# The NA60+ experiment at the CERN SPS

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## **Motivation**

- Heavy ion collisions at low energies  $(\sqrt{s_{NN}} = 6 17 \text{ GeV})$  tool to investigate the QCD phase diagram at large  $\mu_B$
- Could give insights to open questions at large  $\mu_B$ 
  - First order phase transition
  - Presence of a critical point
  - Chiral symmetry restoration



#### A new fixed-target experiment is proposed at the CERN SPS at $\sqrt{s_{NN}} = 6 - 17$ GeV : NA60+ Probe hard and electromagnetic processes in the SPS range 220 < $\mu_B$ <550 MeV

#### NA60+

- Fixed-target experiment proposed at the CERN SPS
- Beam energy scan at 6-17 GeV complementary to RHIC and NA61/SHINE
- High interaction rate (~100 kHz)
- Energy + rate combination is unique



# **Physics motivation**

Several new and unique measurements for EM and hard processes in the region  $\sqrt{s_{NN}} = 6 - 17$  Gev



- First order phase transition temperature measurement with thermal dimuons
- Chiral symmetry restoration with thermal dimuons
- Elliptic flow
- Charmonia suppression
- Open charm measurements
  - transport coefficients
  - hadronization mechanisms
- Strangeness production
- Hypernuclei production

R. Arnaldi, Prospects for open heavy-flavour and quarkonium measurements with NA60+ Track2-HF&Q, June 5, 12:00

#### NA60+ setup



#### Vertex region



#### Vertex detector– stitched MAPS

- Each telescope plane contains 4 large area silicon MAPS (based on wafer-scale sensors)
- Synergy with ALICE ITS3
- Sensor based on ~25 mm long units (RSU), replicated 6 times through stitching up to ~14 cm length for NA60+
- Powering and data transmission from right side
- Maximum rate: 6 MHz/cm<sup>2</sup> → ok for 1-1.5x10<sup>6</sup> Pb/s





#### Next presentation by C. Wang: The ITS3 detector and physics reach of the LS3 ALICE Upgrade

#### **Muon tracker**



- Technology choices MWPC, GEMs
- Suitable for charged particle rate foreseen ~2kHz/cm<sup>2</sup>
- Thick hadron absorber (235 cm of BeO + C) modest rates in the upstream stations
- Prototypes tested at CERN SPS in 2022 and 2023

#### Muon tracker – beam tests



- -50 x [mm] -100 Reconstructed hits in the MWPC detector Rough evaluation of chamber<sup>[mm]</sup> resolution ~100 µm S. Siddhanta, SQM 2024, Strasbourg
- Beam tests with MWPC chambers (1 mm readout strips) and GEMs
  - ~60 cm off the beam line to reduce event multiplicity
  - Continuous readout for MWPC
    - Coincidence of scintillators signals to tag the events (trigger for GEMs)
  - > MWPC resolution ~100 μm
  - GEM data analysis ongoing

# Toroidal magnet



- Ongoing R&D at CERN (support mechanics, magnetic field calculations, cost estimate)
- Eight sectors with 36 turns per coil
- · Low material budget in the acceptance area
- Advanced stage studies on coil design, choice of the power converter, cooling study, preliminary support mechanics
  S. Siddhanta, SQM 2024, Strasbourg

## **Experimental area**

- NA60+ will be installed in the CERN EHN1 - PPE138 area along the H8 beam line
- High-intensity (10<sup>6</sup> ions/s)
- Heavy shielding of iron and concrete dose below 3 µSv/h externally to the experiment (studied by CERN-HSE group)
- Collimated beam → a fully re-designed optics
  - Promising results from October 2023 test beam:  $\sigma \sim 280 \ \mu m$







## Performance studies – thermal dimuon mass spectrum



- Thermal radiation yield accessible up to M = 2.5 - 3 GeV/c<sup>2</sup>
- $T_{slope}$  extracted by fitting the region  $1.5 < M < 2.5 \text{ GeV/c}^2$
- ~2% uncertainty on the  $T_{slope}$ measurement - allows an accurate mapping of the  $\sqrt{s}$ dependence of  $T_{slope}$  around  $T_c$

(0-5% central Pb-Pb collisions)

#### Performance studies – chiral symmetry restoration



- Investigated with the measurement of the  $\rho\text{-}a_1$  mixing
- A 20-30% enhancement is expected in the region 0.8 < M < 1.5 GeV/c<sup>2</sup> for full chiral mixing
- NA60+ could detect a signal of chiral symmetry restoration

## Performance studies – strangeness



S. Siddhanta, SQM 2024, Strasbourg

## Performance studies – strangeness



- Performance studies for  $\,\Omega$  and  $\varphi$
- Studies performed also for K<sup>0</sup><sub>S</sub>
- Possibility of v<sub>2</sub> measurements

#### Performance studies – hypernuclei



- High precision measurement of the properties of  $\Lambda$  hypernuclei
- Possible discovery of light  $\Xi$  and  $\Sigma$  hypernuclei

#### **Present status**

- The <u>Letter of Intent</u> for the NA60+ experiment was submitted to the SPSC at the end of 2022 and was discussed in February 2023 with a favorable feedback
- Project mentioned in US 2023 Long Range Plan for Nuclear Science and in the NUPECC Long Range Plan 2024
- Significant progress was made in the detector and toroidal magnet R & D and beam optics studies in the last year
- Preparation and consolidation ongoing for the Technical proposal
- Technical proposal to be submitted in end 2024

#### Outlook

- Construction during LS3 (2026-28)
- Data taking over 7 years from 2029
- One energy point each year including AA and p-A

	Year 1	Year 2	Year 3	Year 4-5	Year 6	Year 7
Beam energy (A GeV)	160	40	120	20 (30)	80	60
Momentum per charge (GeV/c/Z)	406	101	304	50.7 (76.1)	203	152
Pb ions on target	$\sim 10^{12}$ per energy ( $\sim 30$ days)					
protons on target	$5 - 6 \cdot 10^{13}$ per energy (~ 22 days)					





We welcome additional teams to join the effort! There is still room for impactful contributions.

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