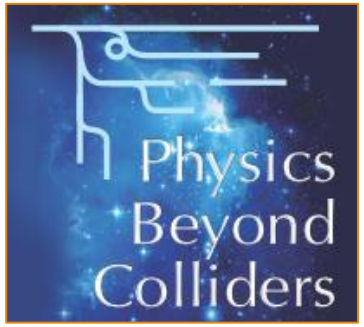
STATUS OF THE FEASIBILITY STUDIES: PB AND LIGHT ION BEAMS IN THE ACCELERATORS & EXPERIMENTAL AREA



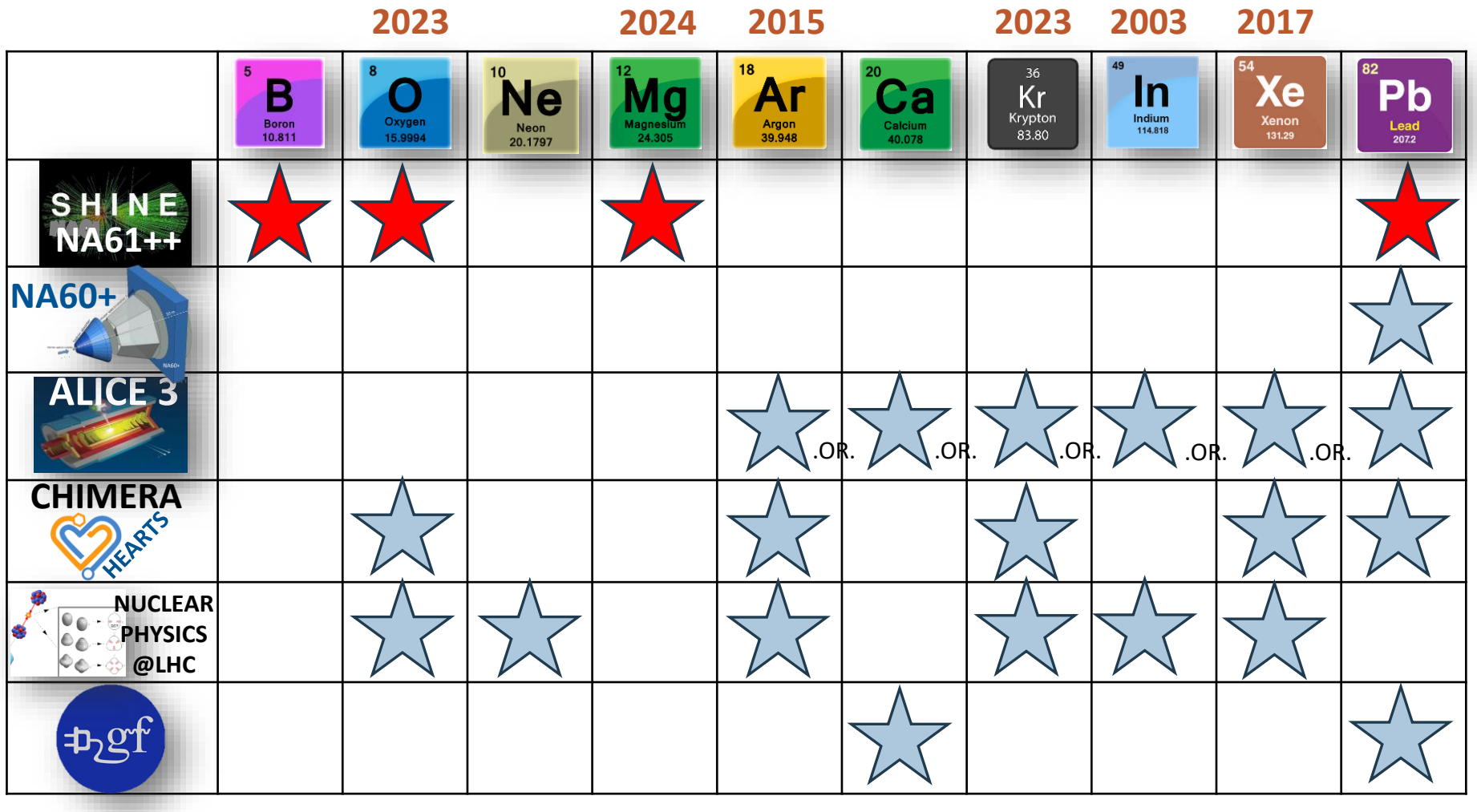
FUTURE
IONS WG

TOPICS:

- BEAM DYNAMICS
- OPERATION AT THE SOURCE
- RP STUDIES & NEW LEIR RISK ASSESSMENT
- PROTON/ION INTERLEAVED OPERATION IN EHN1
- ESTIMATES FOR PB IONS ON TARGET
- OXYGEN & MAGNESIUM TESTS

Acknowledgments: C. Ahdida, G. Arduini, P. Arrutia, H. Bartosik, J. Bernhard, S. Cettour Cave, D. Chapuis , N. Charitonidis, D. Gamba, T. Hakulinen, P. Kruyt, D. Kuchler, T. M. Lang, E. Mahner, T. Prebibaj, , R. Scrivens, M. Slupecki, F. M. Velotti, E. W. Waagaard, , M. Widorski, Linac3, LEIR, PS and SPS operation teams.

CURRENT REQUESTS AND SYNERGIES



Post-LS3

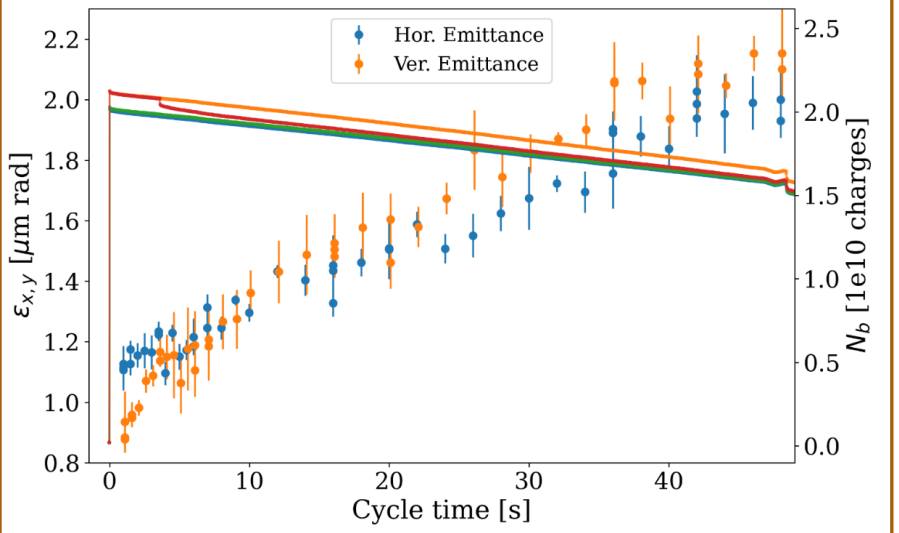
Elias Waagaard BE/ABP

Peter Kruyt BE/ABP

BEAM DYNAMICS

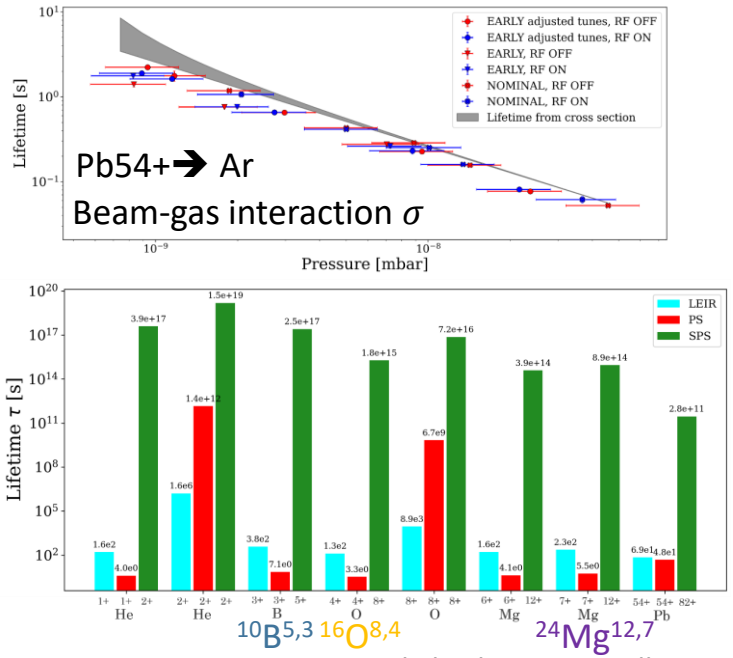
- **The challenge**: performance reach of ion beams limited by space charge (SC), intra-beam scattering (IBS), beam-gas interactions (BG) and electron cooling (EC) performance??
- **The goal: develop simulation** models; **benchmark** with data; **predict performance** for future ions

SPS studies in 2023



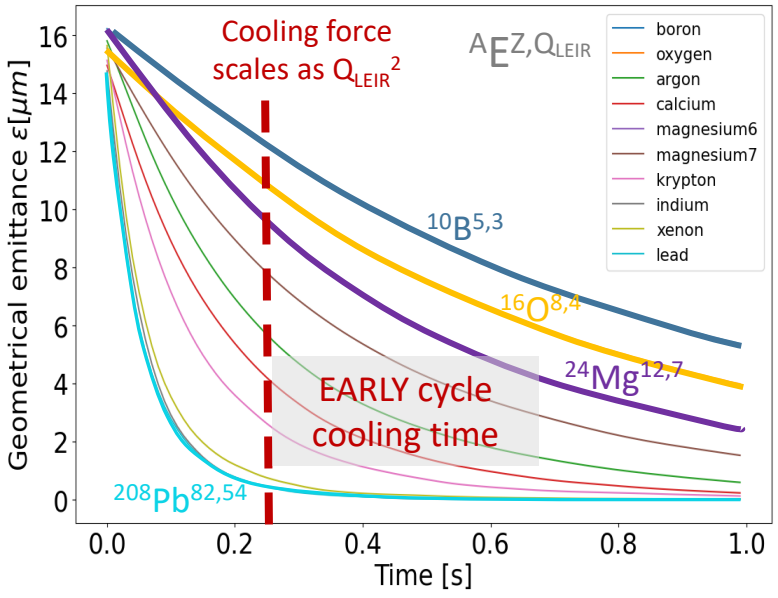
Elias Waagaard BE/ABP

PS studies in 2023



Jakob Olsen Univ Aalborg

LEIR E-cooler simulations (I_e=0.6 A)

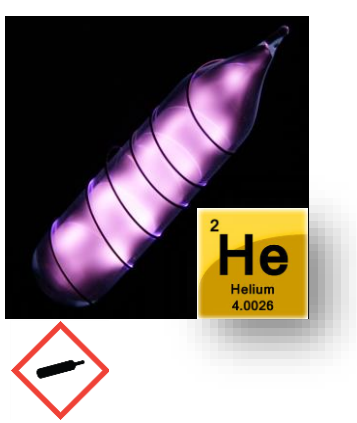


Peter Kruyt BE/ABP

BEAM DYNAMICS

- Plans for 2024:
  - Simulations:
    - Further develop tracking simulation models with SC and IBS, gradually increasing complexity and interplay of effects
    - Further develop non linear tracking with IBS kicks and e-beam SC effects in the EC simulations
    - Compare simulated intensity, emittance evolution and **EC** vs 2023 Pb&**O** data (LEIR and SPS)
  - Measurements:
    - LEIR with Mg
      - Verify space charge LIMIT
      - Study emittance evolution
    - PS with Mg
      - Study lifetime (should have shorter lifetime due to electron loss/electron capture)
    - SPS with Pb
      - Benchmark known controlled resonance excitation with tune ripple in SPS
      - Identify important resonances due to SC, use simulations to optimize working point
  - Compare updated ion performance predictions vs simplified scaling model from 2023

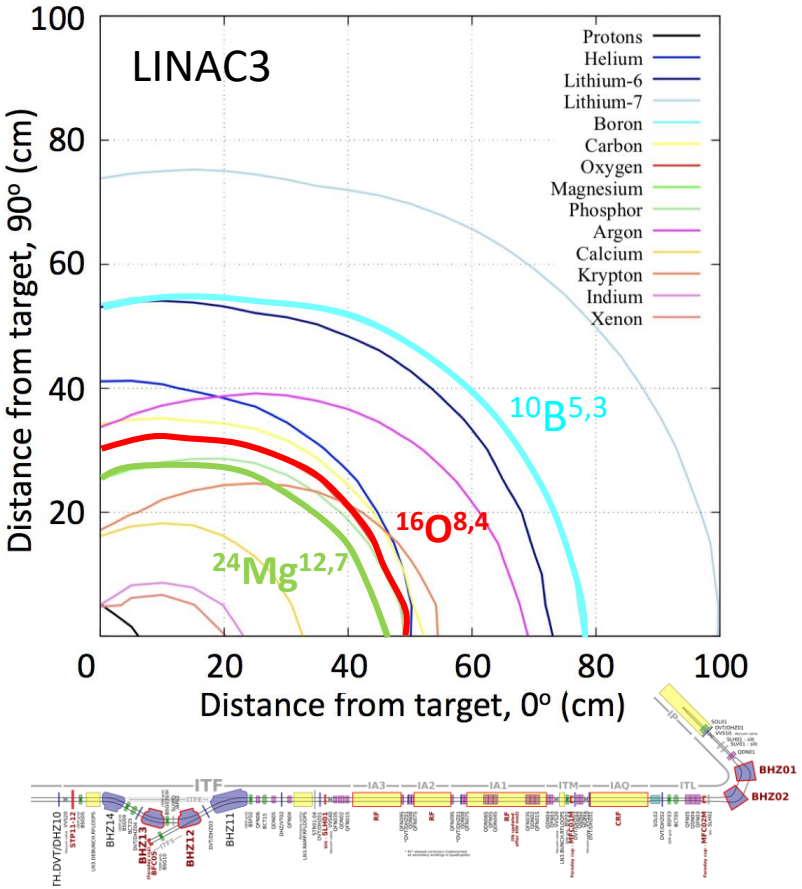
SOURCE OPERATION

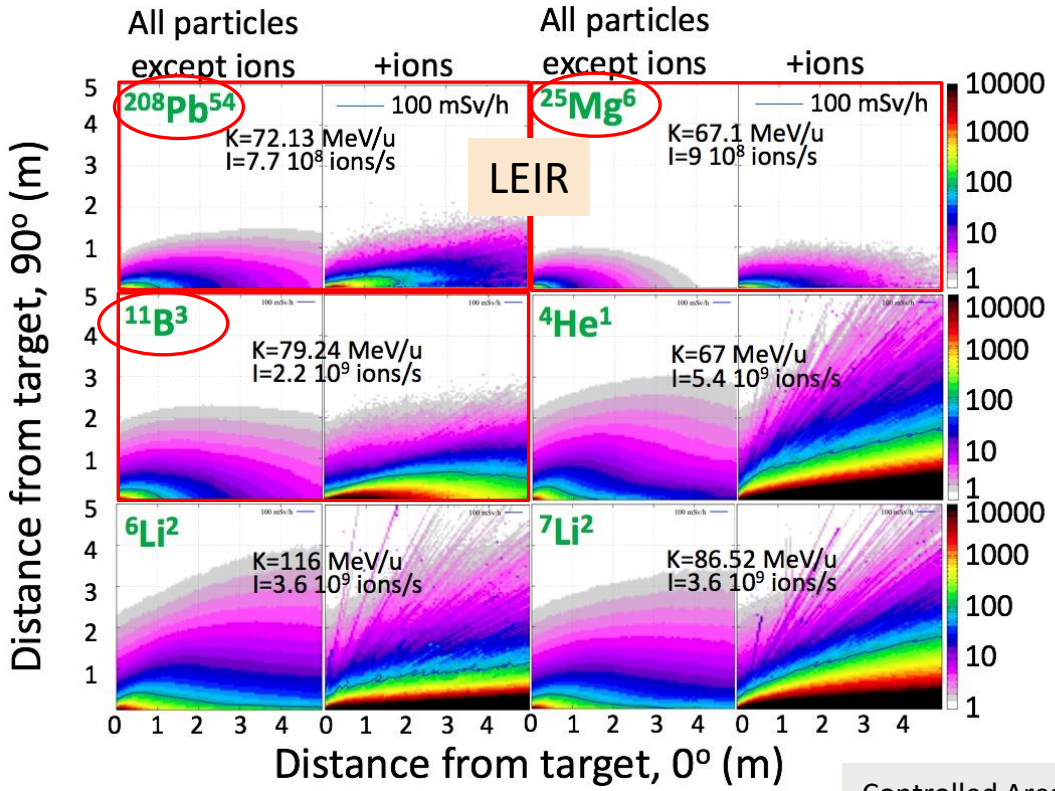


- All requested elements could be produced by the GTS-LHC ion source
- Except the noble gases all materials are linked to severe chemical hazards, proper safety procedures needed (but this is not a show stopper)
- (Lithium has an extra problem: source contamination difficult to clean ➔risk of compromising the performance of a potential subsequent Pb run)

RP STUDIES

Isodose curves 100 μSv/h K=4.2 MeV/u I=1 10^{10} ions/s





Controlled Area < 10 μSv/h
Limited Stay Area < 2 mSv/h
High Radiation Area < 100 mSv/h
Prohibited Area > 100 mSv/h

NEW LEIR RISK ASSESSMENT

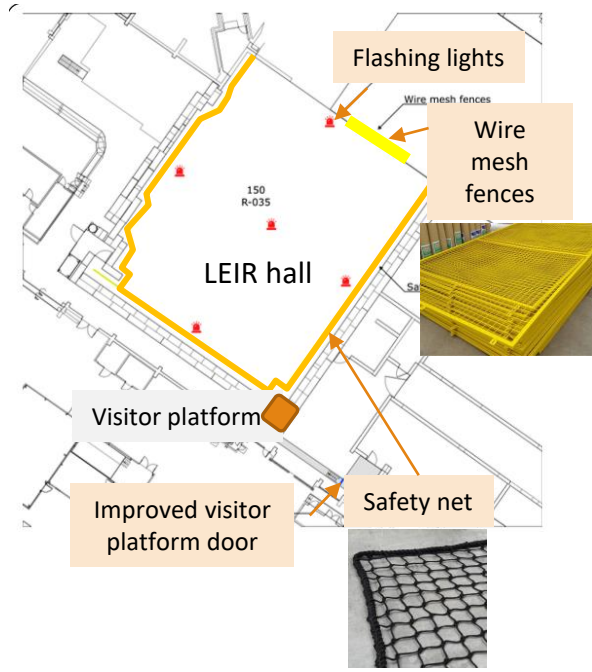
- Operation of light ions in LEIR ➔ new radiation hazards, higher ambient dose equivalent rate
- LEIR is the only primary beam area without roof
- 2 initiating events leading potentially to prompt radiation exposure not covered by current PPS:
  - Worker intrusion over the envelope shielding blocks or from PS bridge
  - Visitor intrusion from visitor platform
- Implementation of new protection measurements needed before operation of **Boron or lighter ions**

EDMS 3064955 Radiation Hazard Mitigation Measures for LEIR

New protection measurements

- 5 flashing lights inside LEIR
- Wire mesh fences @PS bridge
- Safety net around LEIR hall
- Improved visitor platform door

Budget ~ 40 kCHF

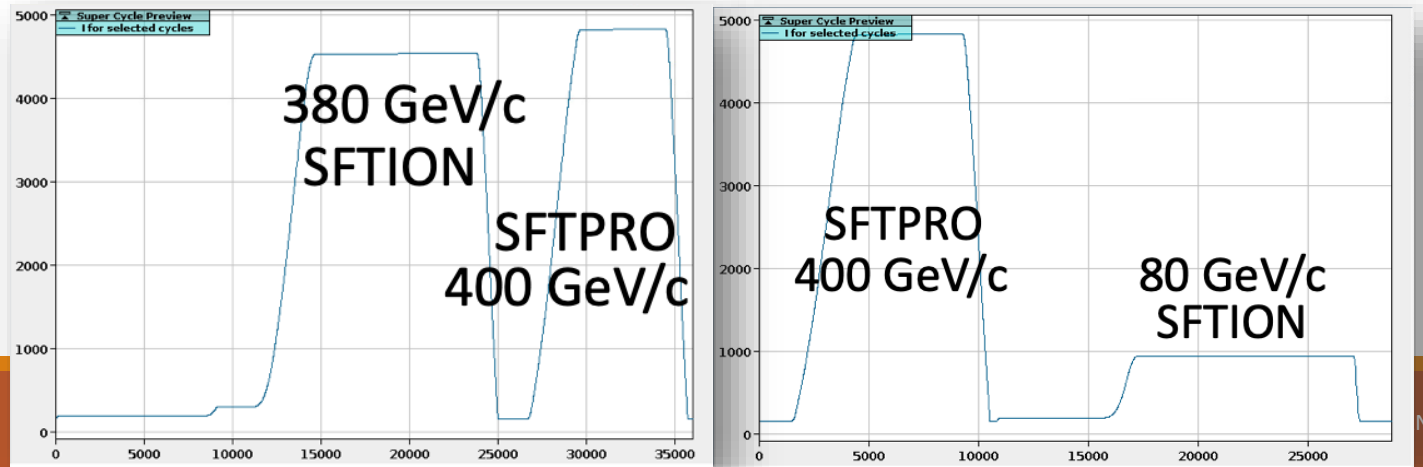


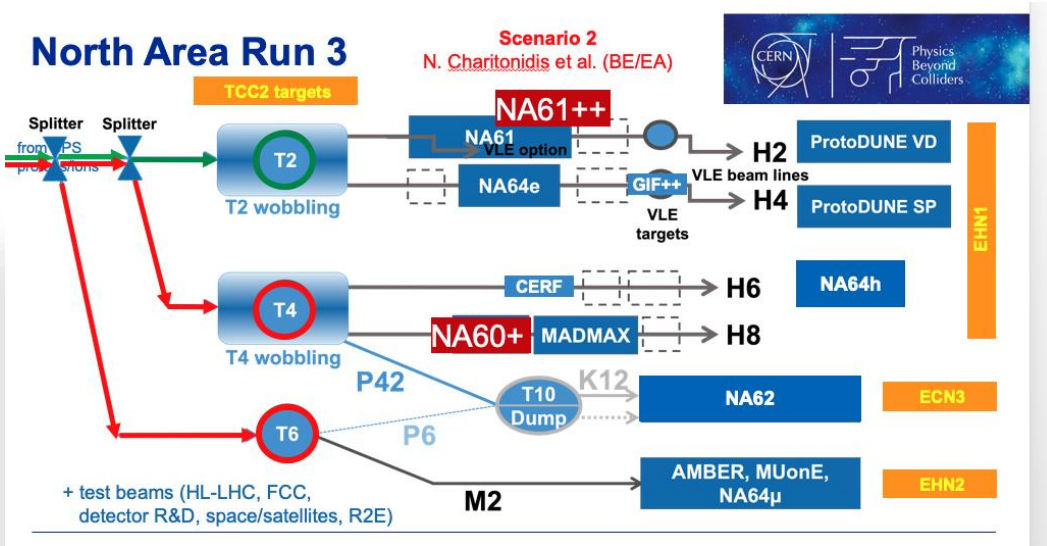
PPS: Personnel Protection System

PROTON/ION INTERLEAVED OPERATION IN EHN1

- Competing requests of light ions (NA61++) and Pb (NA60+) in Run 4 together with p+ users
- One possibility could be interleaved operation of p+ and ions ➔
- SFTPRO & SFTION cycles in the same super-cycle
- At splitter 2: ion beam through field free region and proton beam through field region. NO splitter upgrade needed
- This options involves tight collaboration with BE/OP, EN/AA, HSE/RP, SY/ABT, BE/EA, BE/APB

MAY	JUN	JUL	AUG	SEP	OCT
MIXED	PURE	PURE	PURE	PURE	PURE
p, **Mg**	p	p	p	p	**Pb**
p users NA61++	p users	p users	p users	p users	NA61++ NA60+





PROTON/ION INTERLEAVED OPERATION IN EHN1

- The **p+** and **ion** beam vertical separation at the splitter 2 position is of the order of **around 2 mm**
- Intrinsic beam trajectory **uncertainty ➔ few mm(*) ➔** prevents mm control level at the splitter
- Therefore, it could be possible that the **primary proton beam** or at least part of it, can go through the field free region **towards H2&H4 halls ➔ direct exposure to ionization radiation ➔** How to prevent this?

- **Add an absorber or dump after the splitter** in TT23, similar to what is foreseen for P42 Transfer Line Dump
- **T2 target cannot be used ➔** not dimension to fully absorb a high intensity p+ beam and is in out position for ion primary beam physics
- **Add a trajectory bump** ion beam circumvents the new dump, while p+ go straight to the new dump
- Needs (at least) a **proper personnel access system to EHN1 areas ➔** **foreseen for LS4 nevertheless (NA CONS)**
- This new mode of operation may invalidate or re-design the following two existing interlocks:
  - The LOCKN interlock
  - The NA Ion interlock

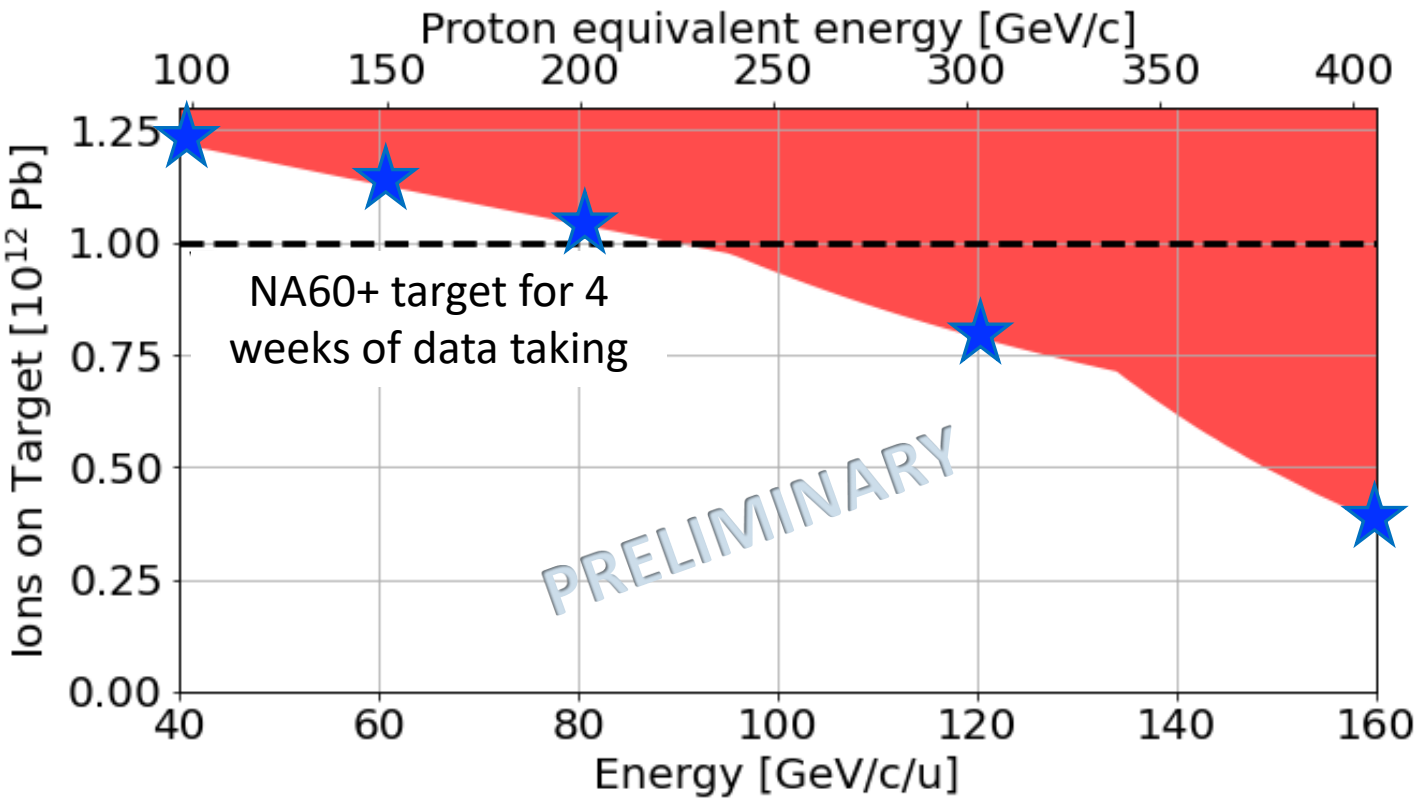
- Conclusion:
  - p+ / ion interleave operation wont be possible until after-LS4
  - For Run 4 beam time arbitration will be needed

(*) due to **magnetic irreproducibility** in the mains and results in **uncertainties** on the **trajectories** through TT20

Tirsi Prebibaj BE/ABP
Hannes Bartosik BE/ABP

ESTIMATES FOR Pb ON TARGET FOR NA60+

- Studies on SPS operation & expected performance for future NA experiments considering accelerator capabilities & other ion users.
- Example of Ions on Target estimates for NA60+ using Pb at different energies (preliminary) over a 4-week period.



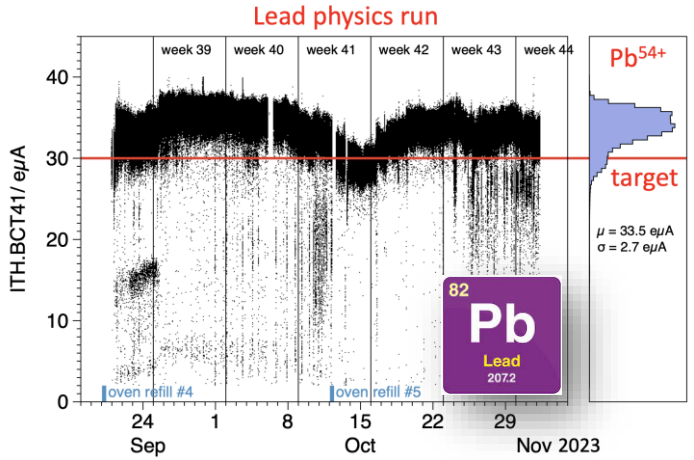
(Preliminary as it assumes extrapolation to lower energies assuming the same shielding setup as for 160 GeV/c)

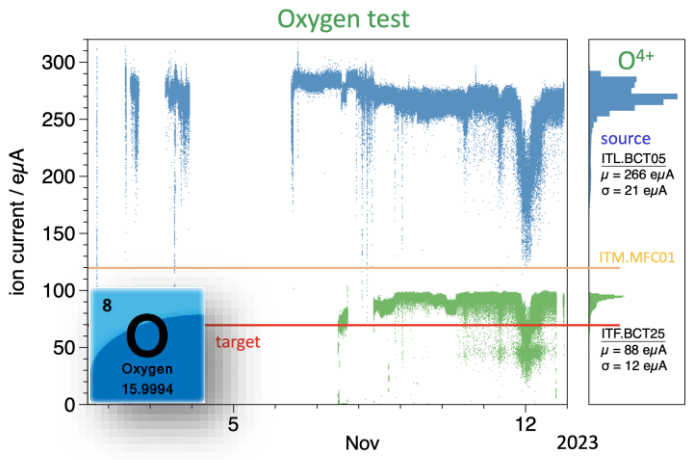
LINAC3 team BE/ABP
LEIR team BE/ABP&OP
PS team BE/OP

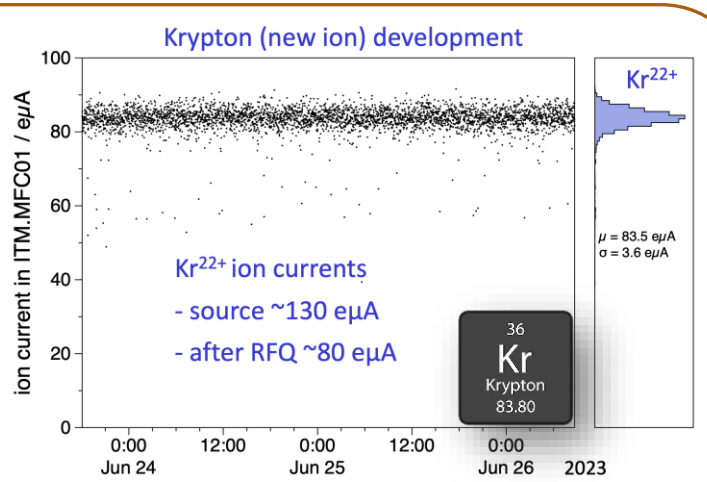
STUDIES FOR FUTURE IONS

2023

For the first time **three species** produced in the **same year**!







2024

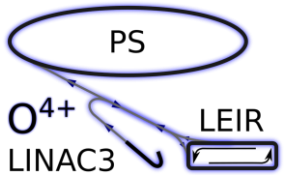
2025

LINAC3 team BE/ABP
LEIR team BE/ABP&OP
PS team BE/OP

OXYGEN TEST RUN IN 2023

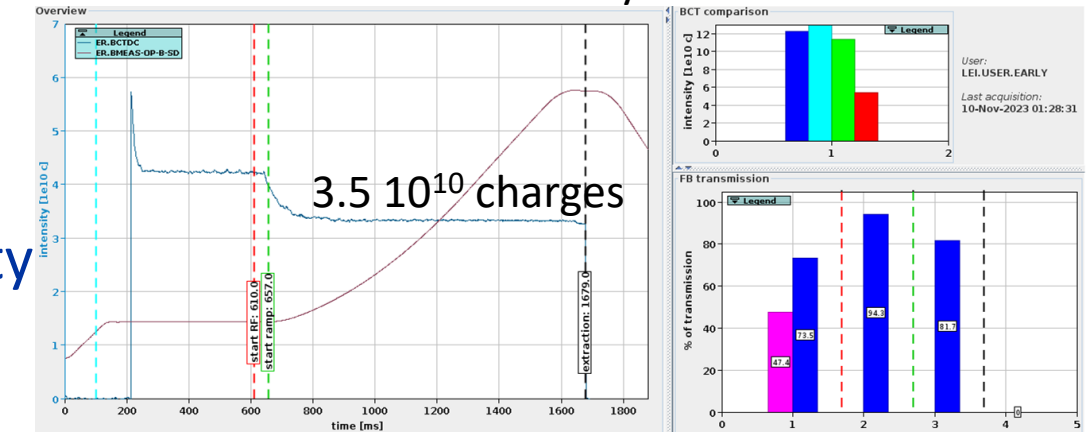
Very successful test

We managed to get **far beyond** the initial plans in just 8 days



- Linac3: 5 days
  - Delivering 120% of expected beam intensity
- Transfer line from Linac3 to LEIR
  - Threading in 2 hours
- LEIR: 2 days
  - Extracting 85% of required intensity for 2024
- PS:1 day
  - Full cycle tested at 30% beam intensity

LEIR EARLY cycle



✓ No major bottleneck was identified

OXY4LHC - test beam results:
https://indico.cern.ch/event/1347387/

PREPARATION OF MG TEST

- Test finally approved by IEFC 9th of February
- Schedule approved
- Mg^{7+} & Mg^{11+} as options as charge state in LEIR
- Both approved by RP

- Measurements:
  - **Assess beam performance for NA61++ (EARLY cycle)**
  - **Beam characterization**
  - **RP measurements**
  - **Reach space charge limit**
  - **Beam lifetime**
  - **E-cooling**

Mg beam to PS!!

Reference	ABP & OP (23.01.2024) agreed (EM, TA)	
Date	Minimum L3 Magnesium programme	
week 12	L3 source start	
week 13	L3 tests Magnesium	
week 14	L3 tests Magnesium	
week 15	L3 tests Magnesium	
week 16	L3 tests Magnesium	
week 17	L3 tests Magnesium	
week 18	L3 tests Magnesium	
week 19	L3 tests Magnesium **AND**	Magnesium Ions to LEIR
week 20	L3 tests Magnesium **AND**	Magnesium Ions to LEIR
week 21	source maintenance	
week 22	source maintenance	
week 23	source comm. Pb	
week 24	source comm. Pb	
week 25	source comm. Pb	
week 26	source comm. Pb	
week 27	source comm. Pb	
week 28	source comm. Pb	
week 29	optical spectroscopy	
week 30	optical spectroscopy	
week 31	Pb Ions to LEIR	

Schedule by Edgar Mahner BE/ABP

CONCLUSIONS

➔ feasibility of NA61++ and NA60+ requests

- 

@ source; chemical hazards to be mitigated by proper safety procedures
- Operation of light ions **in LEIR** ➔ **new radiation hazards** ➔ to be mitigated by **new personnel protection** elements recommended by the **New LEIR Risk Assessment** **before operation of Boron or lighter ions**
- Working on improving our understanding of **beam dynamics effects** to be able to better predict performance across the complex
- But beam intensities out of the source and data to benchmark simulations need tests:
  - 2023: Kr, O, Pb
  - **2024: Mg**, Pb
  - 2025: O, Pb
  - We hope to be able to test Boron in LS3
- Ions on target for NA60+ ➔ **for E<90 GeV/c/u**, above ➔ 4 weeks is very tight
- NA61++, NA60+ and proton users will bring **important challenges in terms of beam time arbitration**

SPARES

ESTIMATES FOR Pb ON TARGET FOR NA60+

- Assumption: RP average < 5 10^5 Pb/s @ 160 GeV/u/c
- NA60+ (preliminary) request: 1 10^6 Pb/spill @ 160 GeV/u/c and 1.5 10^6 Pb/spill @ 40 GeV/u/c
- Flat top limit to 25 s below @ 90 GeV/u/c, otherwise 9 s
- SPS inter-spill time 16 s @ 160 GeV/u/c and 12 s @ 40 GeV/u/c
- SPS and MSNs @NA max power consumption included in the calculations
- Time sharing: ~50% over 4-week run (includes other SPS users and machine availability).