  3) **BTV saturating**
     - Remove glow, investigate UCAP for image processing to provide beam size and position, integrate into steering program
  4) **RP** survey showed **increased radiation** levels in PS **section 63**
  5) **Bump57 too strong** for the power converter
  6) **Cycle to cycle stability** issues

2022 run recap (i)



- **30e10** protons per cycle for **T9 and N** (T10/T11 shared target)
- **60e10** protons per cycle for **T8** (Radiation tests facility : Irrad/CHARM)
- **1 week in August** dedicated to the **CERN shielding benchmark facility (CSBF)** run with variable intensities **(5e9 to 6e11 protons per cycle)**
  - Special cycle on h16LI beam control (VS h8), coupled with a PSB clone of LHCPILOT
- Successful **CHIMERA** run
  - very low adjustable intensity Pb ions at several energies transferred to T8

2022 run recap (ii)



Computed how often in % during a given week, the mean of the gaussian distribution (center of the fitted beam profile on X and Y coordinates) falls at +/- 2mm from the theoretical beam trajectory (X=0, Y=0) +/- its standard deviation

- **IRRAD**
  - 56 different users, > 600 samples processed
- **CHARM**
  - 29 users, 39 system level tests
- **Beam alignment better than in 2018 in H, similar in V**
- **Profiles good** but **not excellent**
  - **Tail** on IRRAD **BPM1** but which **also appears in FLUKA simulations**
- **$1.8^{e}16$ protons / week** delivered on average to **T8** (VS **$1.6^{e}16$ in 2018**)
  - Aim for **$2.2^{e}16$** protons / week

OVERALL GOOD QUALITY BEAMS AND VERY SATISFIED USERS

- **Most important requests identified :**
  - **Higher flux for T8**
  - **Higher repetition rates or longer spill (at lower energies) for T9/N**
  - **Track quality drifts over time (spill, position, trajectories, profiles)**
    - Find a way to **monitor** beam position on targets

Many thanks to D. Banerjee, F. Ravotti, S. Danzeca

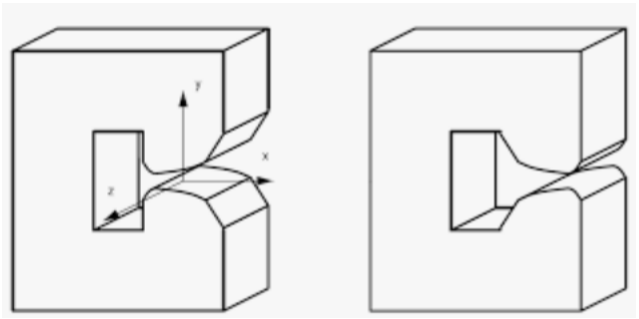
Increased flux or increased repetition rates in a **packed schedule**
(SC constraints and **T8 schedule impacted by MDs, CHIMERA, CSBF)**
We need to increase our scheduling efficiency ; time for automatic beam scheduling ?

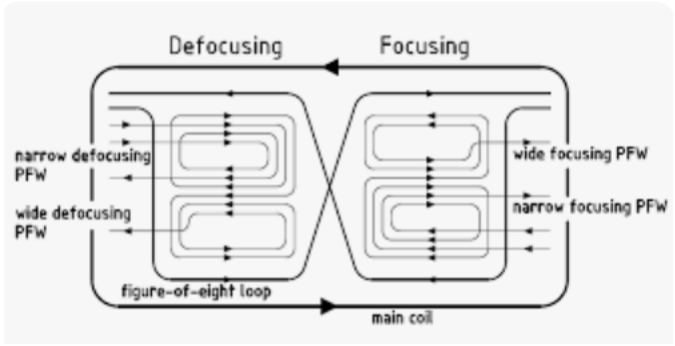
Tune control during slow extraction

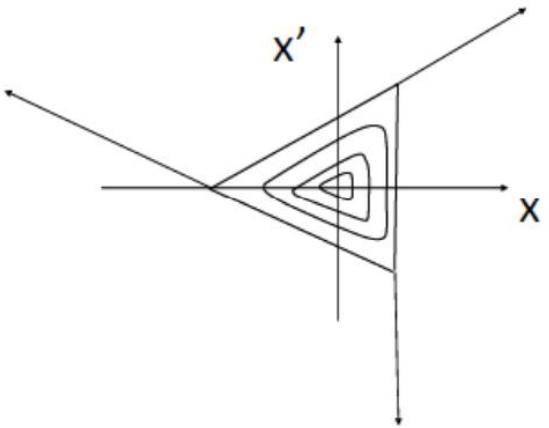
- Third-order resonance : (horizontal) tune brought just below 6.33 by a combination of the **quadrupolar** part of the **combined-function main units** (powered by POPS), **pole face windings** (pfw) and **quadrupoles for slow extraction** (qse)

- At 24 GeV/c, the beam is slowly pushed through resonance via a ramp on **POPS** (i.e, we ramp the main units)

- PFW to fine control the tune





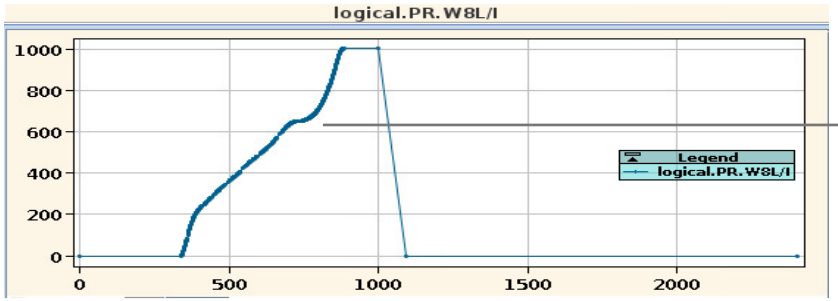


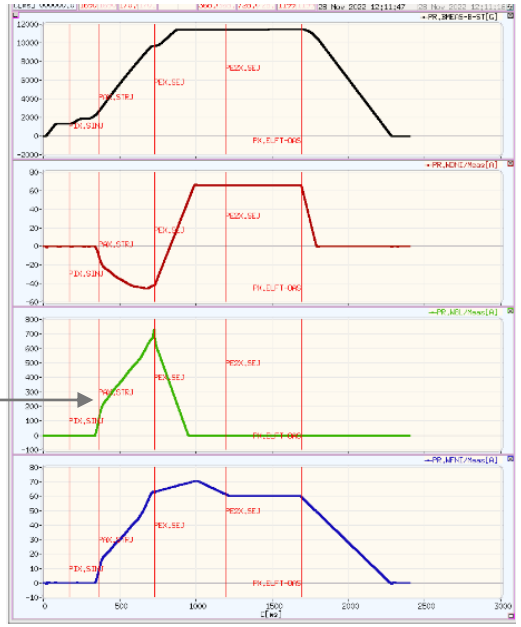
2022 24 GeV/c protons SX adjustements (i)

- **Dynamic** transient **movement** observed on BTVs
  - **W8L Eddy currents** our number 1 suspect

- Impossible to completely remove the W8L, at least with parasitic TOF bunch
  - Try to **bring W8L to 0 as early as possible** and delay the SX as much as possible
  - Alternative working point to be studied next year ?

- **Flat-part** added before ramping POPS again
  - perform the **bunch-rotation** in stable conditions



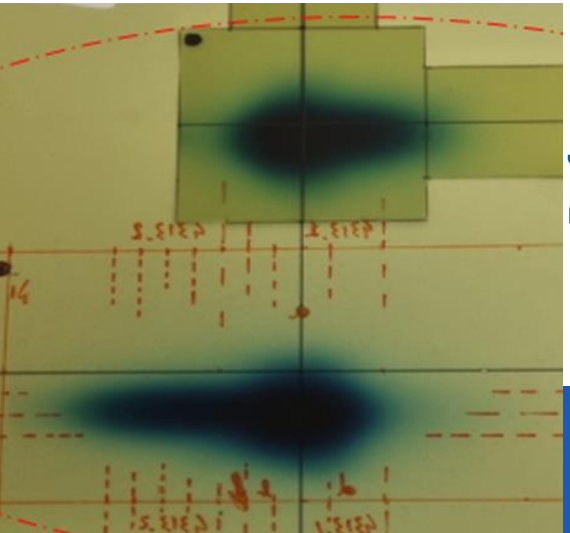


2022 24 GeV/c protons SX adjustements (i)

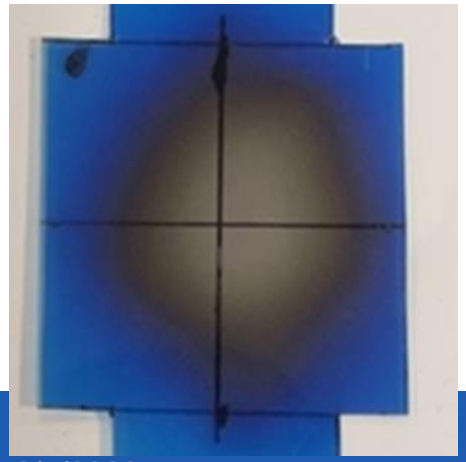
- **Time** given to power converters involved in SX **to settle down**
  - Most SX power converters can start before the qse tune rise (within their limits)
    - *Caution : debunching must occur before the rise of BSW23 since one of the radial loop pickups is inside the bump*
  - **smoothed functions** (manually)
    - *How to handle timings and smoothing when we generate settings ?*

- **Clear (obvious) improvement !**
  - dynamic «shaking» (transient) disappeared: **2021 point 1** ✅
  - pretty nice spill : **2021 point 2** ✅

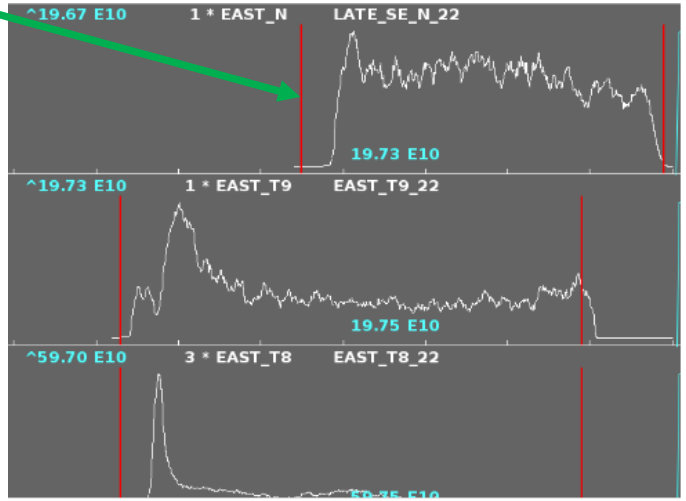
- Confirmed by **IRRAD** films !



Before



After



Settings management and high level knobs

- **New** high level knobs for **bump23** and **bump57** amplitudes
- **High level knobs** for **tune** and **chromaticity** (via **PFW**)
- **New F61BEAM/MOMENTUM** (= PSBEAM/MOMENTUM for transfer lines)

- **New logical devices : K functions for…everything**
  - Model-based approach
  - **Current** for all devices **scaled** with **momentum**
    - One important **exception** though…the **PFW** !
      - Mathematically computed (via a polynomial) from the **B**
      - The flat-top currents for the PFW **can't be generated** and the functions are **NOT SCALED** when we modify **PSBEAM/B**

- **T8** switched to **multiplexed** mode (**ppm**)

- **Multi-ppm** mode **F61.BHZ01.DUMP**.A and B
  - *No logical K, so they are not automatically scaled when we change the B*

Beam instrumentation

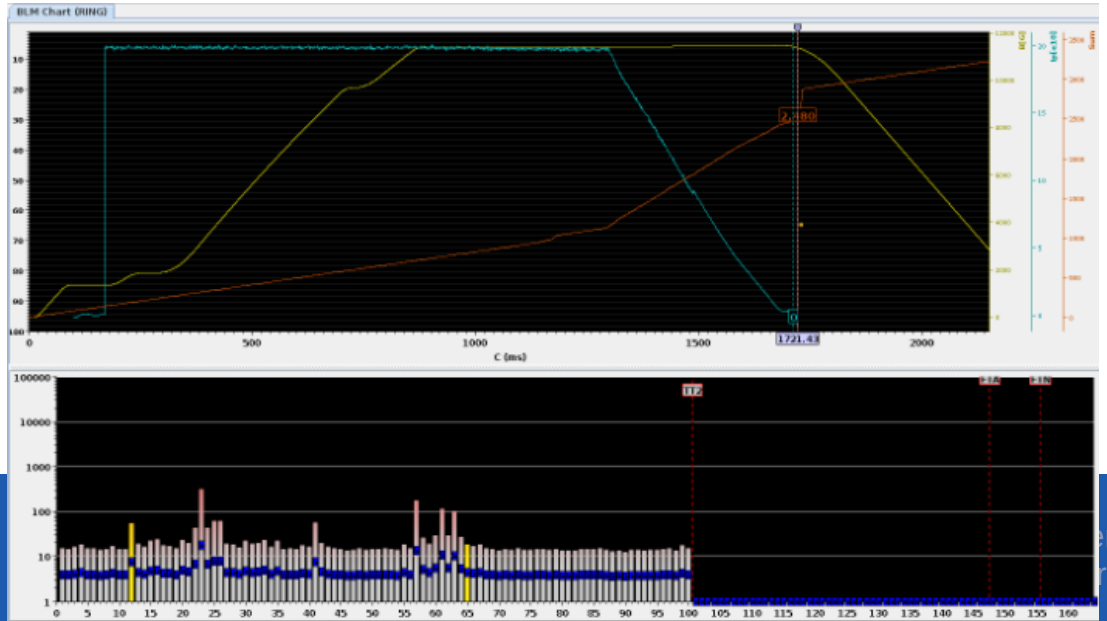
- **5 BTVs** became much **more useful for beam position measurement** after a few modifications
  - **Optical filters** added to avoid **saturation** effects and remanent **glow** from previous cycle(s)
  - **UCAP** devices created by Marcel Coly to process the images
    - provide values for beam size and position
    - analyse the beam position as a function of time during the spill

- **IRRAD BPMs + Multi-Wire Proportional Chamber** now exploitable in our controls infrastructure
  - Nice example of BI-EA-OP-CSS **fruitful collaboration**

- **BTVs, IRRAD BPMs, MWPC** are now **integrated in automatic steering program (new YASP configuration) : 2021 point 3** ✅

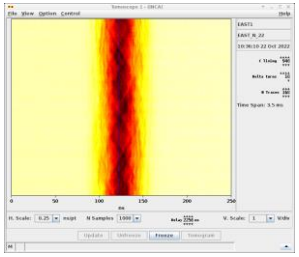
Losses reduction

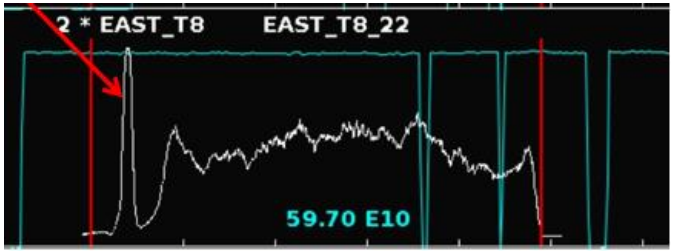
- **East dump is extremely useful** ; still very limited though
  - Radiation alarms for 7e9 p/s ; **not possible to send T8 intensity** !
  - Hysteresis in the bendings
- **2021 : increased radiation levels** in **63**
  - Bad steering on one of the three cycles, beam was hitting the first quad in F61
- **SEH23 position control lost in 2021 due to mechanical issues**
  - Issue fixed in 2022
- **Optimisers**
  - Slow bumps and septa strengths, septa positions optimised with GeOFF
  - **2021 point 4** (radiations in 63) ✅ **and 5** (bump57 too strong) ✅
  - **Autospill** : PS BCT used to adjust the QSE function, then the PFW



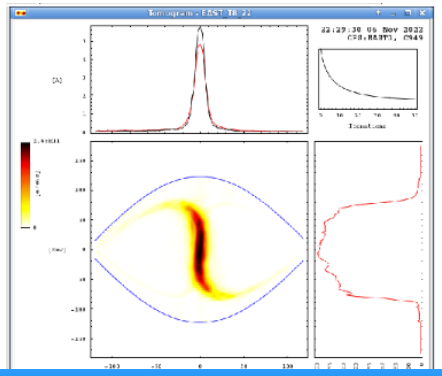
Drifts with time

- **Very nice situation reached end of april** but not so easy to maintain over time
- **Spill quality is very sensitive** (radial position/tune changes)
  - At least **: cycle to cycle stability fixed** (B-train settings problem). **2021 point 6** ✅
- Spill modified when adding the (high intensity) **parasitic TOF bunch**
  - 200 MHz blow up required, RF loops blinded : EAST bunch suffers
  - Can lead to bursts of particles before the spill, i.e. **2021 point 2 can come back**

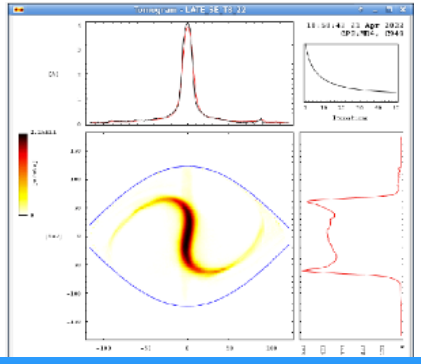




- **Longitudinal distribution** visible on the **wirescanners** (position distribution via dispersion) and the **spill** (tune distribution via chromaticity)



Nice



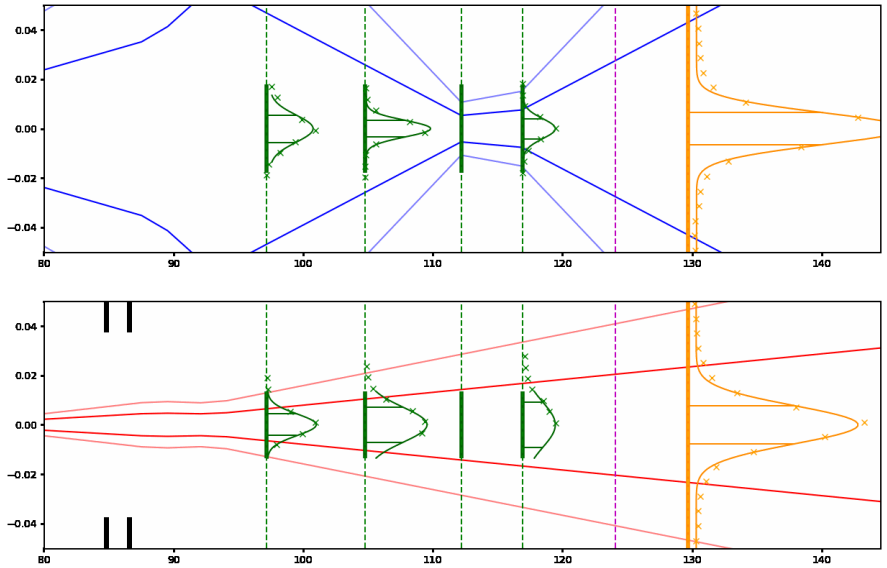
Less nice

Longitudinal degradation is certainly NOT the only source of degradation !

- Impact of **east dump** destination bendings on **trajectories**
- Trims of **radial position** without modifying the **bumps**

Transfer lines optics

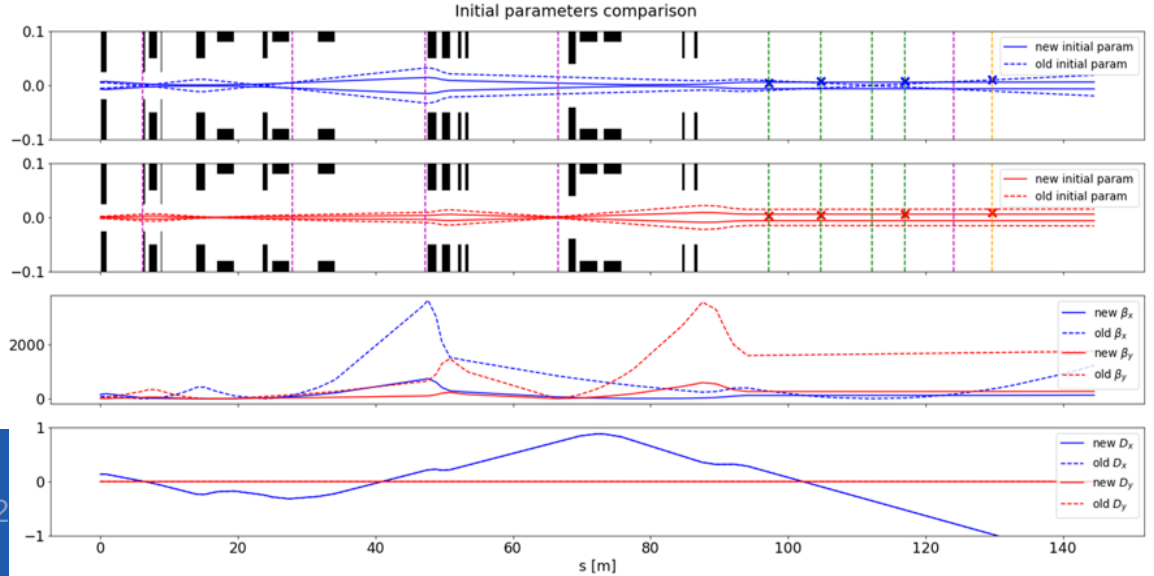
- **Complete quad scans**
  - Using filtered BTVs and MWPC
  - Measure H/V beam size and position
  - Check alignment
  - Validate model
  - Compute initial parameters
    - stray field MU62 better understood



- **New optics possible**
  - Parallel beam on irrad BPMS
  - Changes if requested

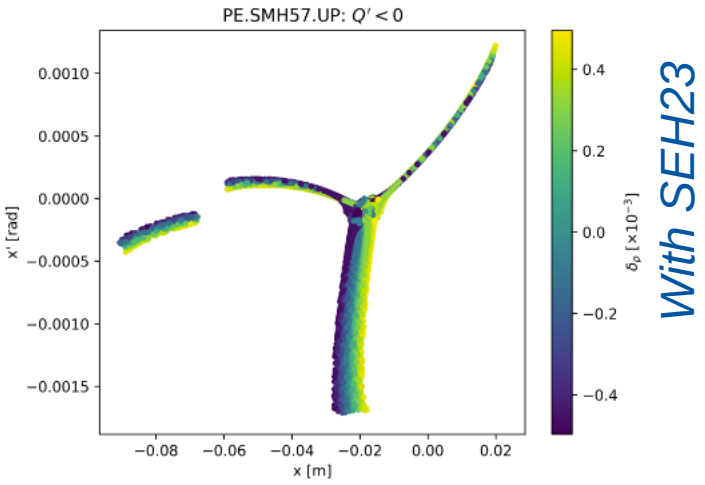
  (like in the past)

Courtesy E. P. Johnson

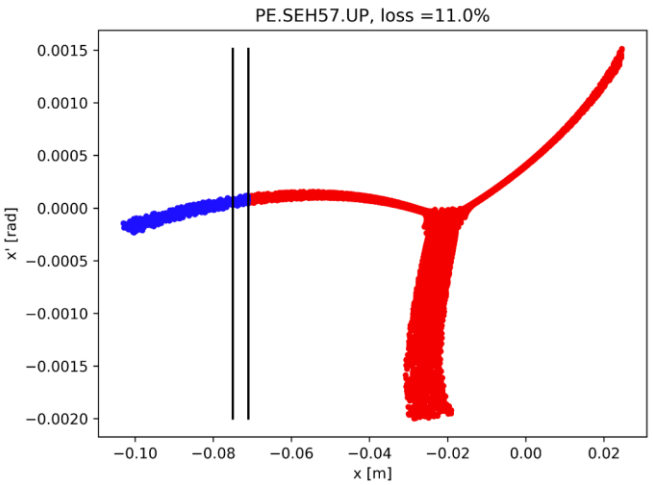


CHIMERA (ions VS protons)

- **CHARM high-energy ions for micro electronics reliability assurance**
  - Part of the collaboration between **CERN** and **ESA** for addressing the challenge of operating electronics in harsh radiation environments
- Main difficulty while using **ions** instead of **protons** : **stripping** of Pb54+
  - Impossible to pass into **thin electrostatic septum** (SEH23) and its Al foils, so **no gap at first magnetic septum**
  - Pb82+ after **stripping** by the **vacuum window** just downstream F61's first quad
  - Slow extraction and transfer feasibility already demonstrated in the past



With SEH23



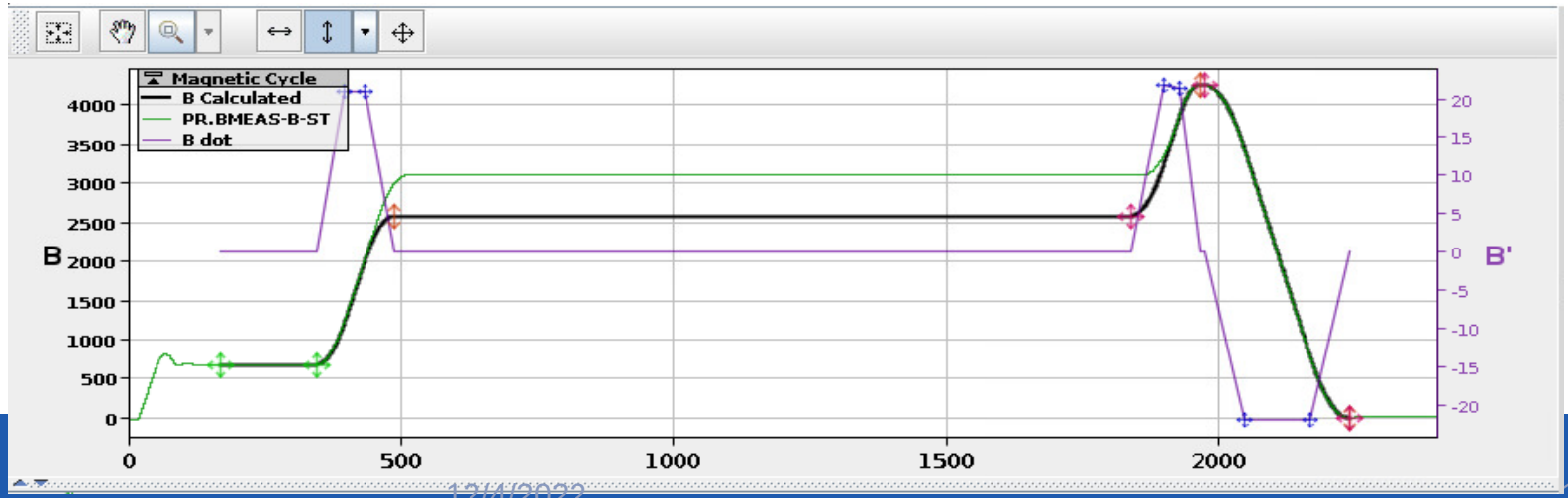
Without SEH23

CHIMERA (reducing beam energy)

- Thanks to the **east dump** we could work **in parallel** to physics
  - Tests on 5.9 GeV/n (24 GeV/c proton eq. = 11 395 G), 2 GeV/n, 1 GeV/n (3102 G), 750 MeV/n (2582 G), 650 MeV/n (2343 G)
- 2 dedicated MDs to **transfer** low energy beams to T8

- **Below transition** (around 10 400 G for ions) and **below saturation** of the MUs

  => We can avoid using the PFW
  - Operational Qh **PFW** = 6.22 VS **bare machine** Qh = 6.25
    - **Decrease** the h tune step given by **QSE**
  - Use **low energy quadrupoles** to adjust the tune
- **The PFW are the only devices which don't automatically scale with the B**



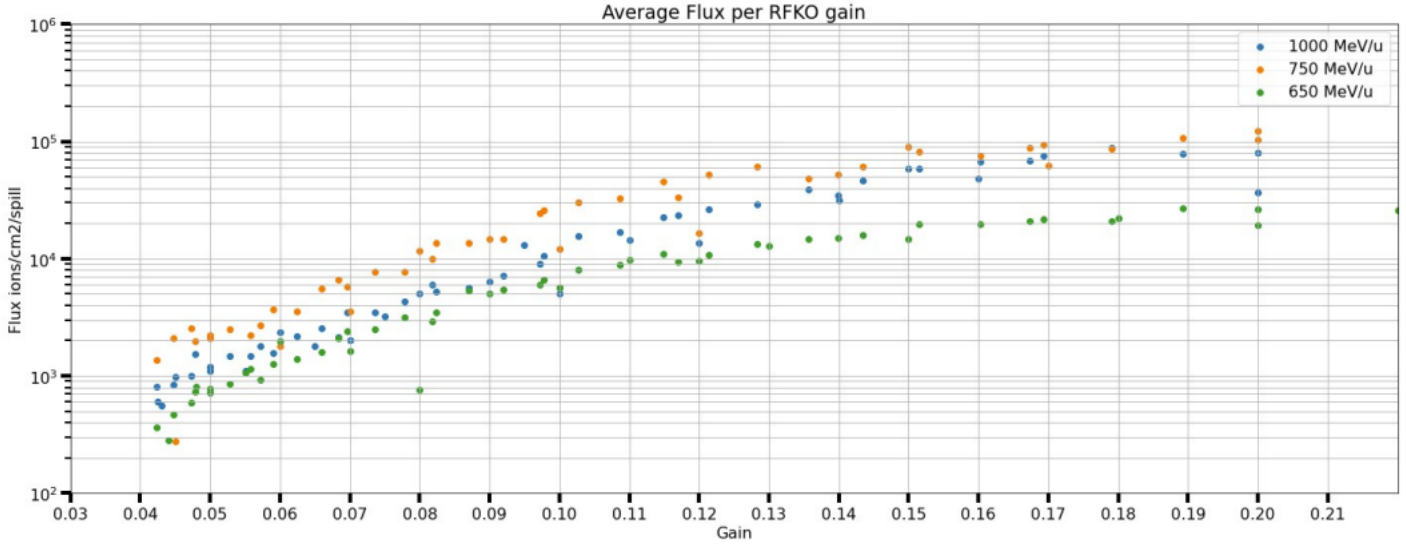
CHIMERA (reducing beam intensity)

- From a few **e10** charges in the **PS ring** to a few **e7** charges **in T8**

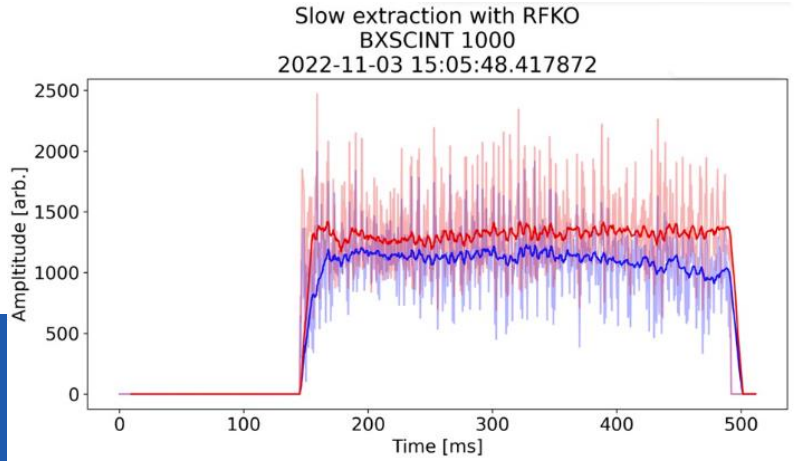
- **Tests (2022 and before)**
  - **Degrade** SX with the **tune**
  - **Scrape** the beam with (inverted) bump23
    - Gives different radial position (hence different tune via chromaticity)
  - **Works**, but **not very stable**, and **not easily controllable**

- **Excite with noise from the transverse damper (RF-Knock Out)**
  - **Static** machine (flat POPS), tune just touching the resonance
  - Use the tune measurement application to **excite** the beam with the **transverse feedback** : chirp every 1 ms for 256 turns from below to above the tune
  - Little by little the excited particles are pushed to larger **amplitude** and end on the separatrices

CHIMERA (RFKO)



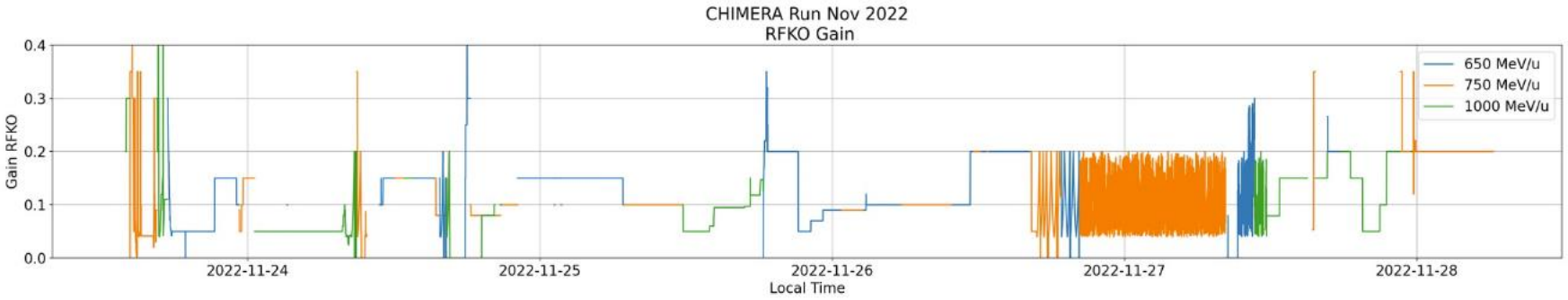
- **Stable, easy to change the flux with high precision**
  - Only **downside** : we see the TFB **frequencies** (excitation frequency but also pulse repetition rate) in the **spill**, which is nevertheless **very nice** !



Courtesy E. P. Johnson

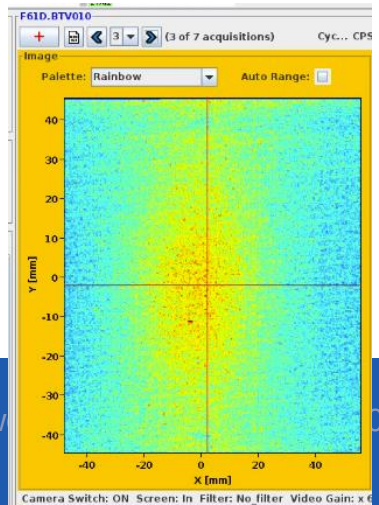
CHIMERA run (23-28/11)

- **3 energies selected to provide a wide range of linear energy transfer**



- Thanks to all the **new logical parameters** and the intensive **preparatory work,** it's just **changing the B and the transverse feedback gain**
  - Eliott Johnson even quickly provided a **script** to provide 10 spills at each of the following energies (MeV/n) : 775, 800, 825, 850, 900, 950, 1100

- **And a final test at 350 MeV/n on the East dump !**



Many thanks to R. G. Alia and K. Bilko (and the whole STI team)
Pictures courtesy E. P. Johnson

Next steps (things to improve in 2023)

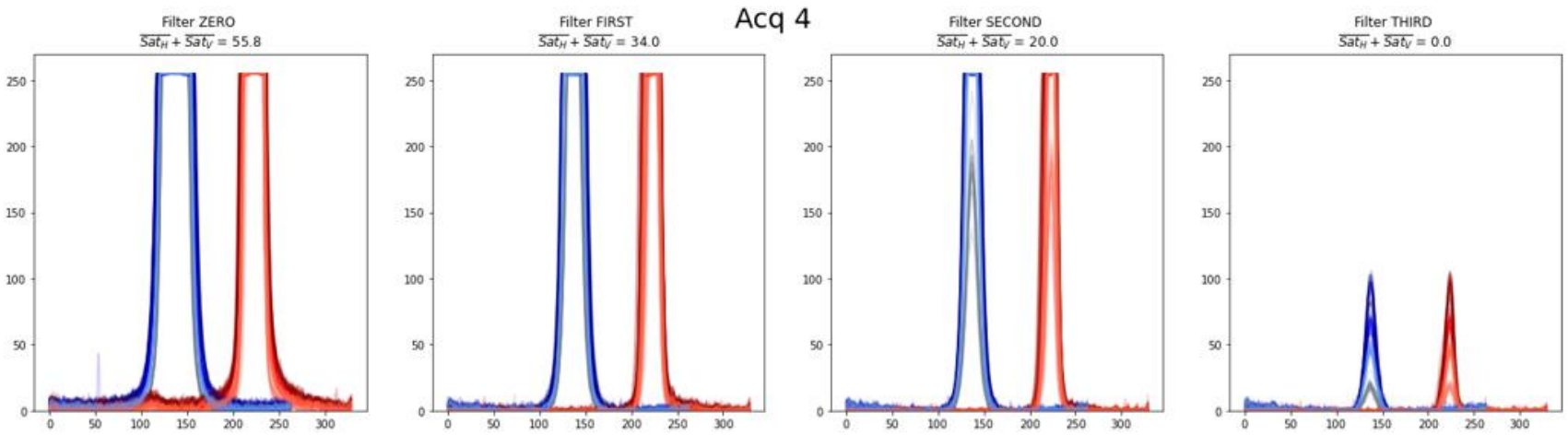
- **T8 intensity increase tests**
  - Require some coordination with users/RP
- **Longer spills at lower energy** with reduced intensity for **T9, N**
  - 20 GeV/c an obvious choice because of TOF, but we can explore other possibilities
- Keep **constant track** of the **beam position** on targets / BPMs / MWPC
- *Continue investigations on **IRRAD tails***
- *Cope with **hysteresis** effects when sending beam to **east dump** (and improve its **shielding**)*
- ***Working point studies** along the cycle, in particular the use of **W8L**, in particular if we want to **increase the parasitic TOF intensity***
- *Review **optics files and settings generation** and test Ksmooth*
- What do **experiments really need in terms of spill quality**, at what frequencies is ripple most problematic ?
  - 100 Hz (PFW), 250 Hz (POPS), frev (debunching), tune, TFB excitation ?

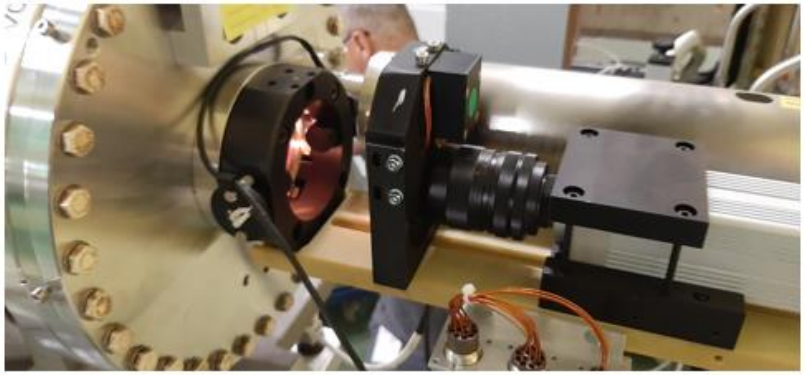
Conclusion

- **2022** was a very **successful year** for East Area beams production
  - Both for 24 GeV/c protons and CHIMERA ions
- A lot of **progress** made and **understanding gained** on the **SX**
- All the **issues** raised by Pablo in **2021** have been **addressed**, **but** :
  - Spill **quality** not so easy to **maintain** ; bursts before spill can reappear
- New **logical devices**, **optimisers**, **autospill**, **east dump** (which needs improvement), **upgraded beam instrumentation** are extremely **useful**
- **If required**, still some room for **further optimization** with some promising R&D tools / ideas in our pockets
  - SX with additional octupoles, lower horizontal emittance studies, RF changes (fill more buckets), feed-forward in power converters, empty bucket chanelling, longitudinal noise, new T8 optics…
- **OP effort** should really be now on **beam performance tracking**
  - Make sure **quality** is **maintained over time**

EXTRA SLIDES

BTVs optical filters

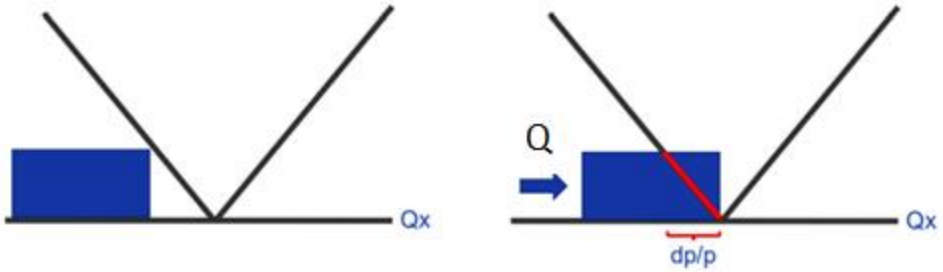




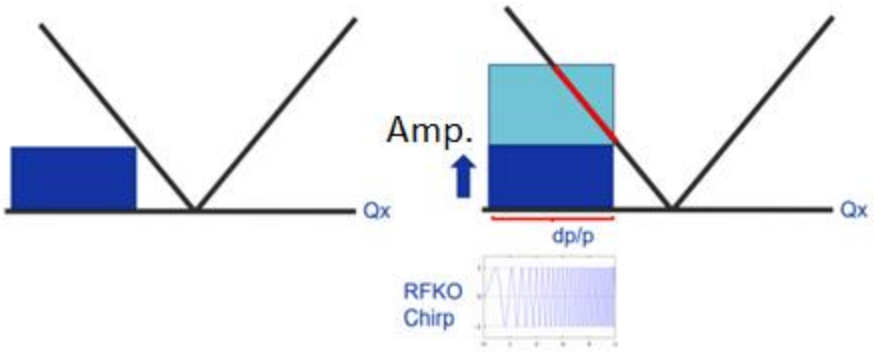
Courtesy S.Burger, E. P. Johnson

CHIMERA (RFKO)

Normal slow extraction

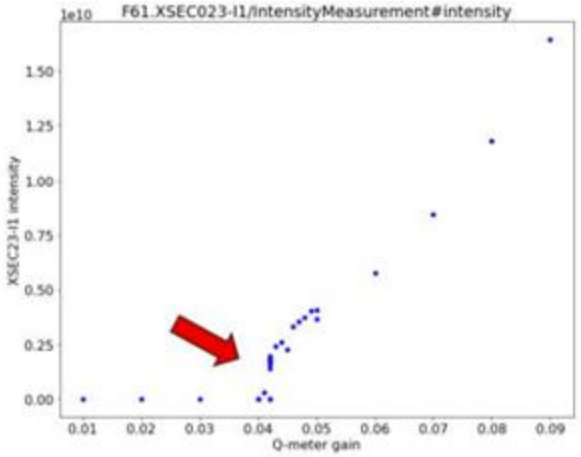


RFKO slow extraction



Gain setting used to increase/decrease the intensity of the extracted beam

Coarse gain scan



Courtesy E. P. Johnson