

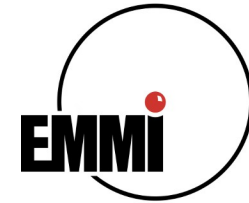
New Ion Collisions @ LHC Run 4 – Community input and roadmap

Reyes Alemany Fernandez and Giuliano Giacalone



September 25, 2026

... in collaboration with the LPCC HI WG conveners



**UNIVERSITÄT
HEIDELBERG**
ZUKUNFT
SEIT 1386

New Ion Collisions @ LHC Run 4

Monday Mar 16, 2026, 3:00 PM → 5:00 PM Europe/Zurich

<https://indico.cern.ch/event/1655628/>



call_for_inputs.pdf

video_recording.t...



There are minutes attached to this event. [Show them.](#)

3:00 PM → 3:20 PM **Introduction to the LPCC H**

Speaker: Alice Ohlson (Lund Uni)

HIWGintro.pdf

3:20 PM → 4:00 PM **Introduction to New Ions C**

Speaker: Giuliano Giacalone

NewIons_pres.pdf

4:00 PM → 5:00 PM **Q&A**

Speakers: Giuliano Giacalone,

- **Initiative with the aim of collecting input about science cases for ion runs that could complement the planned Pb program in LHC Run 4**
- Cases have significant impact on hot QCD thanks to “size scan of QGP features”
At the same time a strong impact on neighboring field(s)
- Cases have clear methodology to yield breakthroughs and “money plots”
- Cases do not assume that a second ion injector will be available in Run 4 (however comment on how the second injector enhances science output)
- Cases are cross-community efforts [heavy-ion theory + experiment (LHC), nuclear structure theory+experiment (ISOLDE), linking possibly to EIC and fixed-target experiments such as NA61++, NA60+, LHCb SMOG]
- Cases are viable and fully developed: ion species, lumi requirements, how they could fit in Run 4, experimental projections, theory predictions
- **Everything will go into a White Paper (target spring 2029)**

Approximately 25 contributions received ... Thanks!

Attached document ...

https://indico.cern.ch/event/1697777/attachments/3293074/5950976/Summary_NewIons@LHC4.pdf

Synthesis of all submissions

Submitted topic	Most relevant species	Key observables	How it enters the recommendation
Onset of collectivity and jet quenching	^4He - ^4He , ^6Li - ^6Li , ^{10}B - ^{10}B , ^{16}O - ^{16}O , ^{12}C - ^{12}C	R_{AA} , high- p_T v_n , flow ratios, R_{AA}/R_{pA}^2	Supports high-statistics O-O and motivates He-He as a QGP frontier case
Thermal radiation and pre-equilibrium dileptons	^{16}O - ^{16}O and other light ions	Intermediate-mass dilepton yields, slopes, polarization, Drell-Yan separation	Supports high-statistics light-ion running and motivates a system-size optimization study
Net-proton cumulants and chiral criticality	^{16}O - ^{16}O primary; ^{40}Ar - ^{40}Ar secondary	κ_4/κ_2 , κ_6/κ_2 , acceptance scans	Quantitative driver for high O-O statistics
Λ polarization	^{16}O - ^{16}O ; possible p-O reference	$P_{s,2}$, $P_s(p_T)$, event-shape dependence	Supports high-statistics O-O
Molière scattering and jet substructure	^{16}O - ^{16}O ; possible Ar/Kr/lighter ions	Soft Drop R_g , EECs, large-angle jet correlations	Quantitative driver for high-statistics O-O and selected system-size points
Charm and heavy flavor	^{10}B - ^{10}B , ^{16}O - ^{16}O , ^{20}Ne - ^{20}Ne , Ar-like systems	D -meson R_{AA} and v_n , DD correlations, Λ_c/D^0 , multi-charm baryons	Supports light-ion luminosity and small/intermediate-size options
$n\alpha$ -cluster scan	^4He - ^4He , ^{12}C - ^{12}C , ^{24}Mg - ^{24}Mg	Flow ratios, higher-order correlations, p_T fluctuations, femtoscopy	Supports He-He, prefers C-C, and motivates a short Mg-Mg sample
Carbon geometry in UPCs	^{12}C - ^{12}C	Coherent/incoherent vector-meson photoproduction, rapidity and t -distributions	Strengthens C-C over B-B as the intermediate light-ion choice
W production and strange nPDF	Isoscalar He, Li, B, ^{40}Ca - ^{40}Ca , high-stat O-O	$\sigma_{W^+} - \sigma_{W^-}$, W^+/W^- , rapidity dependence	Supports isoscalar choices and strengthens ^{40}Ca - ^{40}Ca if ^{48}Ca - ^{48}Ca is not feasible
Light-ion nPDF via asymmetric UPCs	^{16}O + Pb, ^4He + Pb, ^{129}Xe + Pb	Photonuclear jets, D^0 , forward neutrons	Strong conditional case requiring second injector
3D QGP and heavy flavor	^{40}Ar - ^{40}Ar or lighter; SMOG2 gases Ar/Kr/Xe	$dN/d\eta$, $v_1(\eta)$, $v_2(\eta)$, charm/beauty/quarkonia	Supports $A \simeq 40$ with good luminosity
Flavor equilibration	$A \sim 40$ -80, e.g. Ar/Kr/Ca/Ge	Identified yields and flow, especially Ω , ϕ , strange hadrons	Supports at least one intermediate-size run with high-statistics soft-sector data

Submitted topic	Most relevant species	Key observables	How it enters the recommendation
Neutron skin and baryon stopping	^{16}O - ^{16}O baseline; ^{48}Ca - ^{48}Ca , ^{40}Ca - ^{40}Ca , Sn/Xe/Ba extensions	Conserved-charge ratios, central/peripheral double ratios, flow/spectator observables	Strong motivation for ^{48}Ca - ^{48}Ca or ^{40}Ca - ^{40}Ca around $A \simeq 40$
Gluon saturation in UPCs	^{16}O - ^{16}O , ^{40}Ar - ^{40}Ar , ^{86}Kr - ^{86}Kr	Coherent vector meson cross sections for ρ , ϕ , J/ψ , $\psi(2S)$, Υ	Supports system-size scan
Intermittency and multifractality	Xe-Xe, O-O/Ne-Ne, $A \sim 10$ -40	Normalized factorial moments, intermittency exponents, fractal dimensions	Supports high-statistics samples and broad system-size coverage
$0\nu\beta\beta$ NME: ^{76}Ge	^{76}Ge - ^{76}Ge ; ideal ^{76}Se - ^{76}Se comparison with second source	Flow cumulants, deformation, radius/skin, Bayesian structure constraints	Main reason to prefer Ge over generic Kr
$0\nu\beta\beta$ NME: ^{136}Xe	^{136}Xe - ^{136}Xe ; ^{136}Ba - ^{136}Ba comparison	$^{136}\text{Xe}/^{129}\text{Xe}$ and $^{136}\text{Xe}/^{136}\text{Ba}$ ratios	Main reason to add Ba before Xe
Coherent photoproduction with overlap	^{238}U - ^{238}U	Centrality-dependent coherent J/ψ and $\psi(2S)$ photoproduction	Specialized high- Z opportunity
ALP searches in UPCs	^{16}O - ^{16}O primary	Displaced $a \rightarrow \gamma\gamma, \ell^+\ell^-$, non-pointing photons, late conversions	Additional motivation for high-statistics low-background O-O UPC data
ISOLDE program	All considered species	To be delineated with the relevant community	Synergy across CERN, energy scales and infrastructures

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Synthesis of all submissions

Submitted topic	Most relevant species	1 Oxygen QGP program and the Helium frontier		Submitted topic	2 System scan	How it enters the recommendation	
Onset of collectivity and jet quenching	^4He – ^4He , ^6Li – ^6Li , ^{10}B – ^{10}B , ^{16}O – ^{16}O , ^{12}C – ^{12}C			Neutron skin and baryon stopping	^{40}O – ^{40}O baseline; ^{48}Ca – ^{48}Ca , ^{40}Ca – ^{40}Ca , $\text{Sn}/\text{Xe}/\text{Pb}$	Conserved-charge ratios, central/peripheral double ratios	Strong motivation for ^{48}Ca – ^{48}Ca or ^{40}Ca – ^{40}Ca around $A \simeq 40$
Thermal radiation and pre-equilibrium dileptons	^{16}O – ^{16}O and other light ions	Intermediate-mass dilepton yields, slopes, selection. The LHC4 program is motivated by the need for high-statistics data in the intermediate-mass region.	Supports high-statistics light-ion running and selection.				
Net-proton cumulants and chiral criticality							
Λ polarization							n-size scan
Molière scattering and jet substructure							statistics load average
Charm and heavy flavor							prefer Ge over
$n\alpha$ -cluster states							add Ba before
Carbon geometry in UPCs							n-Z
W production and strange nPDF							ivation for low-background
Light-ion nPDF via asymmetric UPCs							
3D QGP and heavy flavor							CERN, energy structures
Flavor equilibration							
		strange hadrons	high-statistics soft-sector data				

Summary of contributions received

The input received from the community highlights the interest in a controlled scan in ion size, from very small systems to intermediate and heavier nuclei, to clarify the onset and evolution of QGP-like phenomena (jet quenching, collective flow, strangeness production), nuclear modifications of parton distributions, and sensitivity to nuclear structure. The requests essentially split into two categories.

1 – Oxygen: Around 40% of the contributions received propose a high-statistics ^{16}O – ^{16}O run, that we recommend to supplement by a ^4He – ^4He run.

2 – System scan: Beyond this, the science cases highlight (i) intermediate light-ion runs with ^{12}C – ^{12}C and ^{24}Mg – ^{24}Mg in synergy with the SPS NA61/SHINE proposal; (ii) a calcium run ($A \simeq 40$) with preference for ^{48}Ca – ^{48}Ca ; (iii) a germanium run ($A \simeq 80$) with preference for ^{76}Ge – ^{76}Ge , and (iv) a xenon-region program featuring ^{136}Ba – ^{136}Ba collisions.

Comment on Beam Time: While **Case 1** definitely requires a high-statistics run, many of the science goals of the size scan in **Case 2** could be achieved via short opportunistic runs.

Approximately 25 contributions received ... Thanks!

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https://indico.cern.ch/event/1697777/attachments/3293074/5950976/Summary_Newlons@LHC4.pdf

Synthesis of all submissions

Oxygen QGP program and the Helium frontier

Submitted topic 1

Most relevant species: ^4He – ^4He , ^6Li – ^6Li , ^{10}B – ^{10}B , ^{16}O – ^{16}O , ^{12}C – ^{12}C

Onset of collectivity and jet quenching

Thermal radiation and pre-equilibrium dileptons

Net-proton cumulants and chiral criticality

A polarized medium

Molière scattering and jet substructure

Charm and heavy flavor

$n\alpha$ -cluster states

Carbon geometry in UPCs

W production and strange nPDF

Light-ion nPDF via asymmetric UPCs

3D QGP and heavy flavor

Flavor equilibration

System scan

Submitted topic 2

How it enters the recommendation

Neutron skin and baryon stopping

^{16}O – ^{16}O baseline, Conserved-charge ratios, central/peripheral double ratios

^{48}Ca – ^{48}Ca , ^{40}Ca – ^{40}Ca , $\text{Sv}/(\text{X}_0/\text{P}_{\text{ch}}$

Strong motivation for ^{48}Ca – ^{48}Ca or ^{40}Ca – ^{40}Ca around $A \simeq 40$

Summary of contributions received

The input received from the community highlights the interest in a controlled scan in ion size, from very small systems to intermediate and heavier nuclei, to clarify the onset and evolution of QGP-like nuclear modifications of hadron production, which is essentially split into two cases:

- 1 – Oxygen:** Around $A \simeq 16$, that we recommend for Run 5
- 2 – System scan:** From $A \simeq 40$ to $A \simeq 200$, with ^{12}C – ^{12}C and ^{24}Mg – ^{24}Mg for Run 5, and ^{76}Ge – ^{76}Ge for Run 6

Comment on Beam Energy: The science goals of the size scan in Case 2 could be achieved via short opportunistic runs.



Not discussed here

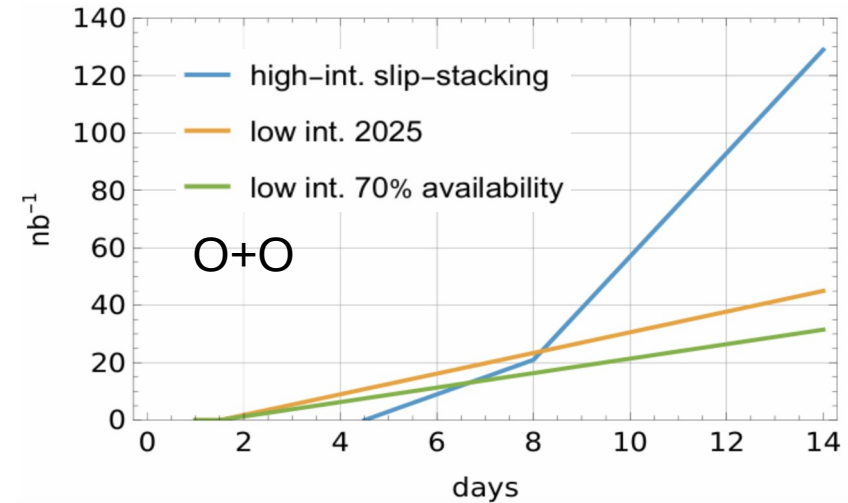
- Cases requiring a second source
- Cases requiring month-long runs

Could be rediscussed for Run 5

Oxygen QGP (precision) program

Many cases pointed out:

- Pre-equilibrium dileptons;
- Precise heavy-flavor measurements at forward rapidity;
- EW-boson production measurements in isoscalar nuclei;
- Strange hadron equilibration;
- Studies of Λ polarization and Λ - $\bar{\Lambda}$ correlations;
- Higher-order net-proton cumulants;
- Revealing the particulate nature of QGP via jet substructure;
- Heavy flavor program in light-ion collisions.



[Pablos, Sambataro, Kudinoor, Belin ...]

Main question – May require O(2 weeks) beam time to get x10 current statistics

Detailed requested luminosities should now be estimated

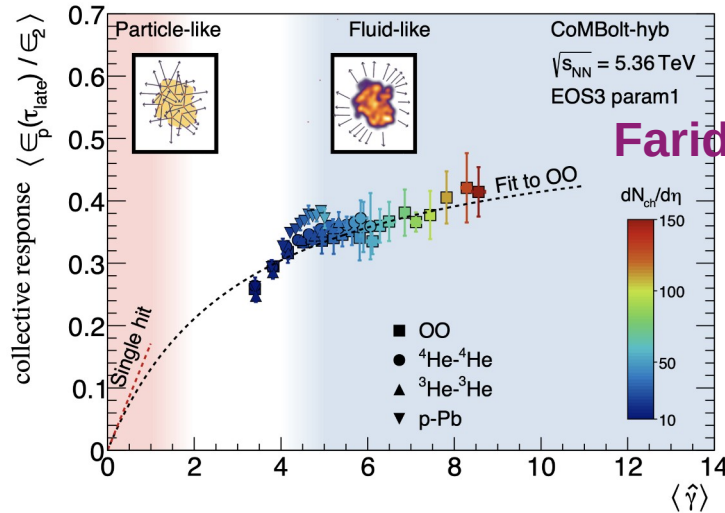
The Helium frontier – Soft and hard cases

1

Deviations from hydrodynamic predictions should be taken serious in the search for indications of breakdown of standard model of HICs

Soeren Schlichting

- if necessary need to go even smaller (e.g. He+He)



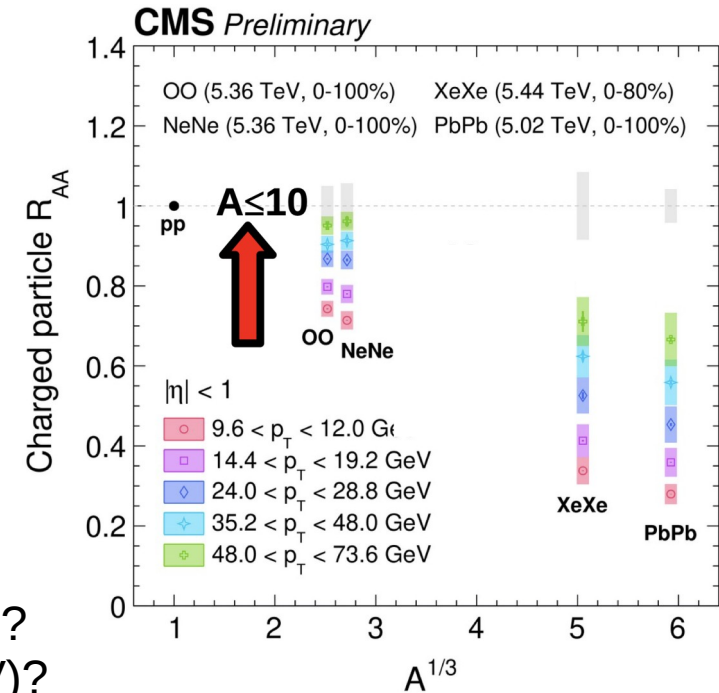
Farid Taghavi

2 Expand A dependence of R_{AA}

The nPDF dilemma:

(i) is lithium-6 more favorable? (Cole Faraday)

(ii) shall we have as well p+He collisions (after p+Pb)?
or extrapolate from p+He from SMOG2 (~100GeV)?



System Scan I – Clustered nuclei and synergy with SPS program

Core opportunity

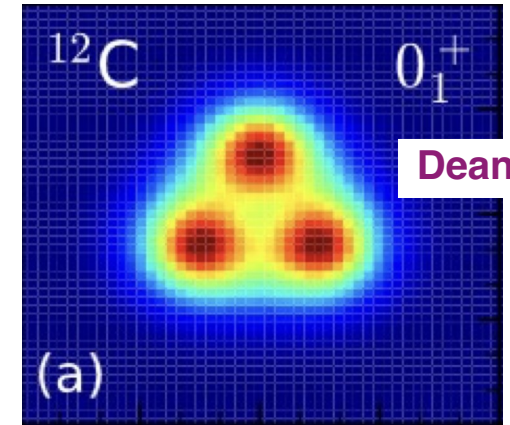
After oxygen and helium, there is interest in other light nuclear systems. Preferred intermediate light ions appear to be ^{12}C – ^{12}C and ^{24}Mg – ^{24}Mg . They offer broad physics opportunities, combining QGP onset, transition from α -cluster structures to deformation, UPC vector-meson photoproduction, and charm/nuclear-geometry studies. These science cases could be fulfilled opportunistically with short runs of such nuclei, in synergy with the physics programme proposed by the NA61/SHINE collaboration at the SPS for Run 4. This allows the accelerator sector to serve a broad physics community with one and the same beam-preparation effort.

$^{12}\text{C} + ^{12}\text{C}$	$^{16}\text{O} + ^{16}\text{O}$	$^{24}\text{Mg} + ^{24}\text{Mg}$
$\text{C} + \text{C}$	$\text{O} + \text{O}$	$\text{Mg} + \text{Mg}$
$A = 12 + A = 12$	$A = 16 + A = 16$	$A = 24 + A = 24$
$Z = 6 + Z = 6$	$Z = 8 + Z = 8$	$Z = 12 + Z = 12$
$N = Z$ ($N = 6, Z = 6$)	$N = Z$ ($N = 8, Z = 8$)	$N = Z$ ($N = 12, Z = 12$)

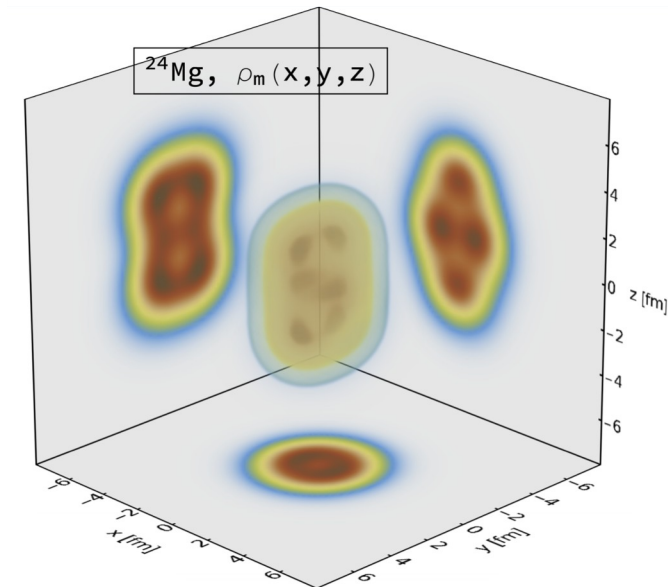
Isospin symmetric systems ($N = Z$)
— ideal for a clean isospin test

Maja Maćkowiak-Pawłowska
Olga Bessidskaia-Bylund

Short opportunistic runs when nuclei run in SPS



Dean Lee

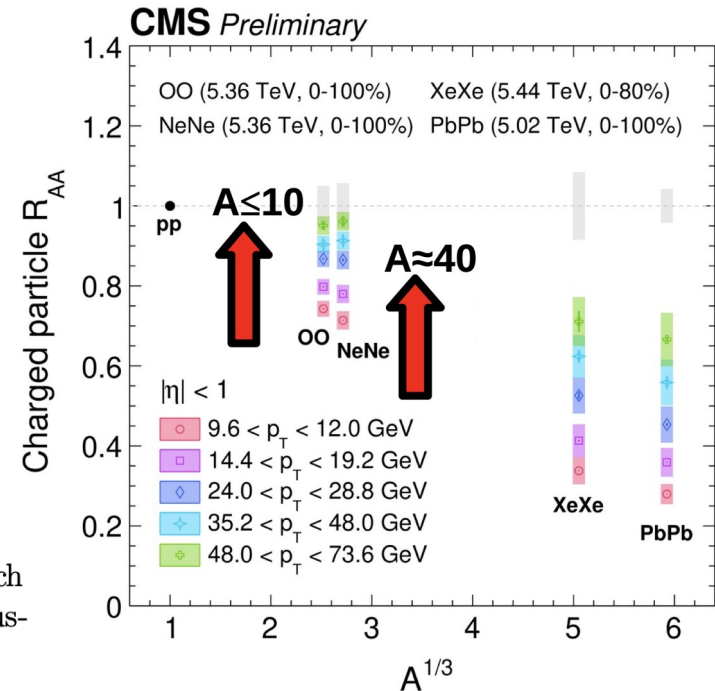
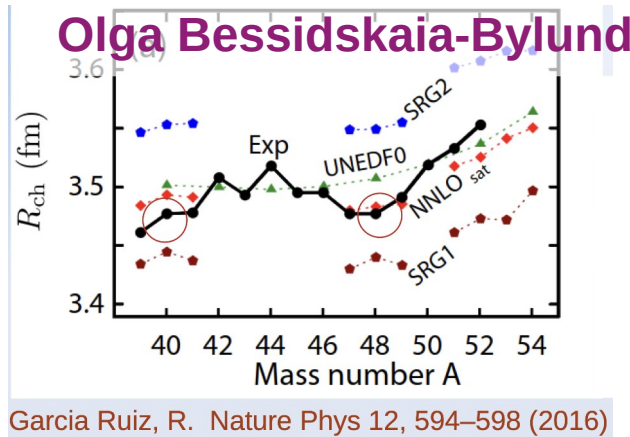
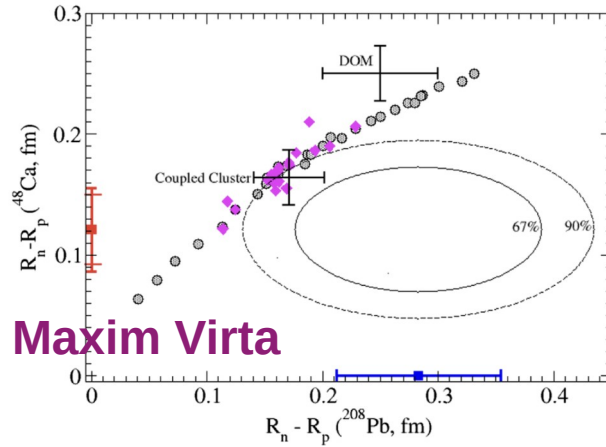


System Scan II – The omnipotent Calcium (A~40)

Core opportunity

The $A \simeq 40$ region is strongly motivated by the system-size evolution of QGP phenomena. The preferred collider system is $^{48}\text{Ca}-^{48}\text{Ca}$ because it probes this dependence while adding a high-impact neutron-skin/EOS connection. Otherwise, $^{40}\text{Ca}-^{40}\text{Ca}$ remains more compelling than a generic $^{40}\text{Ar}-^{40}\text{Ar}$ choice for an isoscalar and nuclear-structure-controlled scan.

Scrutinizing PREX-CREX dilemma at LHC – Understanding isotopic chain dependence of radii/collectivity



Q: Can we get 40-44-48Ca ? ... Maximizing impact

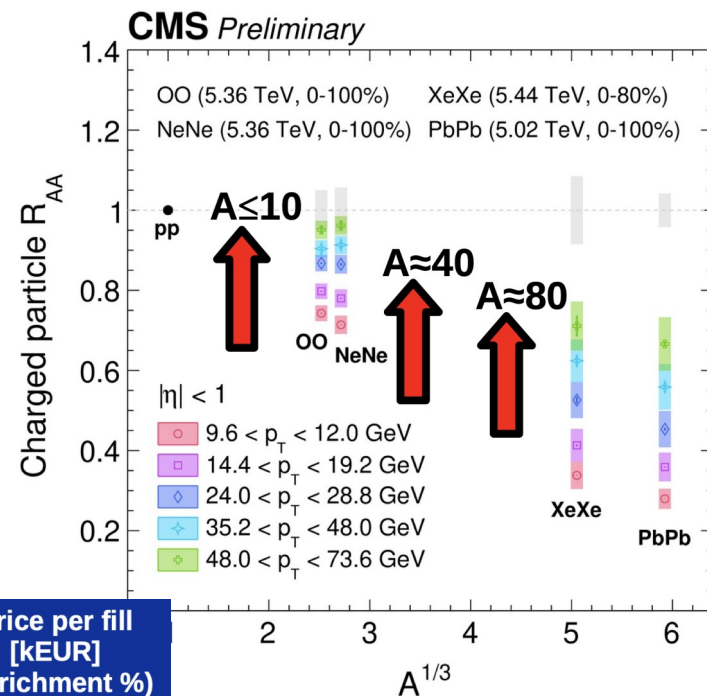
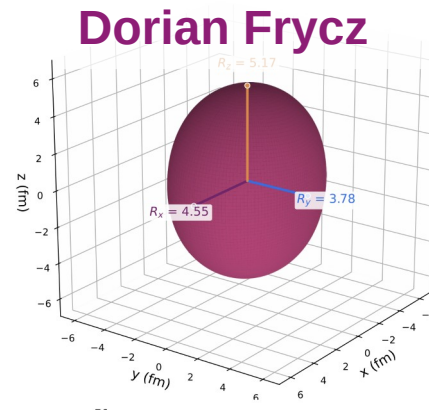
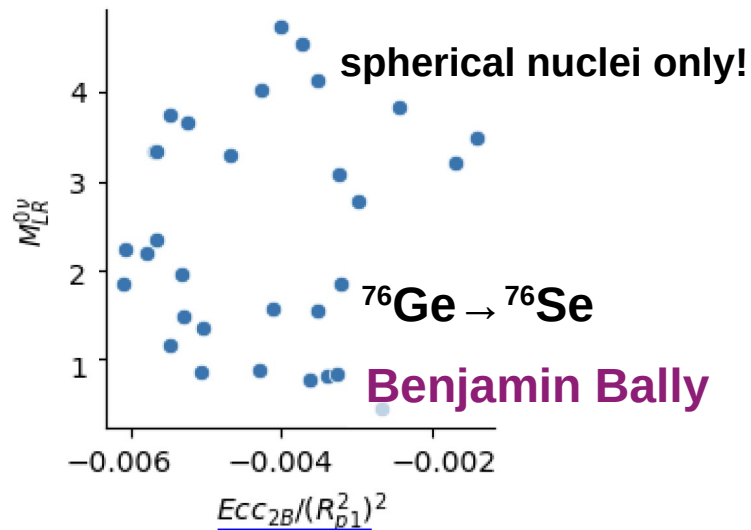
Electroweak probes and strangeness in isoscalar nuclei. In isoscalar-nuclei collisions such as $^{40}\text{Ca}-^{40}\text{Ca}$ collisions, the $W^+ - W^-$ difference becomes directly sensitive to the strange-minus-charm content of nuclei. $^{40}\text{Ca}-^{40}\text{Ca}$ represents the endpoint of the isoscalar chain.

System Scan III – The annoying nuclear matrix elements (A~80, A~136)

Jordy de Vries

Endpoint of the system size scan

Toward ab-initio-driven correlations between flow and NMEs (^{76}Ge)



Ion	Baseline form / compound	Delivery method	Main challenges	Estimated oven sample lifetime* [days]	Price per fill [kEUR] (enrichment %)
^{76}Ge	GeO_2	Micro-oven	High T Deposition on the plasma chamber walls	10	7 (96%)
^{76}Se	metallic	Low-T reservoir & heated transfer pipe	Too volatile $\rightarrow$ parasitic plasma heating Condensation in transfer pipes	12	12 (98%)
^{136}Ba	$\text{Ba}(\text{NO}_3)_2 + \text{Al}$	Sputtering	Extreme reactivity No mature micro-oven design No beam production experience worldwide	8**	5 (95%)

not feasible in Run4?

New Ion Collisions @ LHC Run 4 - Call for Abstracts

31 October 2026
Europe/Zurich timezone

<https://indico.cern.ch/event/1697777/>

Overview

Call for Abstracts

EMMI Workshop on Light
Ion Collisions 2026

We would like to warmly thank all colleagues who contributed to the first call for community input on New Ion Collisions @ LHC Run 4 (<https://indico.cern.ch/event/1655628/>). The response was very positive and underscored broad community interest in the initiative.

We recall that the approved ion program for LHC Run 4 currently comprises p -Pb and Pb-Pb collisions (see e.g. [CERN-2019-007](https://cds.cern.ch/record/2619007)). From the inputs received, we identified compelling physics cases for collisions with additional ion species that merit further development and that, should the opportunity

Abstract =
a few sentences
giving idea/prospective
calculations and goals

Helpful to gauge
size of White Paper

Anyone interested in joining
the effort can be included

Here are more details about the call for abstracts and the next phases of this initiative:

- **The deadline for abstract submission is October 31, 2026.** We will take a first glance at the progress of the submissions in a dedicated discussion session at the EMMI Workshop on Light Ion Collisions 2026 (<https://indico.gsi.de/event/25022/>).
- **After the deadline, we will open, on this Indico page, a call for contributions to the White Paper.** These will be short publication-level contributions that will be part of the final manuscript.
- **The planned deadline for these contributions will be October 31, 2028 --> We leave two years for the realization of the prospective physics studies.** After that, we will gather the material and proceed to the write-up of the White Paper.

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the realization o**
proceed to the wr
- Abstract submission (by Oct 31st)
 - We remain open to new suggestions beyond the four selected tracks ... just get in touch!
 - Looking forward to your contributions and to the White Paper (done by $\approx$ spring 2029)



Multidisciplinary exchanges in workshops are very valuable. The idea of adding Neon after the Oxygen run emerged during a cross-disciplinary workshop in November 2024 involving theoretical, experimental, and accelerator physicists — a good demonstration that bottom-up initiatives can work



Finding ways to reach agreement more efficiently on which ion species to collide and when, could be a valuable lever for more effective future planning

Otherwise makes harder for the machine to move forward in a well-defined direction



We hope the White Paper initiative offers an efficient path forward



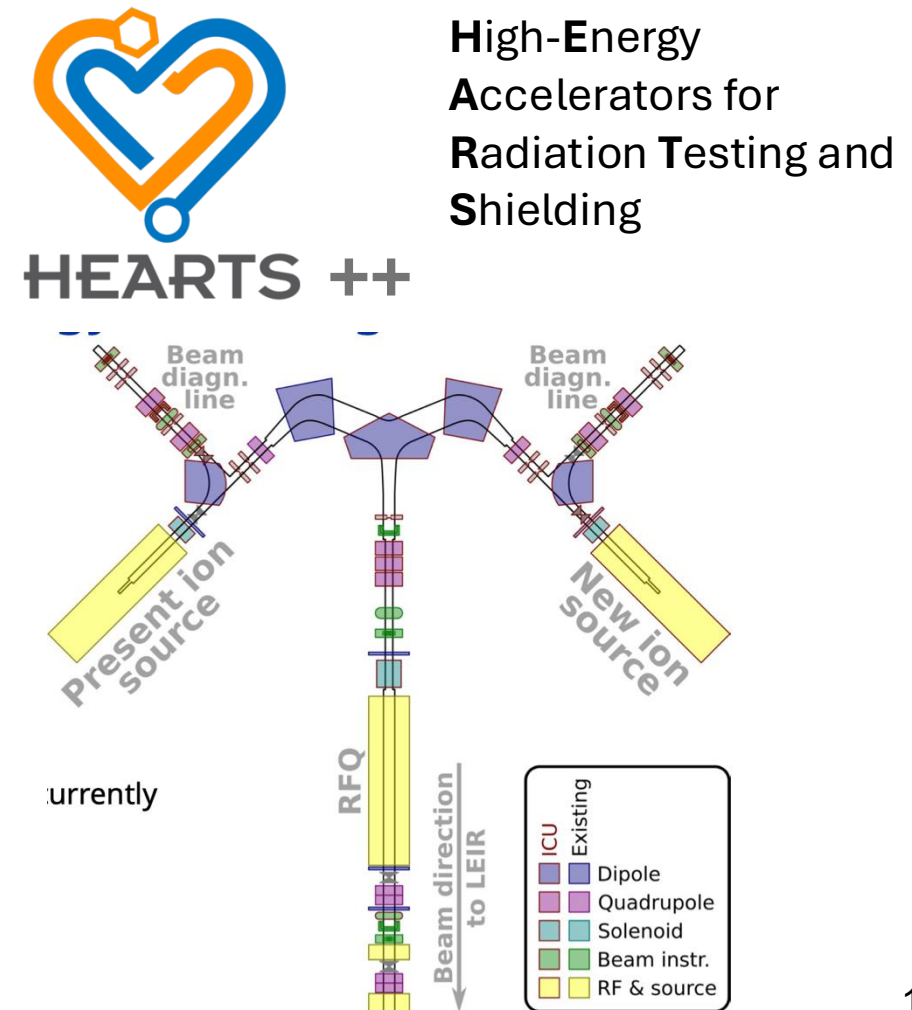
We want to bridge all possible energy scales: nuclear physics, SPS energies, SMOG energies, EIC, LHC energies and astroparticle energies.

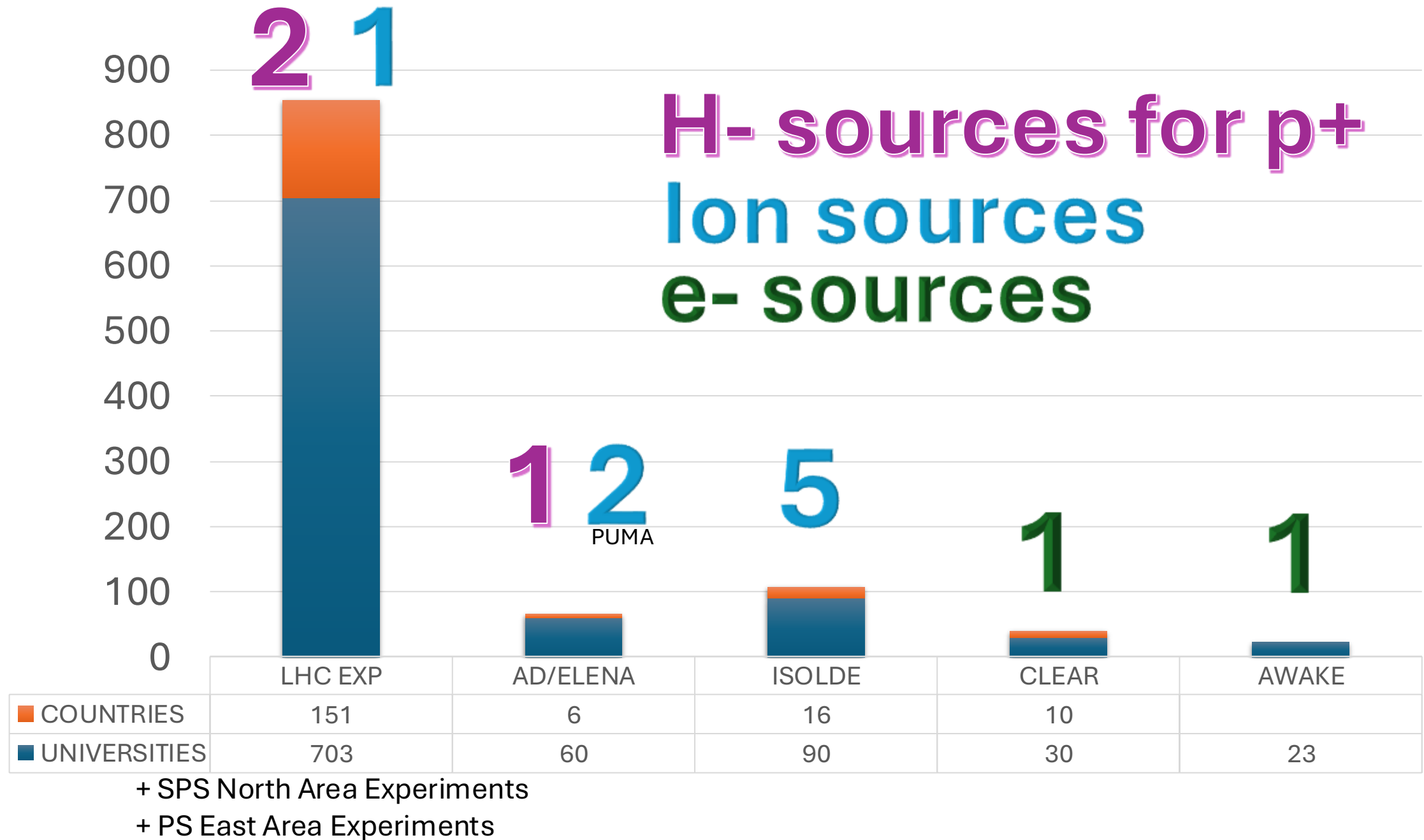
By doing so we build bridges between communities:

- nuclear physics
- astroparticle physics
- forward physics
- critical point physics
- fixed target physics
- high energy physics

Status of the second source

- CERN management approved submitting a proposal to the European Union's (EU) call to build a European electronics irradiation facility for accelerator and space applications.
- Sep 2026: 80 pages of documentation sent to the EU
- If approved by EU, the **first phase** of the project would receive about **€4 million**, aimed, among other goals, at preparing a **Technical Design Report by 2031** (includes 2nd source and connection to Linac 3)
- After TDR if the project is approved by the EU and CERN management
 - Ready for procurement and installation during LS4
 - Start operation in Run 5
- **HEARTS++ is a key opportunity:** A joint interest from the LHC experiment in a second injector will greatly strengthen this.

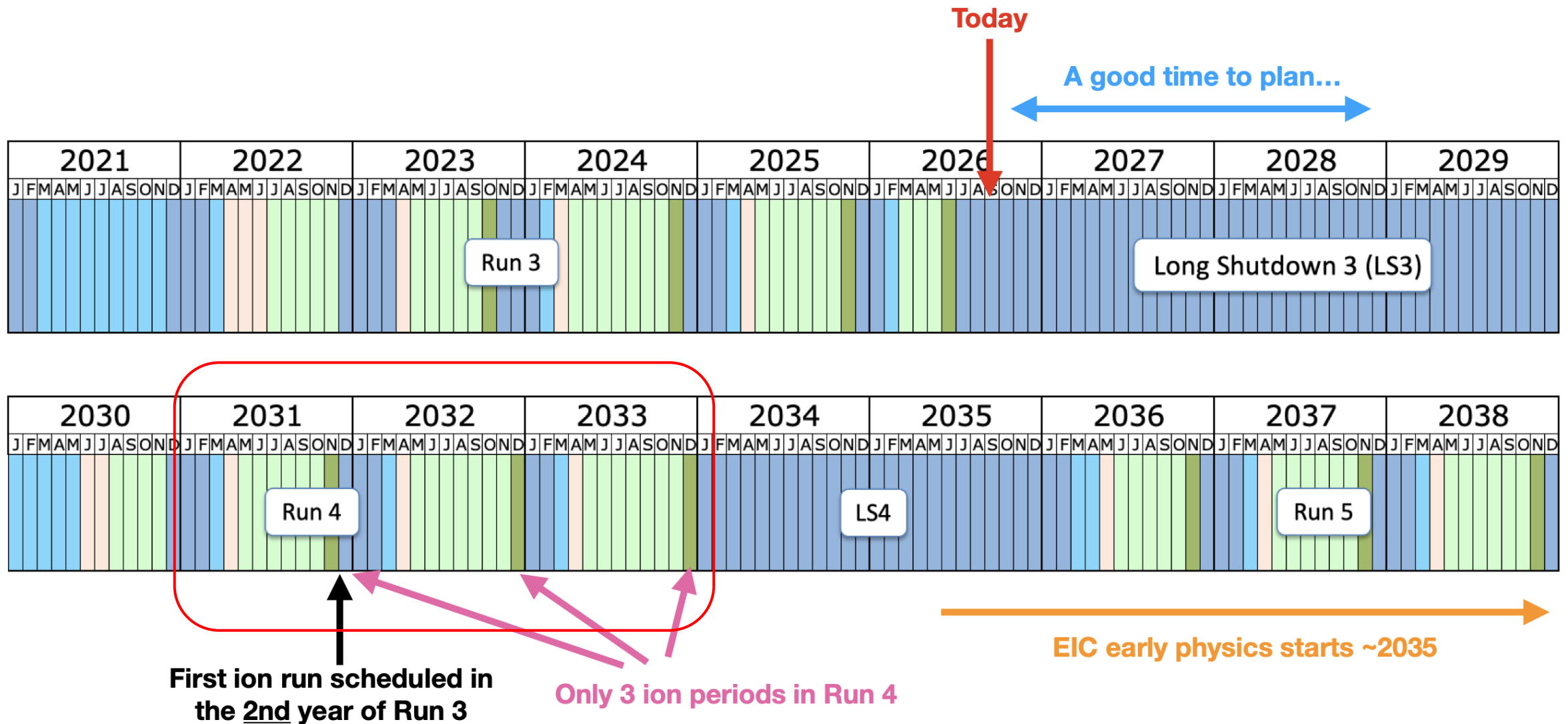




Potential ion development program

	First half (example 1)	First half (example 2)	Second half
2026	Ge	Ge	Mg
2027			C
2028	Cocktail/Ge/Kr/Xe	Cocktail/Ge/Kr/Xe	Pb (O $\leftrightarrow$ Pb test)
2029	O slip-stacking	O slip-stacking	Pb
2030	C (NA61++)	C (NA61++)	Pb
2031	O/He (NA61++/LHC)	(C,O) or (O,He) (same Q/A)	Pb
2032	C (NA61++/LHC)	Ca48(,Ca40)	Pb
2033	Mg (NA61++/LHC)	(Ge,Kr)	Pb

This is a suggestion, we remain flexible



Run 4 is our opportunity to answer the most important questions that will allow us to plan Run 5 in the most effective way collecting the very relevant data before the shut down of the last hadron collider for several decades.