THE NA60+ EXPERIMENT AT THE CERN SPS: DILEPTON AND HEAVY QUARK PRODUCTION AT LARGE μ_B

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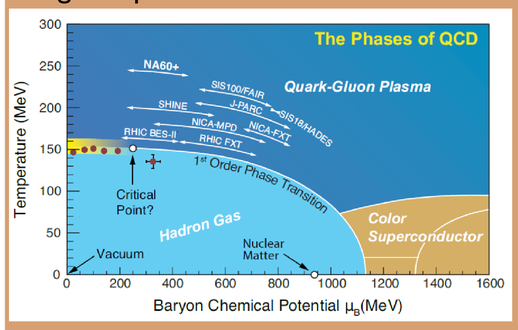
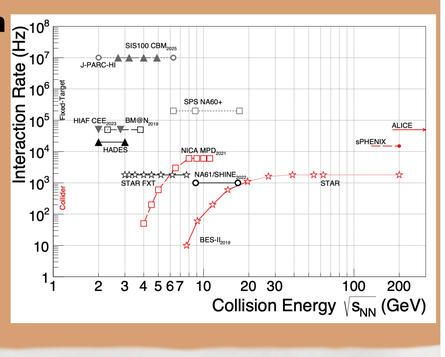
Introduction

The region of high baryonic densities (μ_B) of the QCD phase diagram is the object of several studies, focused on the investigation of the **order of the phase transition** and the **search for the critical point**. Rare probes, including heavy-quarks and thermal dimuons, are experimentally challenging to access as they require large integrated luminosities. At SPS energies they can be studied with fixed-target experiments



NA60+ focuses at significant improvement and extension of the physics reach w.r.t. its predecessor NA60 experiment

- **Wide μ_B** region coverage
- Possibility of reaching **high interaction rates** of hundreds kHz
- Complete physics reach for **dileptons and charm**
- Energy range complementary to FAIR/GSI and J-PARC

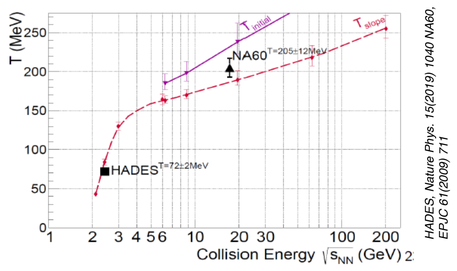


NA60+ is a proposed experiment which aims to study **hard and electromagnetic** processes at **CERN-SPS energies**

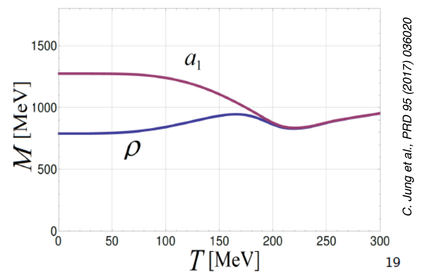
*NA60+ is based on **state-of-the-art technologies** and will allow a **high-statistics study of dileptons, quarkonia and open charm** in **Pb-Pb** and **p-A** collisions from low (**20-30 AGeV**) to top (**160 AGeV**) SPS energy*

The NA60+ physics case

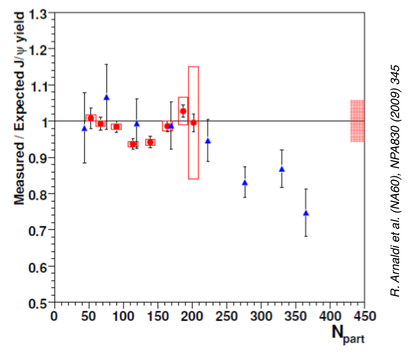
Thermal dimuons from QGP/hadronic phase: **caloric curve for first order transition**



ρ-a_1 modifications: **chiral symmetry restoration**

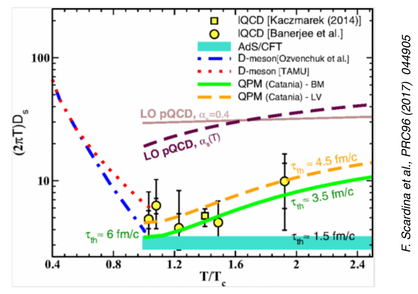


Quarkonium suppression: signal of deconfinement



Explore the centrality dependence of J/ψ suppression vs √s, detect deconfinement threshold and correlate with T

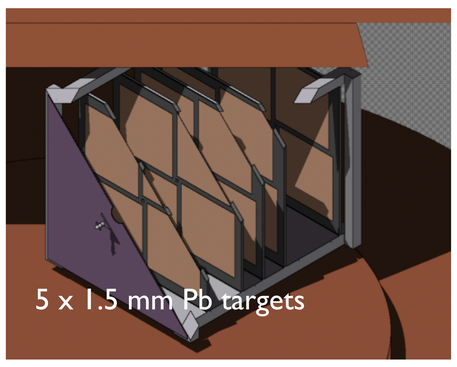
Hadronic decays of charmed mesons/baryons: **QGP transport coefficients**

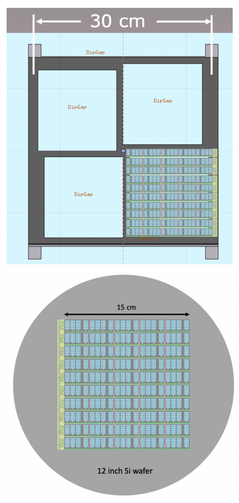


The diffusion coefficient Ds quantifies the interaction of heavy quarks with the medium and allows directly accessing the thermalization time

R&D: vertex spectrometer

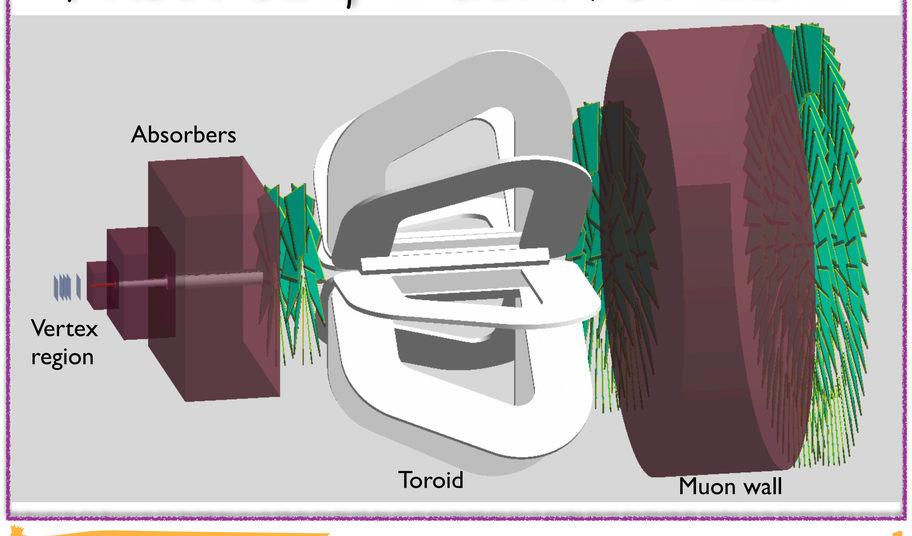
- 5 planes of MAPS detectors inside MEP48 dipole magnet (1.5 T)
- Each tracking station has 4 15x15 cm² sensors





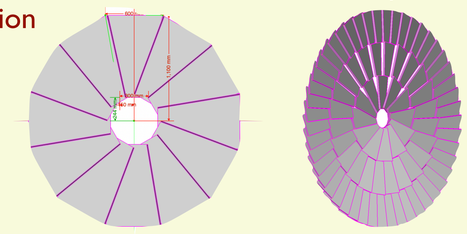
- Common development of **ALICE** and **NA60+**
- State-of-the-art imaging technology **TowerJazz 65 nm**
- Stitching principle and stitched sensor proposed for NA60+

NA60+ setup in Geant4 simulation

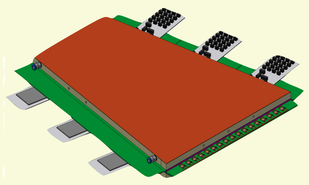


R&D: muon spectrometer

- 6 muon tracking stations before and after toroidal magnetic field
- All stations are based on a **standard module**
- Spectrometer provides an **independent measurement of muons** after the hadron absorber
- Muons are matched to the tracks measured in the silicon vertex telescope
- Specifications ~100 m² area and ~200 μm resolution



- Two robust technologies are currently considered: **Gas Electron Multiplier (GEM)** and the **Multi-Wire Proportional Chamber (MWPC)**
- Large area can be produced at a low cost
- Flexible geometries

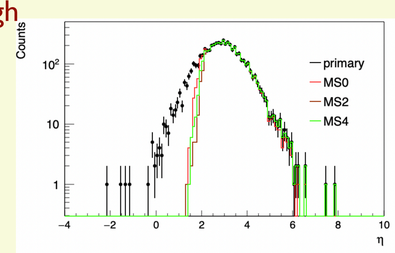


Muon spectrometer module **Prototype (~1:1 scale) is being designed**

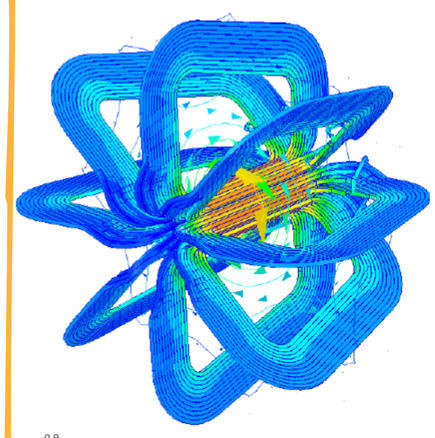
The prototype will be **tested at the cosmic test bench in Mexico laboratory at WIS** and at beam tests **at CERN** in November 2022

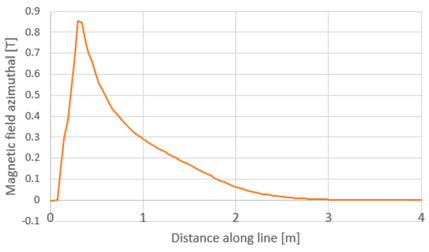
Simulations:

- 50000 muon pairs were simulated and propagated through the G4 setup
- Geometrical acceptance and efficiency studies for muon tracking stations
- Refine the design based on the simulations



R&D: toroidal magnet



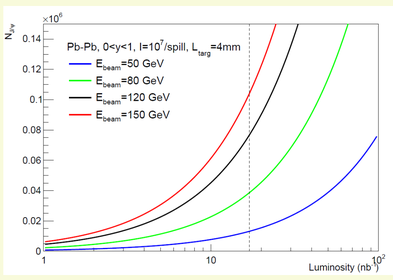


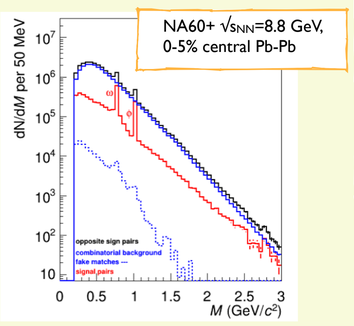
1:5 scale prototype built and tested at CERN to:

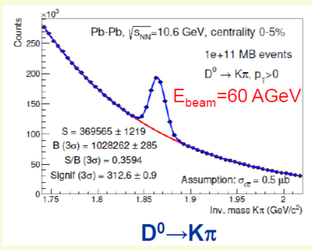
- investigate mechanical solutions, in view of the toroidal magnet final design
- check simulations/calculations of magnetic and cooling parameters

Physics performance

- Detailed performance studies currently in progress for the various physics topics that will be investigated by NA60+







With 4 mm Pb target and 1 month of data taking (L_{int} =17 nb⁻¹), NA60+ can aim at

~O(10⁴) J/ψ at 50 GeV

~O(10⁵) J/ψ at 158 GeV

Summary

- Precision studies of electromagnetic and hard probes in the region $6<\sqrt{s_{NN}}<17$ GeV are currently lacking
- **NA60+ is a new dimuon experiment:** possible **breakthrough** on several hot topics
- The project is part of the **Physics Beyond Colliders** CERN initiative
- A **Letter of Intent** is currently in the advanced preparation stage, to be submitted in the second half of 2022
- From **design to realization**: R&D studies are ongoing, CERN test beam periods in the end of 2022 are planned
- Goal: to obtain the CERN approval and build the experiment for data taking not later than the **end of LHC Long Shutdown 3** → 2029
- Foresee **at least 5-6 years** of data taking (one energy point per year with p-A and Pb-Pb)