Starting point: IEF Workshop 2021
AD/ELENA Beam Performance Status
Main successes and pitfalls of 2022
Retrospective from 2021 to 2022 and wish list for 2023

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Main conclusions from IEFW 2021

- Beams close to design values were delivered to happy users!
- Areas that **required improvement:**
  - Consolidate/improve instrumentation: availability and **accuracy** a generic issue from FTA to AD/ELENA to LNE, e.g. BPMs in FTA line? IPM in AD? Intensity in ELENA?
  - Monitoring/logging: for detecting and promptly acting on degradation, e.g. PS extraction
  - Collect/use references: for critical systems such as s-cooling
  - Tooling: e.g. for transport optimization or for following hardware drifts
  - Reduce radiation levels: e.g. p losses in FTA, shielding of AEgIS experimental area
  - Recover pre-LS2 pbar/p yield
- **Hunting** for even **higher performance:**
  - Increase p intensity/quality in PS: coupled bunch instability in PS limited the **p intensity** to about 1500e10 p/cycle. To check if p bunch length should be reduced (or not)
  - Improve AD/ELENA deceleration efficiencies
  - Improve stability: mainly at AD target and extraction, other sources to be found
  - Improve repetition rate: AD cycle length, improve PS super-cycle composition

For details, see presentation at IEF Workshop 2021
Flash-forward: from end 2021 to end 2022
AD/ELENA Repetition Rate

- **Number of daily good pbar shots (>10% than nominal intensity) per day extracted from ELENA**
  - On average, 514 shots/day in 2021, **606 shots/day in 2022**; to be compared to target of about 650 shots/day

- **AD extraction anticipated by 10 s! but AD cycle total length reduced by ~4 s**
  - Had to wait for ELENA ejection before new AD cycle: experiments sensitive to AD magnetic field ramping up!

- **On the PS side, still some room for improvement:**
  - ~10% potential cycles lost in 2021, and ~7% in 2022 (computed over the last 60 days of operation)
  - Experiments ask also for regular repetition rate (see also Stefan’s talk)
**Overall performance:** pbar per proton on target

- Looking last ~20 days of operation for 2021 and 2022

**Warning!** In 2021 (and most of 2022) we were fooled by ~40% overestimate of beam intensity at ELENA ejection! Still uncertainties on pbar intensity measurement!

**Overall:** another excellent year for AD/ELENA with performance improvements!

- Still need to work on stability, repetition rate, and transmission…

*All ELENA eje data presented here was rescaled to match the latest calibration estimate*
How did we get there:
main successes and pitfalls of 2022 run
5 bunches operation in PSB and PS

- 5 p bunches were available at AC times, but not for AD due to conversion of PS complex for LHC
  - Limitations removed after LS2 with LIU high brightness capabilities of PSB
- Studies ignited by C. Lombard to make 5 bunches back in operation for AD
  - In PSB, it required to implement bunch splitting in R3
    - Needed to increase longitudinal blow-up to equalise emittance (as for SFTPRO)
    - Since R3 has twice the intensity, had to compensate for higher space charge effects by staying at higher injection tunes (4.43 instead of 4.34) and for much longer to equalise emittances (as for LHC)
      - Needed to make sure that the resonances overlapped are compensated
  - In PS:
    - Optimisation of the cycle to reduce losses by OP team
    - New sequence of harmonic numbers for up to 5 bunches during batch compression
      - It allows to have any number of bunches from 1 to 5 for AD
      - see H. Damerau et al. for details

Excellent work by PSB and PS colleagues, also profiting of LIU effort!
High intensity proton generation and transport

With 5th bunch unlocked the possibility to increase proton intensity (and potentially pbar) by 25%:

- Tests in the PS ensured to be able to reach up to 2.1e13
- No issues observed during p transport test to AD:
  - No major losses in FTA line
  - Minor beam size degradation on the target
- In agreement with STI colleagues, proposed to increase smoothly proton intensity above target design:
  - Plan endorsed by IEFC 7th Oct 2022 (EDMS 2783690)
  - Limited by AEgIS radiation levels!
  - Target degradation also to be expected at some point!

Excellent work by PS and ABT colleagues!
Proton transport and pbar production optimisation

- **Studies** on FTA optics and transport:
  - see Rebecca’s talk on Wednesday afternoon

- **Optimisation** of AD Target region:
  - see Tim’s talk on Wednesday morning

- **Optimisation** of DI line (Target to AD Ring):
  - Some tests done using optimiser algorithm;
    - But only **marginal success** due to **limited** number of shots/hour available and limited instrumentation
  - Still mainly work for **experienced/patient operators**:
    - We must find a way to setup this line in a way that is not based on “try and error”
  - Plans by STI and ABT colleagues to work on modelling the pbar production and DI line optics/aperture (see Tim’s talk)
  - Must plan a discussion with BI to see if new/different instrumentation could be useful.
    - See also Athanasios’s talk on Wednesday afternoon
  - **Concerns about magnets/PC aging!** see Anthony’s and Francois’s talks
AD Dipole Trim (BHZ-Trim) PC failure end of April

- EPC did not manage to get it back online
  - Old equipment, difficult to diagnose
  - See details at IEFC meeting #306
- Found a patch using all orbit correctors
  - Managed to conclude the run in this state, but we should get back to the nominal setup!

Main Quadrupoles (QMAIN)

- Several trips especially during summer time
- Interventions to improve reliability often resulted in different machine
  - (typically, different tune): not straightforward to debug

Horn power converters not able to sustaining max voltage (sparks!)

- Weakness in the design identified, but probably just a single bad cubicle.
- Issues with communication/trips being investigated

More and more urgent to think about anticipating(?) the powering consolidation?

See Francois’ talk on Thursday afternoon
Instrumentation Reliability and Accuracy

- **AD BCCCA stopped working**
  - Started the year in degraded mode
  - Had to find a workaround to make it work
  - Finally unusable in October
  - Cross-calibrated an RF signal using historical data as temporary replacement
    - Only works for bunched beam, and is not self-calibrated

- **Intensity monitor** in ELENA ejection line turned out to be wrong by ~40%!
  - We must improve! This is the primary information we provide to our users.

- **AD IPM only partially operational**
  - Still, it allowed us to see that transverse cooling at 100 MeV/c is done in 5 s instead of 15 s
  - We should get this instrument fully operational: it will be a game changer! (see also Francois’ talk)

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Horizontal beam size as a function of time while scanning on e-pbar alignment
Overview of Beam Instrumentation Improvements wrt 2021 (see also Athanasios’, Rebecca’s and Francois’ talks)

- **FTA BCT9053**: Calibration wrt other BCTs?
- **DI BCTs and BTVs**: Exploitation of noisy signal Calibration?! Triggers?!
- **FTA**: Better BTVs? BPMs? BLMs?
- **Neutrals profile monitor**
- **Replace LNR BTVs**: Mechanical problem
- **AD IPM**: Radiography planned during YETS 2023 More tests in 2023
- **AD/ELENA BPM**
  - Acquisition system issue with change of h
  - Consolidation of head amplifiers
- **DE and LNE BCTs**
  - Signal quality (RF)
  - Calibration (BI)
- **AD/ELENA scrapers**
  - Control/integration + understanding
- **BCCCA (DR.CCC1501)**
  - It must work!
- **ELENA intensity measurement**
  - along cycle missing
  - ObsBOX-RF? BPM-BI? LPU-RF?
- **Missing/broken/reliability**
  - SEM in LNE lines

**Target BTV degradation**

**Electron Cooling**

**Stochastic Cooling**

**E-cooler BPMs**
- Final e-orbit integration
Work on Machine Understanding and Documentation

- **Weekly MDs** with biweekly discussions (see wikis)
  - Investigate **hardware issues/limitations**
    - E.g. AD bunch rotation
  - LSA tools debugging
    - E.g. LLRF makerules, cycle setting management
  - Setup of new beamlines
    - Successfully sent beam to PUMA and STEP!
  - Take machine references
    - E.g. s-cooling
  - Improve performance
    - … still, mainly to follow hardware drifts

- **Improve logging** of machine performance
  - Setup of BPT page for AD/ELENA

- **Still missing** (among others)
  - Improve emittance at ELENA extraction
    - Still x2 bigger than design values
    - Very limited time invested on this
  - ELENA B-Train (operational, but not used):
    - No time, but also doesn’t seem to be a limitation

![S-cooling automatic BTF measurements](image1)

![Trombone disconnection during scans](image2)

![Emittance measurement in LNE lines](image3)
Beam Delivery to Users

- **Transport** through the LNE lines is very **stable and reproducible**
  - Only minor cabling mistakes on new lines commissioned this year: once fixed, using design optics

- **Impact of stray magnetic fields:**
  - From other experiments:
    - We would benefit from magnetic shielding of transfer lines (see François’s talk)
    - ABT effort on the modelling and possibly automatic correction (see IPAC2022)
  - From AD:
    - “wasting” ~5% of AD cycling time to wait for ELENA ejection before starting a new cycle, such as to ensure reproducible transport

- **Close collaboration with our users to respond to their needs**
  - Experiments benefit from support by CERN expertise beyond the delivery point!

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**ASACUSA2 transfer line – BSGW0546**

**Mean x position [mm]**

- CERN detectors
- GBAR’s detectors

**Measured beam size**

- horizontal, with dpp
- horizontal, without dpp
- vertical, with dpp
- vertical, without dpp
Conclusions: what we still need to work on
Areas that **required improvement:**

- **Consolidate/improve instrumentation:** Many steps done, still work to do, +BCCCA reliability must be addressed!
- **Monitoring/logging:** BPT put in place, opening the room for easier performance analysis
- **Collect/use references:** work on s-cooling ongoing, several references taken for efficient 2023 restart?!
- **Tooling:** mainly concentrating on status/diagnostics (new Vistar, Live Schottky, Inspector panels,…), still need to spend more time on “correction” (eventually feedback) tools
- **Reduce radiation levels:** plans to improve RP shielding around AEgIS
- **Recover pre-LS2 pbar/p yield:** some improvement, probably not yet there: see Tim’s talk
- **+Hardware Reliability!:** Powering!, Instrumentation!

**Hunting for even higher performance:**

- **Increase p intensity/quality in PS:** limited by radiation levels in AEgIS
- **Improve AD/ELENA deceleration efficiencies:** >80% reached, but difficult to maintain it!
- **Improve stability:** too little time available to work on this
- **Improve repetition rate (+stability):**
  - 10% AD cycle length reduction!
  - Ideally, better matching with PS super-cycle could be improved, or at least stabilized!
IEFC pending actions

- FTA line optimisation/upgrade plans to meet beam size requirements and reduce losses
  - See Rebecca’s presentation on Wednesday afternoon

- Make formal decision for keeping ELENA $H^-$ source operational
  - GBAR interested in $H^-$ beam also for complementary physics program
  - Informal-agreement to maintain the source as is for the next 2-3 years with shared responsibility ABP/OP
    - Several actions already taken to consolidate spare parts and documentation

- Investigate the possibility for ELENA to eject pbar beams at 80 keV
  - Preliminary test by OP to verify that ELENA can decelerate ($H^-$) in ring to at least 85 keV
  - No time for dedicated studies with pbar ejecting at 80 keV in the transfer lines
    - Not a high priority from experiments (optimised for 100 keV already)
Conclusions and top 3 desiderata

- Generally, another excellent year for AD/ELENA!
  - Despite several reliability issues and bad surprises
  - Thanks to determined and motivated AD/ELENA teams with invaluable support from uncountable colleagues from the PS-crew, BI, RF, EPC, MSC, …

- Short term top 3 desiderata:
  - **Reliability:**
    - Need to (or aim to) avoid working in degraded condition
    - Key ingredient if we want to profit of feedback/automation tools
    - Advancing consolidation plans? More support/time allocated from equipment owners to improve availability (e.g. PC, instrumentation, …)
  - **Stability:**
    - Studying transmission drifts and find ways to compensate/stabilize
    - It includes rep-rate, mainly from PS super-cycle composition
  - **Understanding target/injection area:**
    - Must be a joint effort STI-OP-ABT-ABP-BI

Thank you for your and attention and support!!!
Appendix
BPT Plots Selection (2022 target)

Protons on target

Pbars yield
Some other issues not covered…

- Orbit drifts on AD target: considerable drifts observed
- Beam size and proton bunch length on AD target: not studies yet
- AD ejection orbit oscillation by septa (and/or other effect?)
- Compensation of field lag in AD
- Saturation of BPMs at 100 MeV/c in AD
- Issues with AD bunch rotation control
- AD e-cooler drifts due to vacuum condition and HV sparks
- AD e-cooler HV switches problem
- Water leaks problems (DI magnets, AD e-cooler)
- AD FINEMET cavity issues
- …