QM QUARK MATTER KRAKÓW 2022

29TH INTERNATIONAL
CONFERENCE ON ULTRARELATIVISTIC
NUCLEUS - NUCLEUS COLLISIONS
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KRAKÓW, POLAND

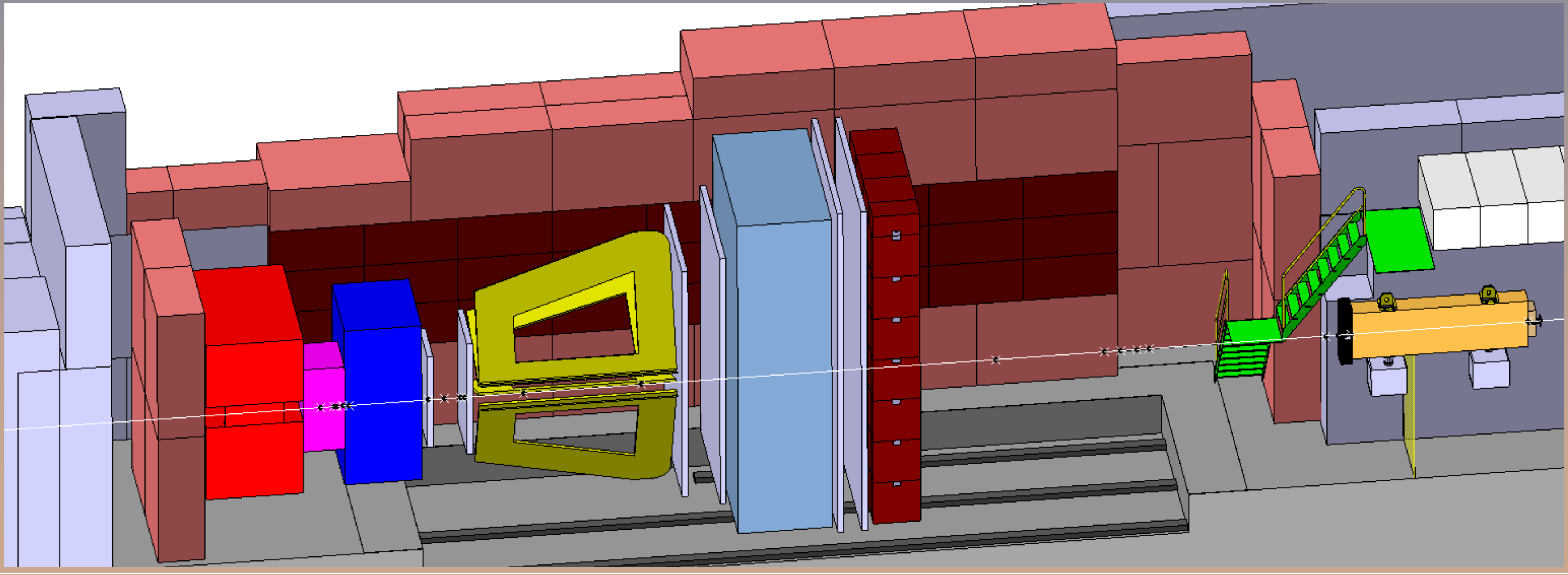
Dilepton and heavy quark production at large μ_B: the NA60+ experiment at the CERN SPS

E. Scomparin (INFN Torino, Italy) for the NA60+ Collaboration

Overview

- ❑ The **physics case**: dimuon, heavy quark and strangeness production in Pb-Pb collisions at the SPS
- ❑ Designing a fixed-target experiment for a beam energy scan from 20 A GeV to 160 A GeV
  - ❑ Ongoing **R&D studies**
  - ❑ Integration, radiation issues and beam optics
- ❑ **Physics performance** studies
- ❑ Timescale and conclusions

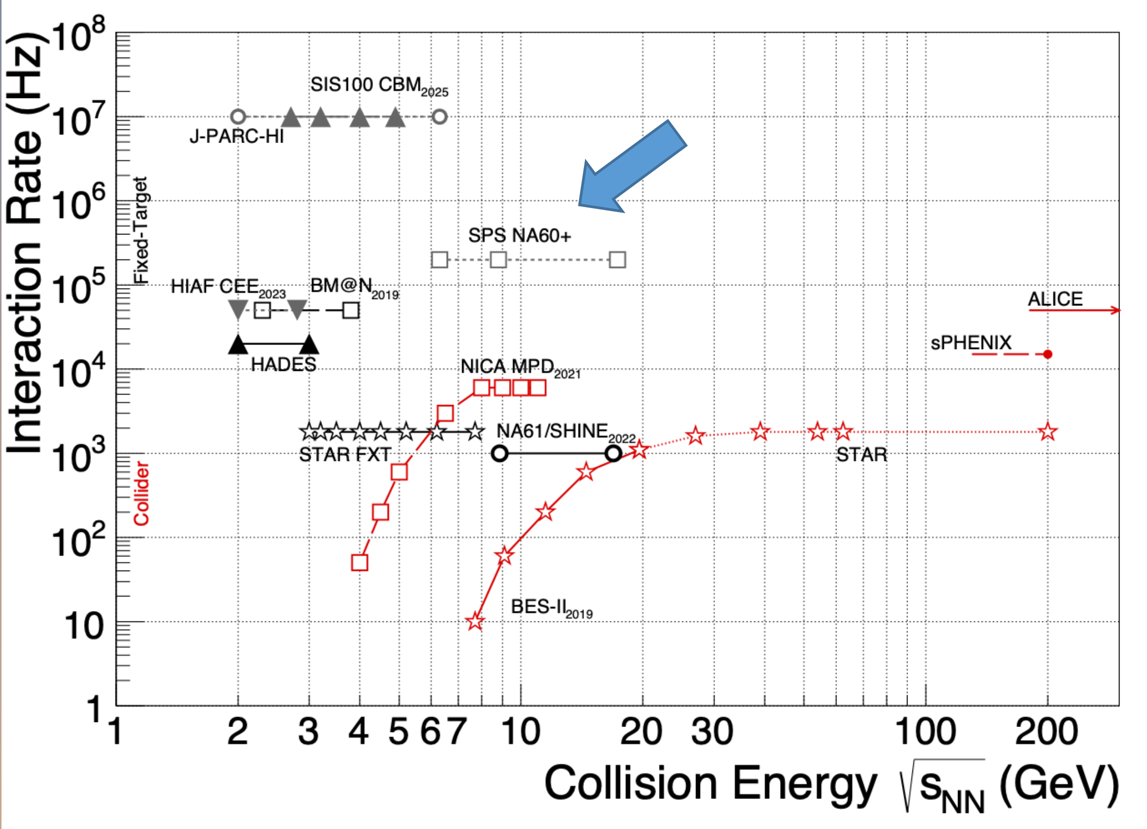
https://na60plus.ca.infn.it/



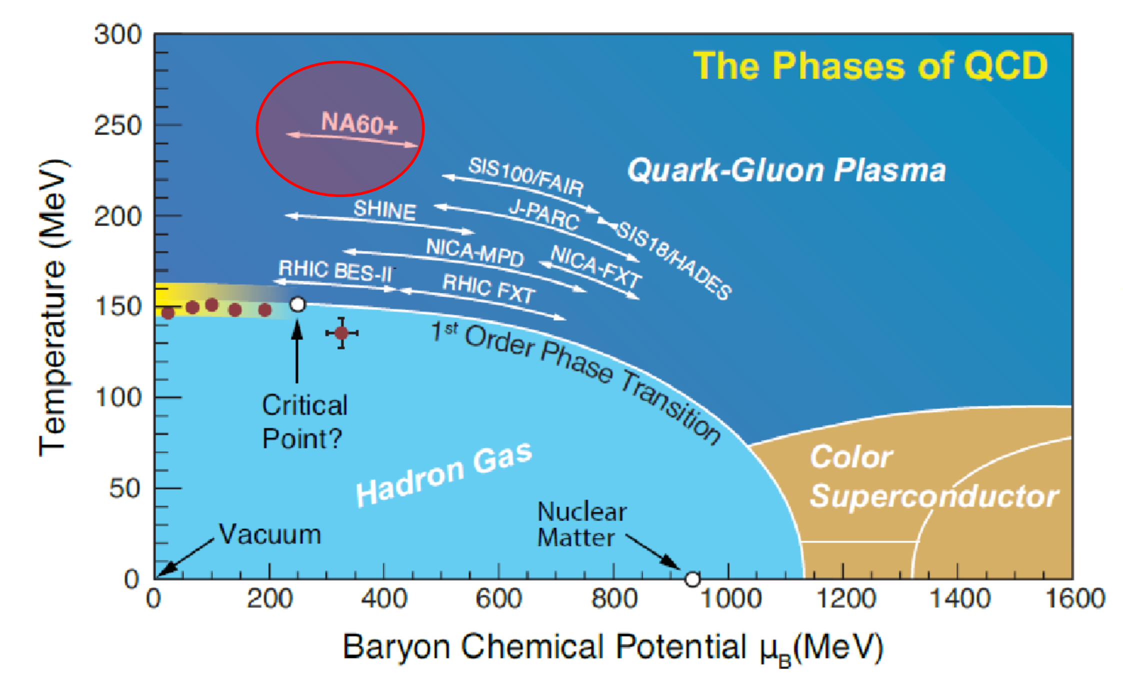
Physics case

NA60+

- Study of hard and electromagnetic processes at the CERN-SPS: an investigation of the high-μ_B region of the QCD phase diagram via an **energy scan** ($\sqrt{s_{NN}}$=6 to 17 GeV)



(from T. Galatyuk)



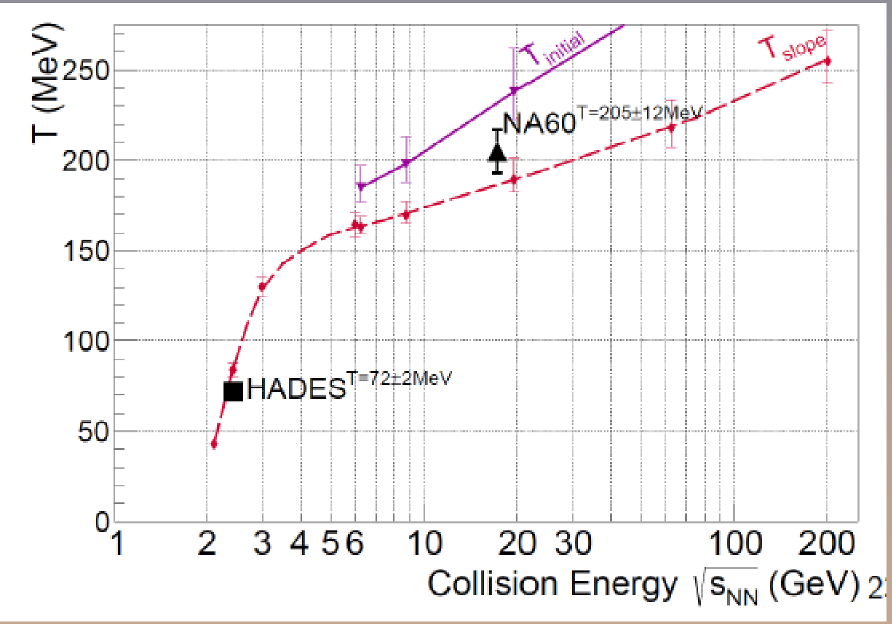
- Main features
  - Coverage of a **wide μ_B region**
  - Precision physics: possibility of reaching **high interaction rates** (hundreds kHz)
  - Complete physics reach for **dimuons and charm**
  - Energy range complementary to FAIR/GSI (and J-PARC)

Aim at significant improvement (and extension) of the physics reach wrt the former NA60 experiment

The "pillars" of the NA60+ physics case

Measure:

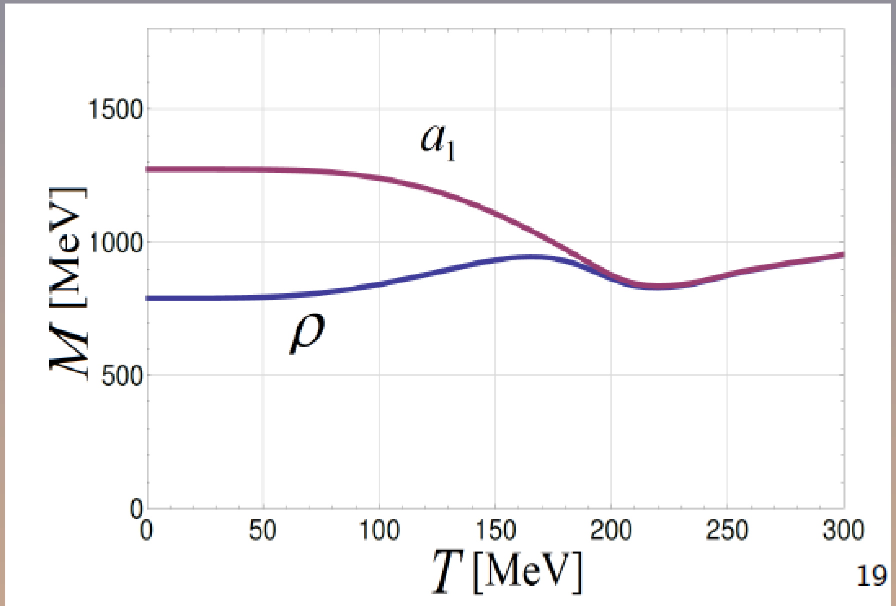
- **Thermal dimuons from QGP/hadronic phase: caloric curve for first order transition**
- **ρ-a_1 modifications: chiral symmetry restoration**
- Quarkonium suppression: signal of deconfinement
- Hadronic decays of charmed mesons/baryons: QGP transport coefficients



HADES, Nature Phys. 15(2019) 1040
NA60, EPJC 61(2009) 711

Extract temperature via fit
$dN/dM \propto M^{3/2}\exp(-M/T_s)$
→ Possible flattening in
√s-dependence of T_s

Full chiral ρ-a_1 mixing
→ dimuon enhancement
in the region
$1<M<1.4$ GeV/c^2



C. Jung et al., PRD 95 (2017) 036020

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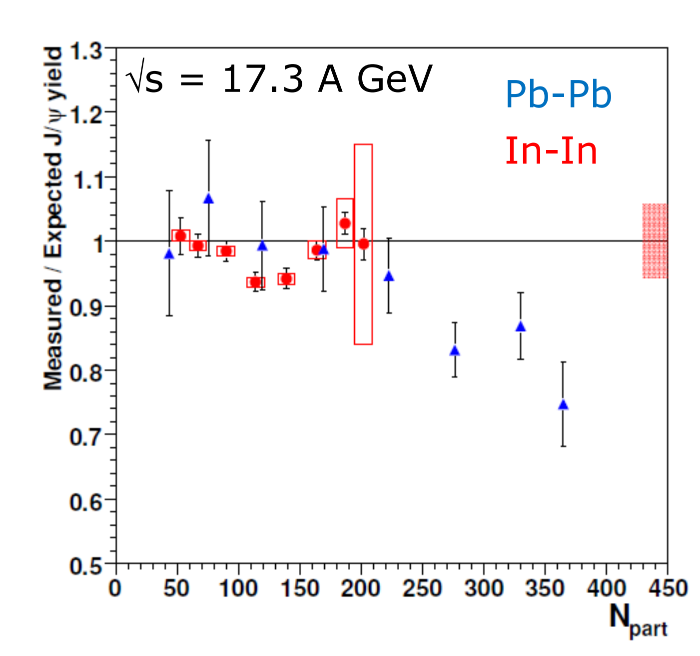
F. Prino and R. Rapp, J.Phys.G 43 (2016) 9, 093002



R. Arnaldi et al. (NA60), NPA830 (2009) 345

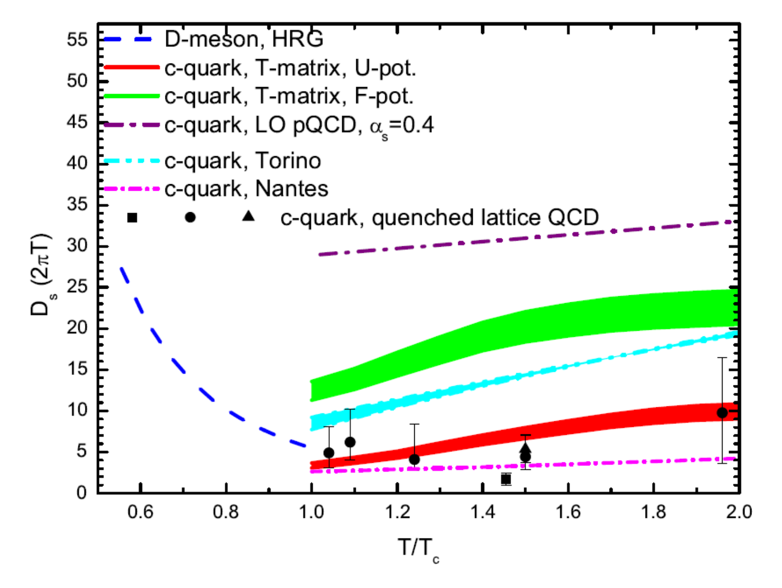
Explore the centrality dependence of J/ψ suppression vs √s

→ Detect deconfinement threshold and correlate with T

Measure 2 and 3 prong decays of charmed mesons and baryons

→ R_{AA},v_2 : transport coefficients

→ Λ_c ,D, D_s : study hadronization mechanisms



F. Scardina et al., PRC96 (2017) 044905

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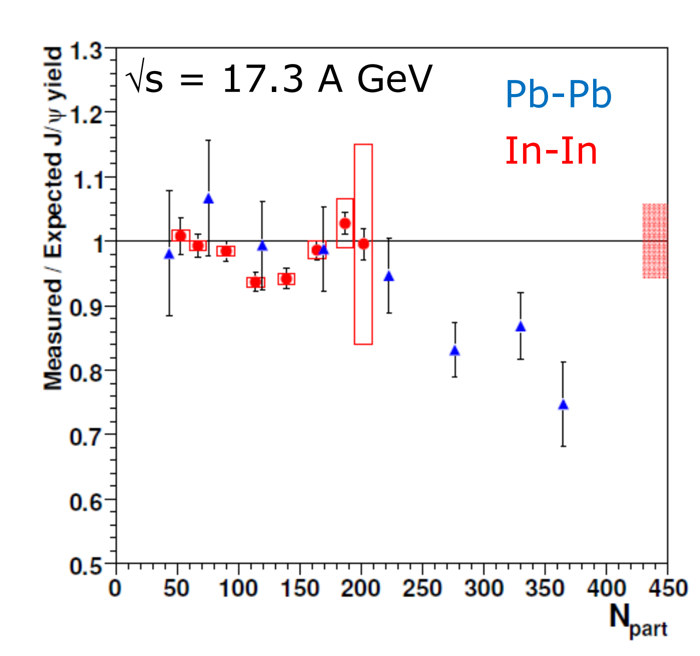

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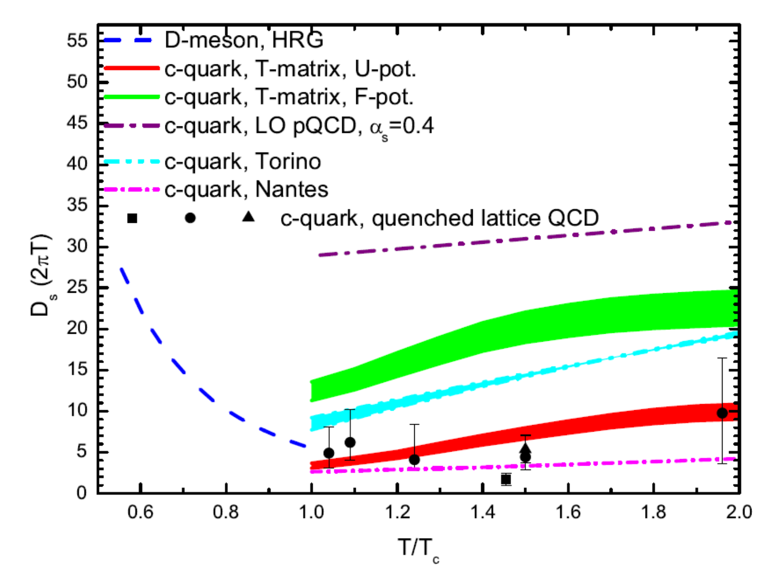


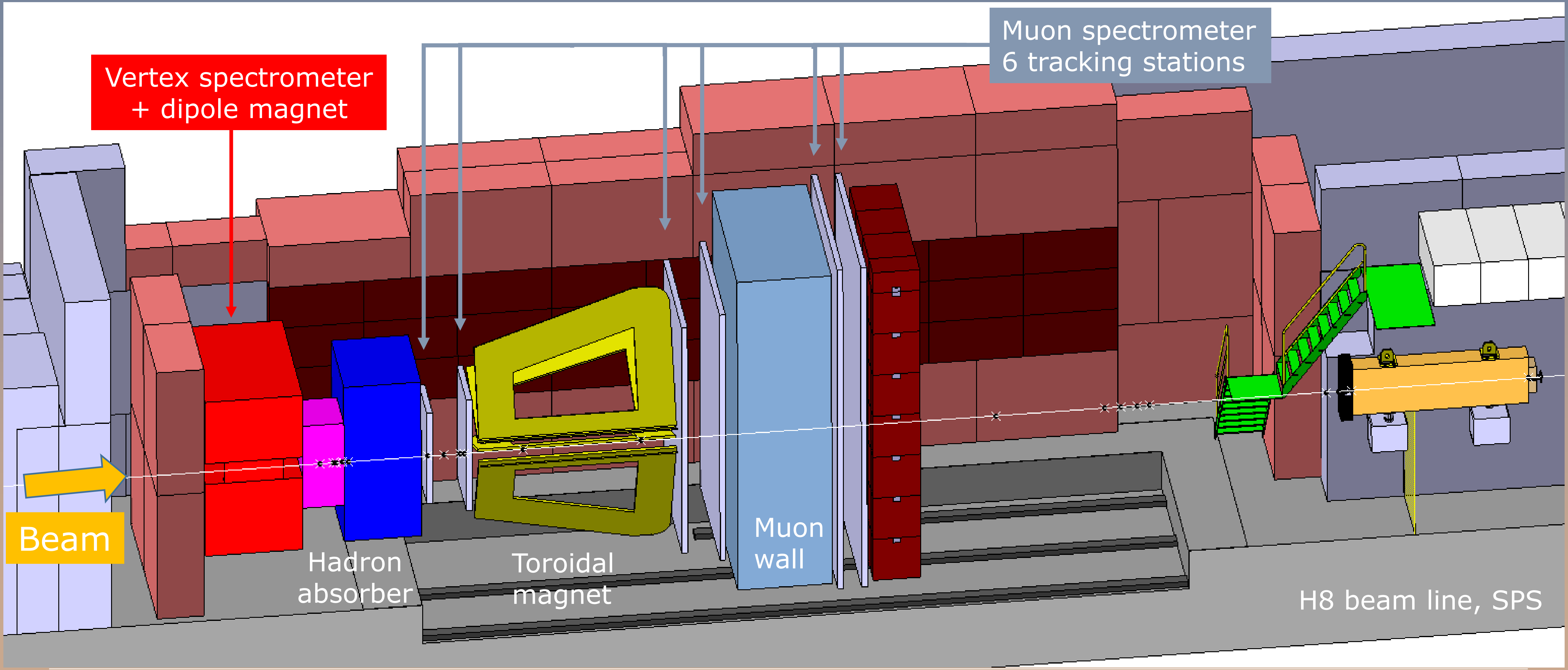
F. Scardina et al., PRC96 (2017) 044905

Also study strangeness production → hadronic decays of K_S^0, ϕ and hyperons

Experimental set-up and detector studies

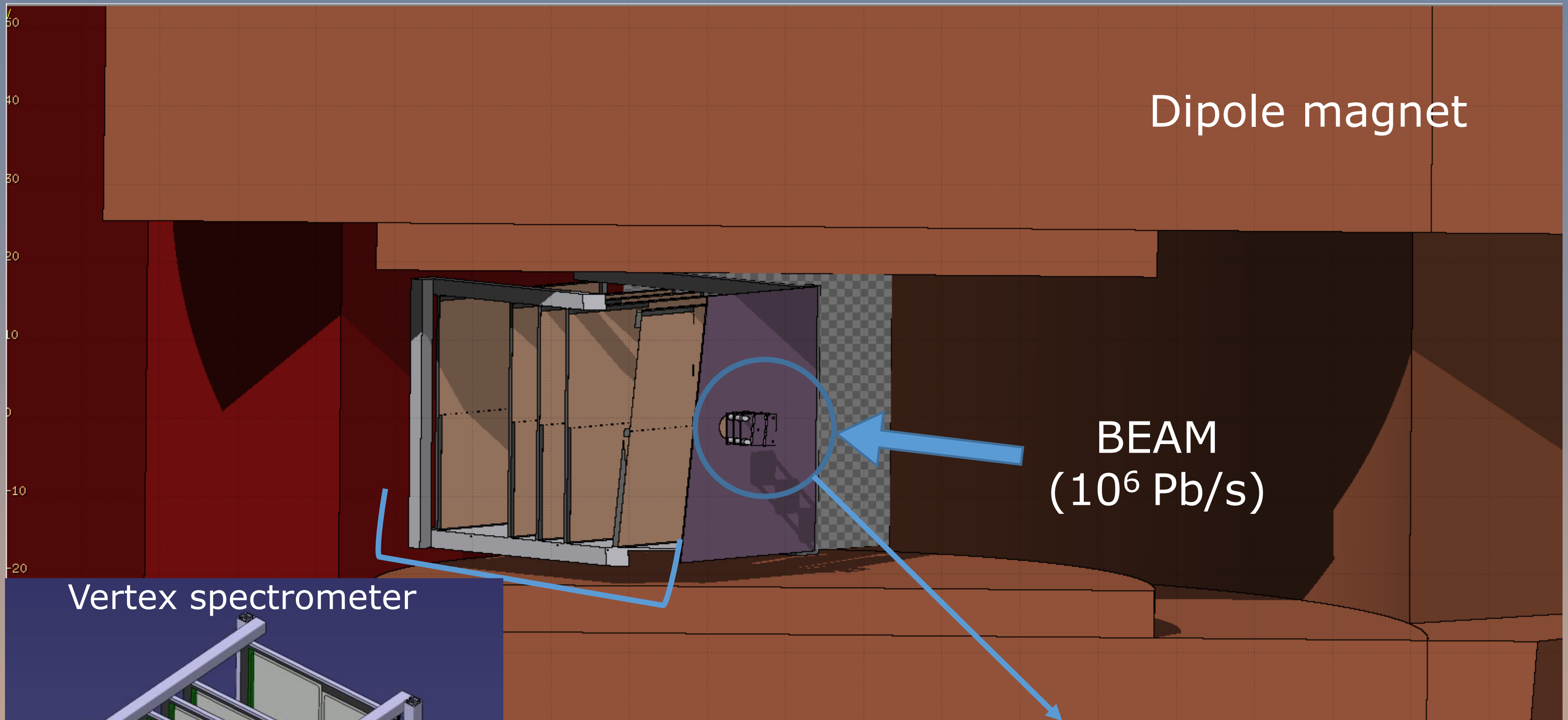
NA60+ set-up

Muon spectrometer position will be varied (rails), to cover mid-rapidity at different collision energies

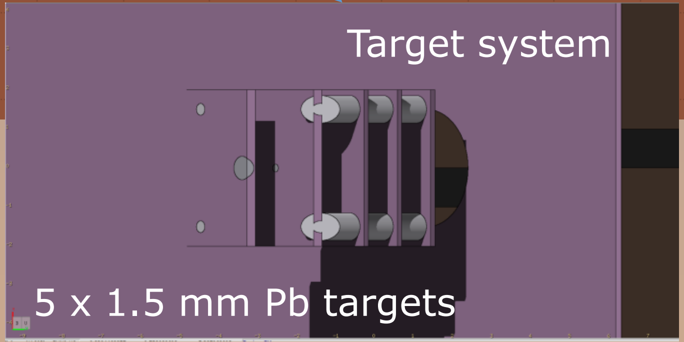


NA60+ set-up: vertex region

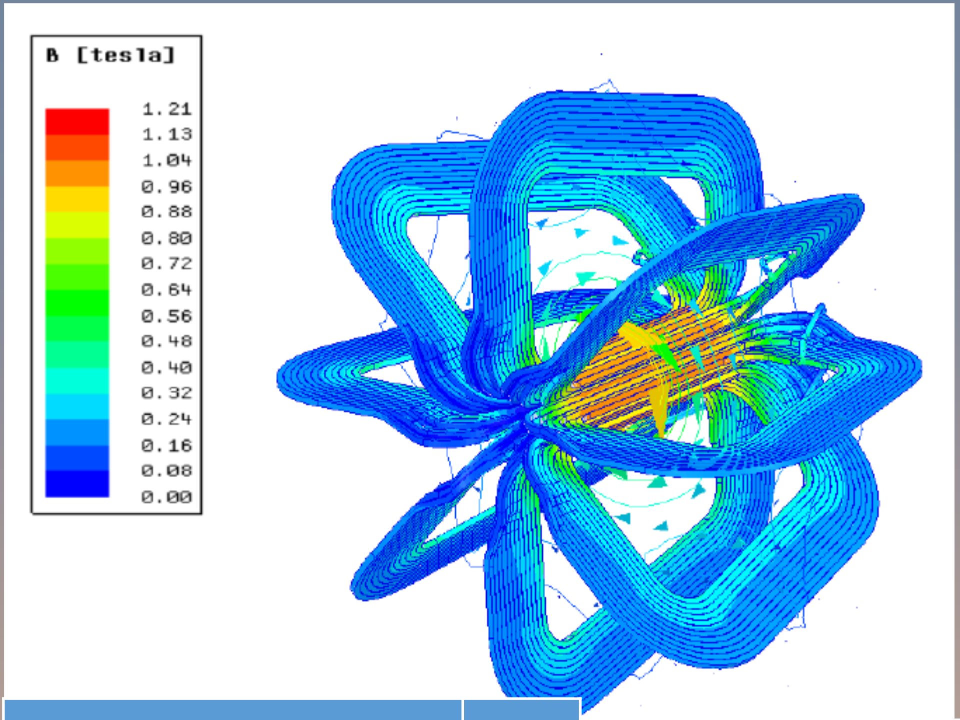
MEP48 dipole magnet
Field 1.5 T over a 400mm gap



5 planes of
MAPS detectors
(up to 10)

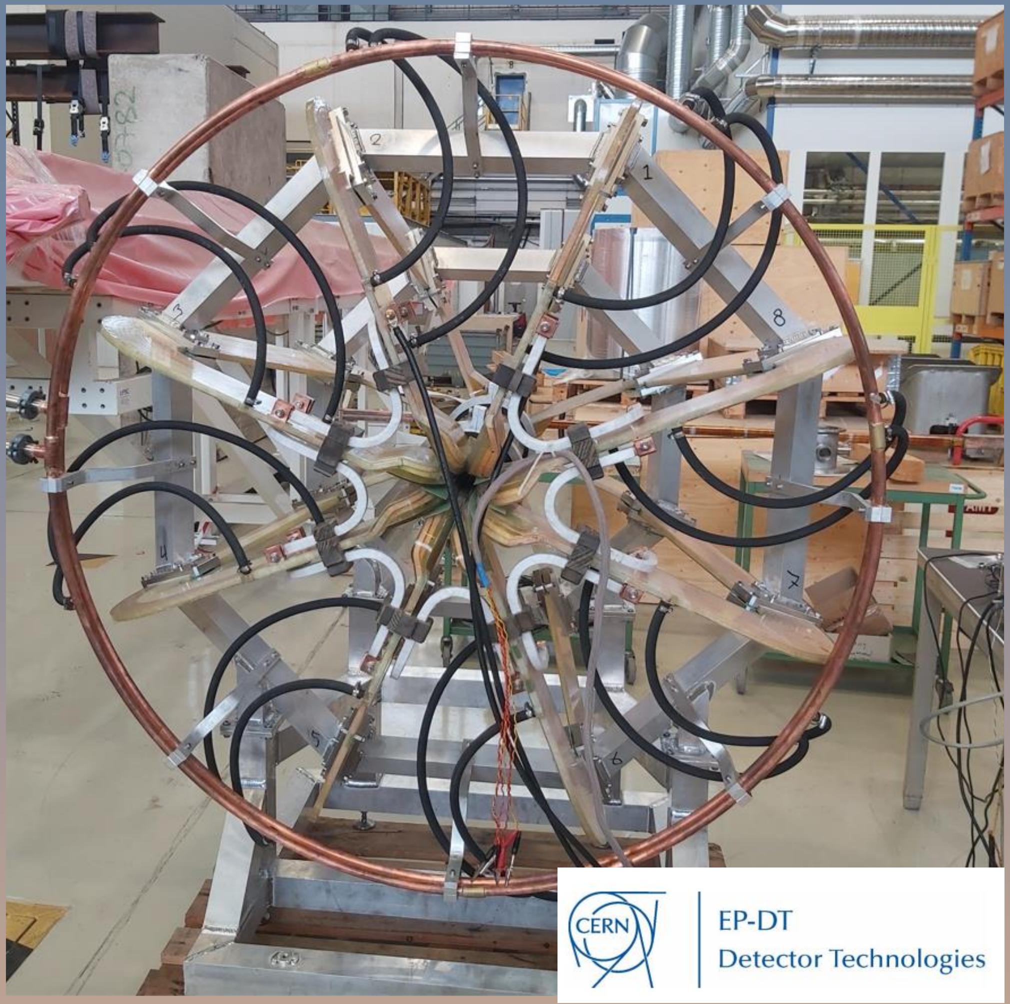


R&D: toroidal magnet

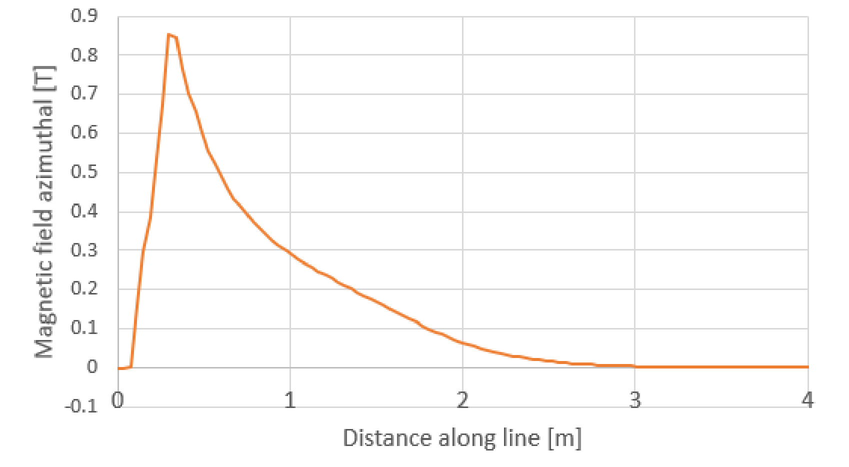


Eight sectors, 12 turns per coil

Conductor has a square copper section with a circular cooling channel in the centre



Operating Current [kA]	16.6
Amp-turns [kA]	199
Combined inductance [mH]	9.5
Resistivity Al 1100 @RT [μΩ.cm]	2.67
Length Conductor [m]	800
Total resistance [mΩ]	10.4
Dissipated power [MW]	2.8

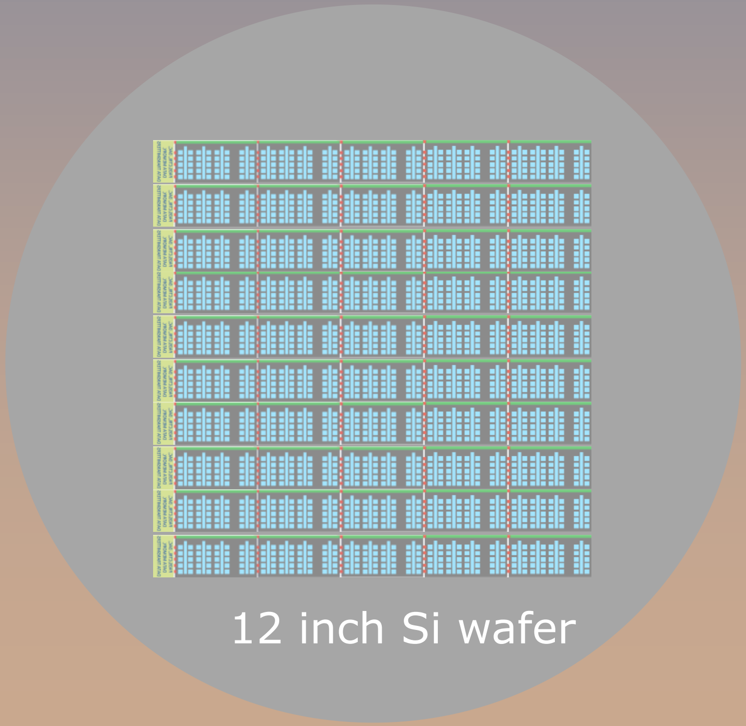


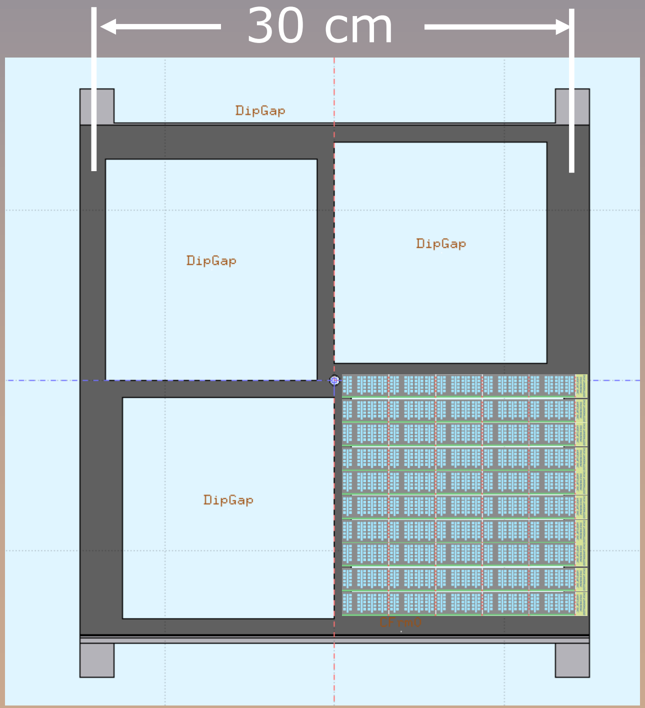
- **Prototype (1:5 scale)** was built and tested in 2020-2021, to check calculations and investigate mechanical solutions, in view of the final object

→ **works correctly and as expected**

R&D: vertex spectrometer

Sensor based on 25 mm long units, replicated several times through stitching
→ up to **15cm length** for NA60+





R&D in progress
Common development
ALICE ←→ NA60+

State-of-the-art imaging technology
TowerJazz 65 nm

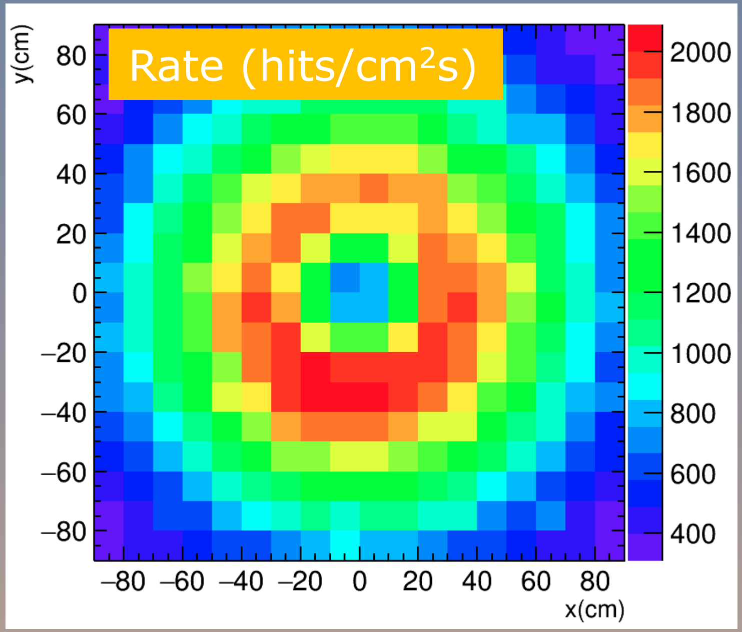
Sensor thickness:
few tens of microns of silicon
→ material budget **<0.1% X_0**

Spatial resolution ≤ **5 μm**

Cooling studies (NA60+ geometry)
in progress

Complete NA60+ station → 4 sensors

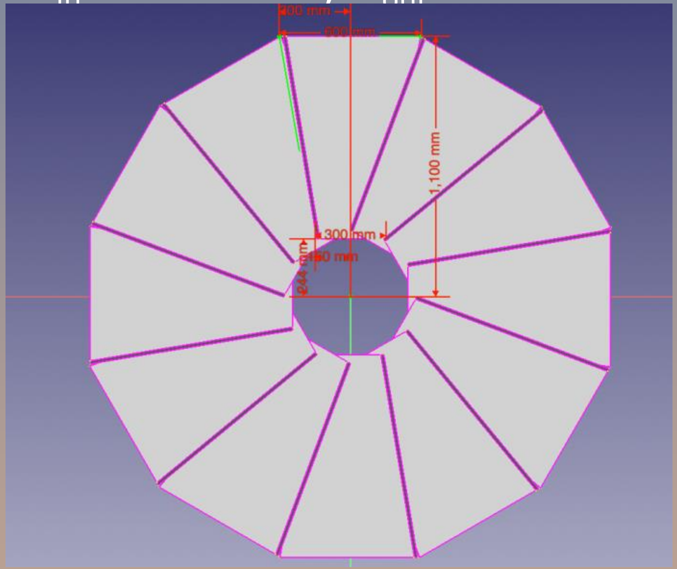
R&D: muon tracker



Rates (FLUKA) in the upstream stations are modest, thanks to the thick absorber (235 cm BeO +C)
For a 10^6 s^{-1} beam → charged particle rate ~$2 kHz/cm^2$

Can be matched by GEM or MWPC detectors
Discussion on technology choice in progress

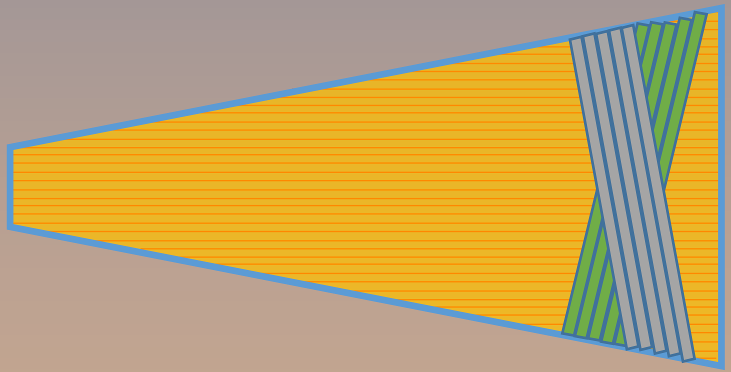
Upstream stations
R_{in} =24.5 cm , R_{out} = 110 cm



Triple **GEM chambers** with 2D strip readout

Stony Brook University

MWPC with 3 mm wire pitch and 3 mm gap from anode wire to cathode
Analog strip R/O (strip pitch to be defined during R&D this year)



SPS beam test of first prototype(s) in October/November

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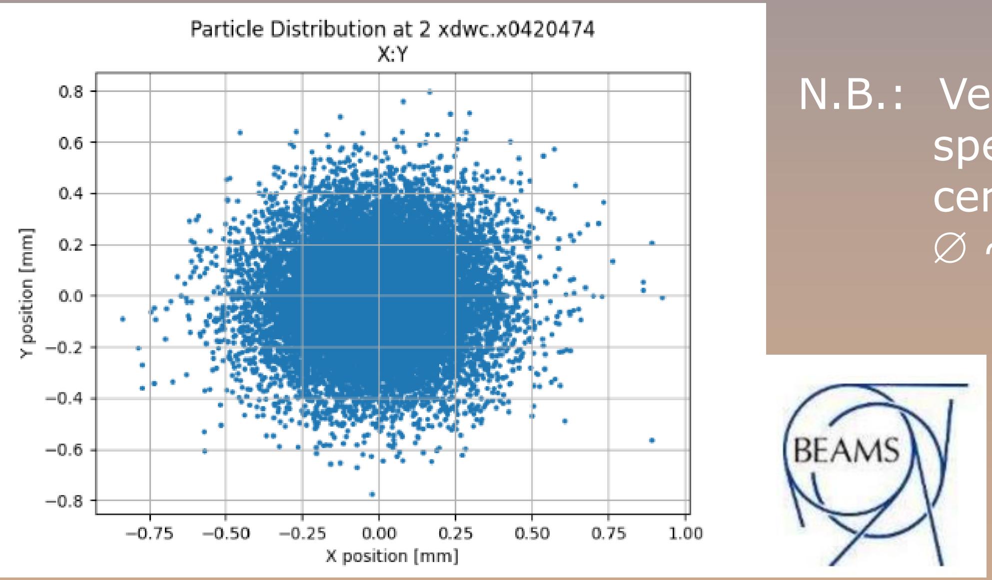
Beam and RP studies

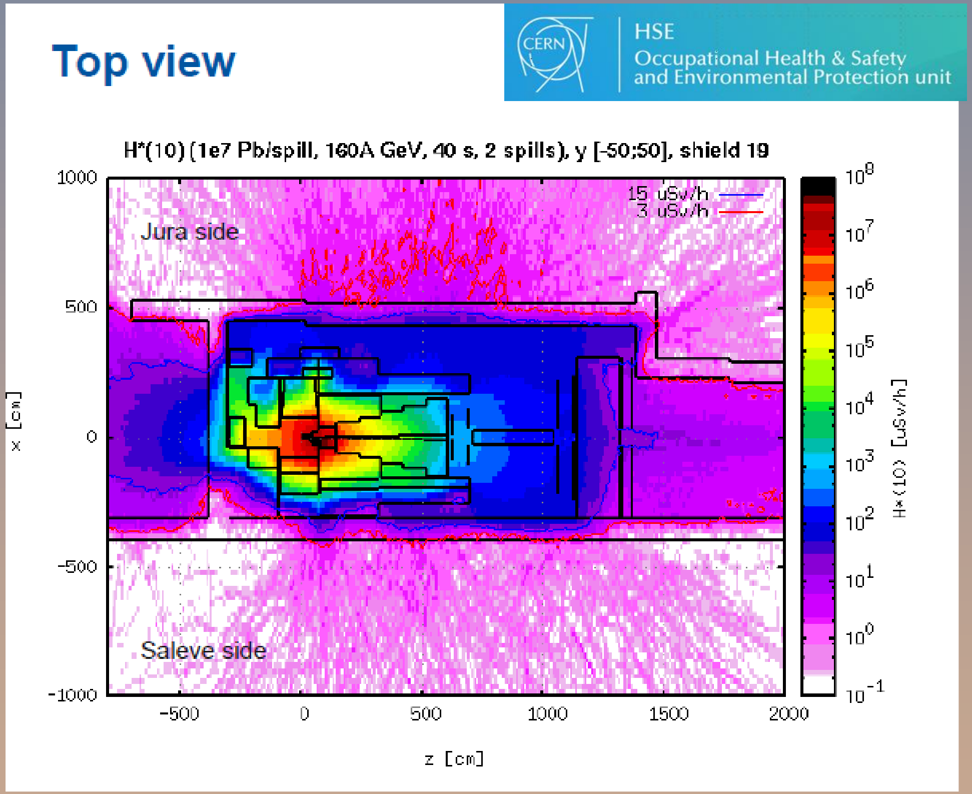
- ❑ Need **high-intensity** (10^7/spill), **collimated** (σ < 1mm) beam at all foreseen energies
- → Fully re-designed optics (final CERN PBC note submitted), to be **tested at SPS** in November 2022

Parameter in zone 138	160 GeV/c	30 GeV/c
σ_x (mm)	0.19	0.33
σ_y (mm)	0.19	0.36
Transmission from T4 (%)	32.43	23.5



N.B.: Vertex spectrometer central hole, ∅ ~ 0.6 cm

- ❑ Radioprotection studies represent a major technical issues
- → **Heavy shielding** (iron/concrete) was designed



Dose below 3 μSv/h externally to the experimental hall

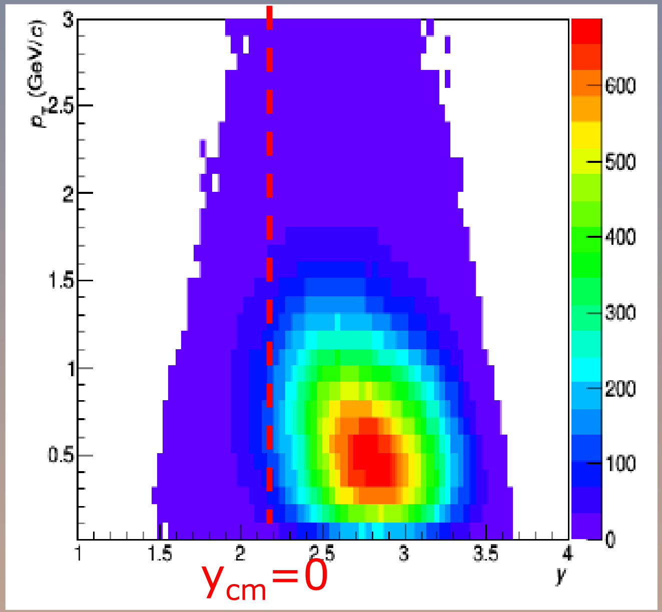
Integration studies for detector and infrastructure also performed → proposal finalized

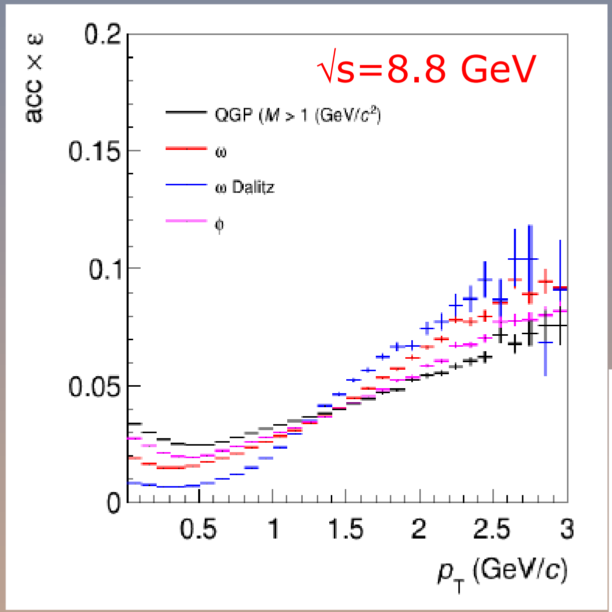
Physics performance studies

(Di)muon detection performance

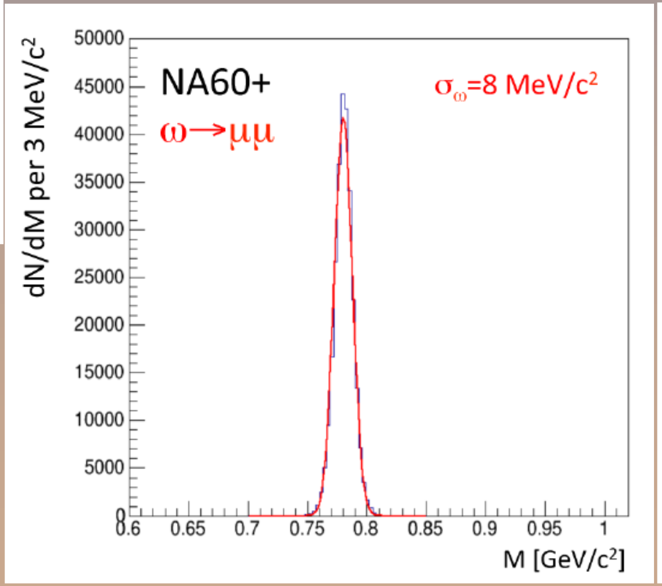
Detector performance studies → based on a **simulation framework** with a semi-analytical tracking algorithm (Kalman filter)
FLUKA for background studies

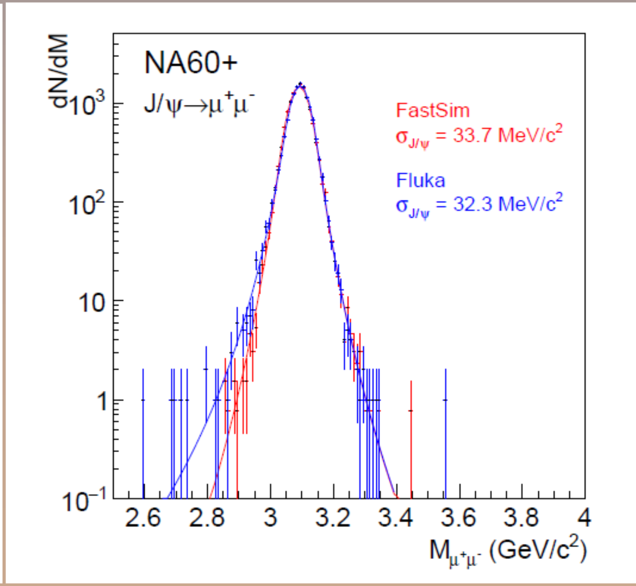
QGP (m>1 GeV/c²)





- ❑ Full phase-space acceptance at dimuon low and intermediate masses → >1%
- ❑ Good coverage down to midrapidity AND zero p_T, realized at all energies by displacing the muon spectrometer

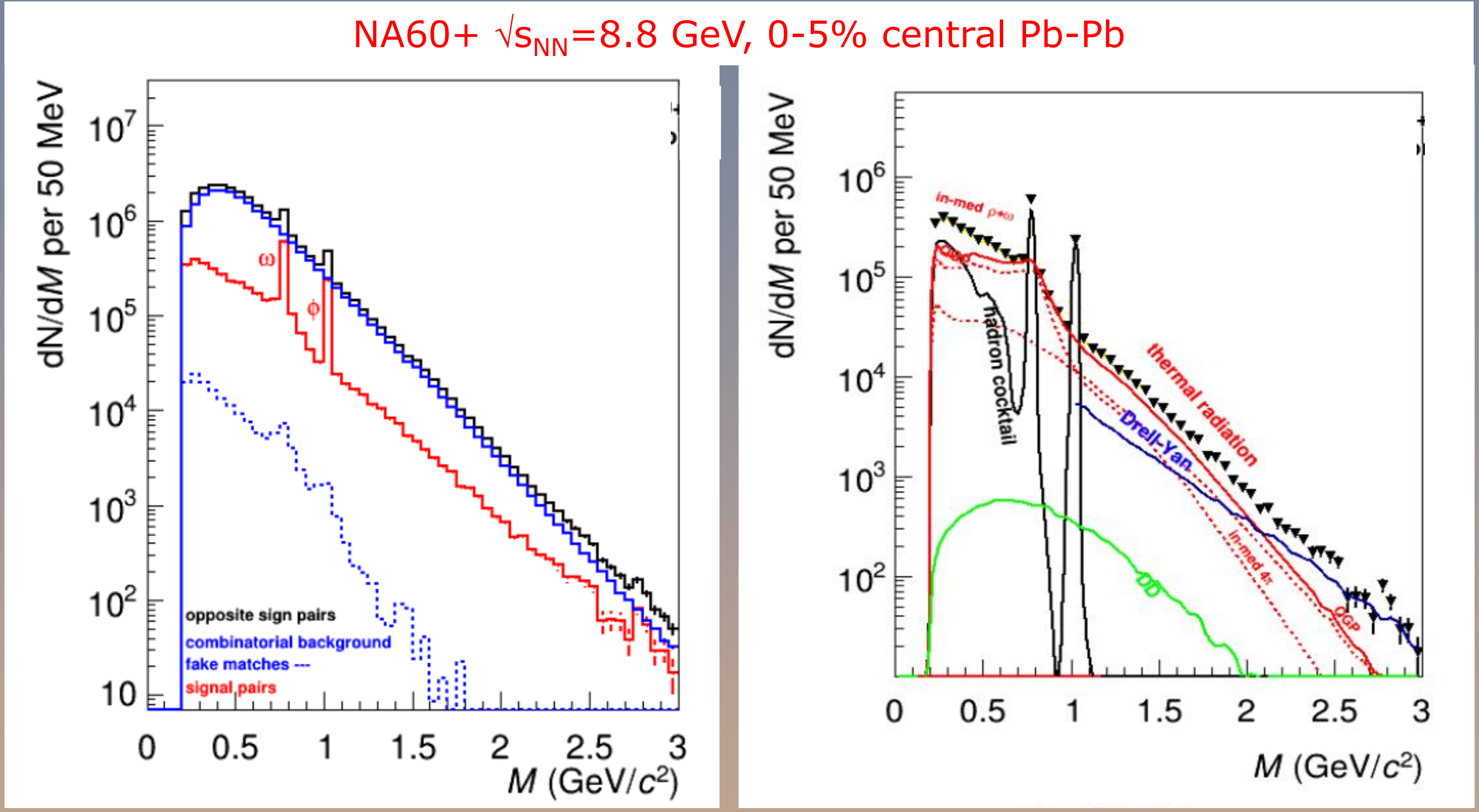




The mass resolution for resonances varies from <10 MeV (ω) to ~30 MeV (J/ψ)

(factor >2 improvement with respect to NA60)

Dilepton spectrum



- Thermal radiation yield
  - Dominated by ρ contribution at low mass
  - Accessible up to $M=2.5\text{-}3\ \mathrm{GeV}/c^2$
- Drell-Yan contribution
  → to be also estimated via p-A measurements
- Open charm
  Negligible dimuon source

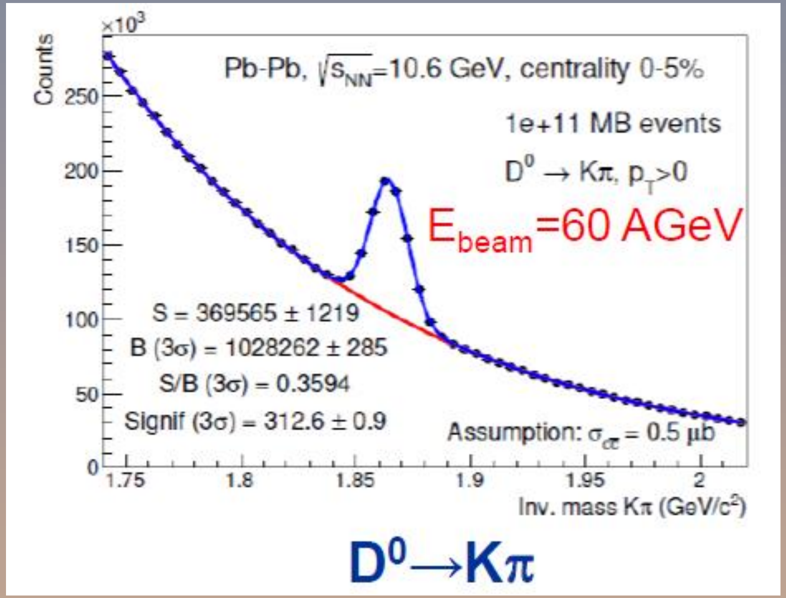
~2% uncertainty on the evaluation of T_{slope}

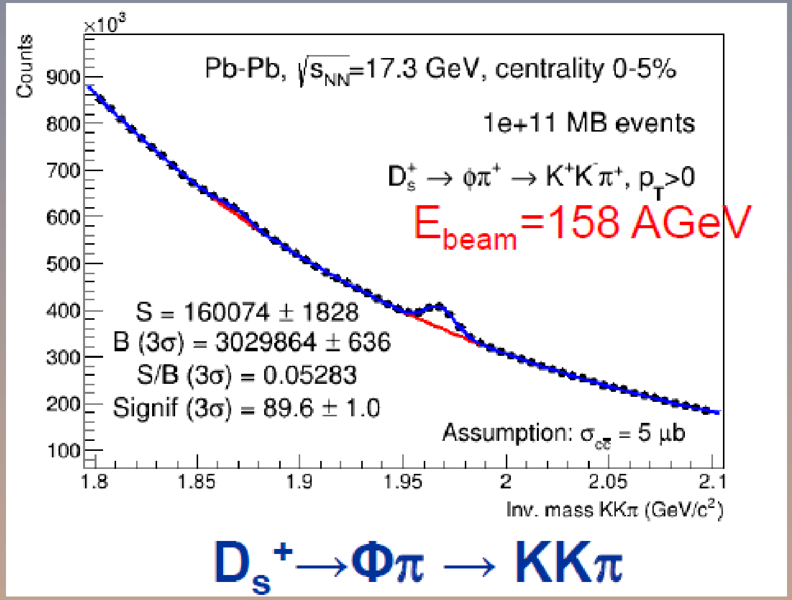
- 4×10^6 reconstructed central Pb-Pb for 1 month data taking at interaction rate ~200 kHz
  → Factor ~20 improvement with respect to NA60 (min. bias)!

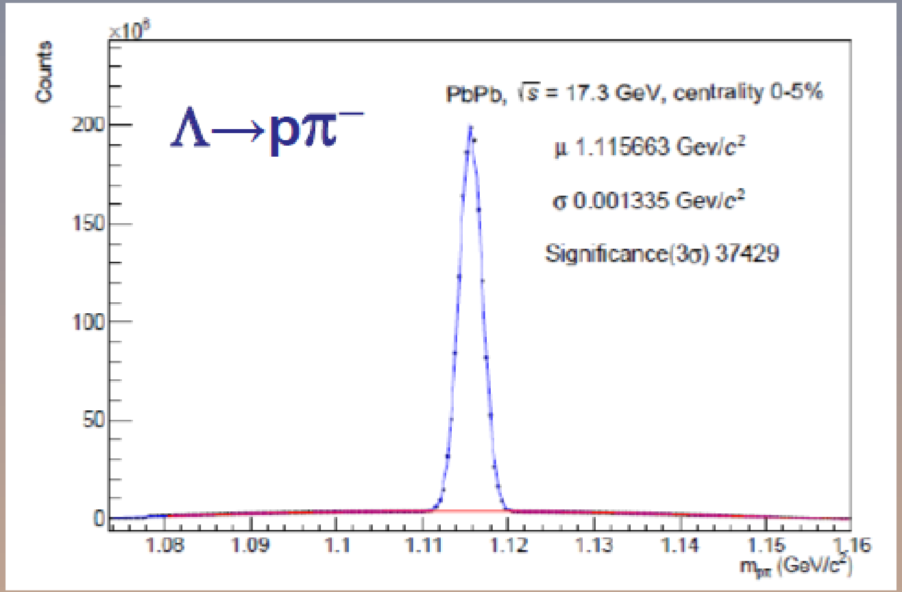
Accurate mapping of the region where T_{pc} is reached
→ Strong **sensitivity** to possible flattening due to 1st order transition

Open charm and strangeness

- **Open heavy flavor and strangeness measurements**
  → Hadronic decays of charm hadrons detected in the vertex spectrometer
- All simulations based on 10^{11} minimum bias events in Pb-Pb collisions (~1 month data taking)







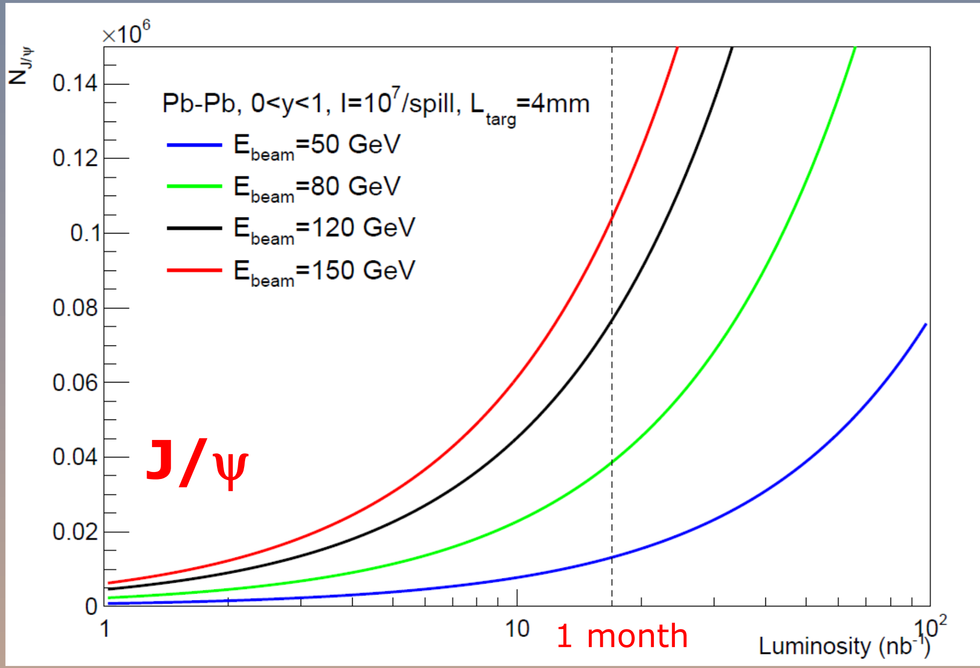
2-body HF decays studied down to low SPS energy

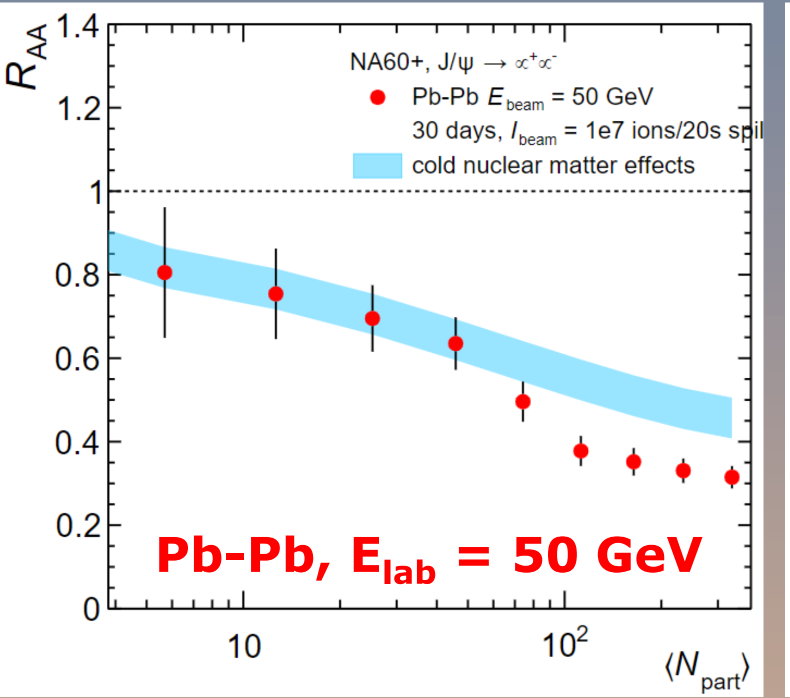
3-body HF decays studied for the moment at top SPS energy
→ Also Λ_c should be accessible

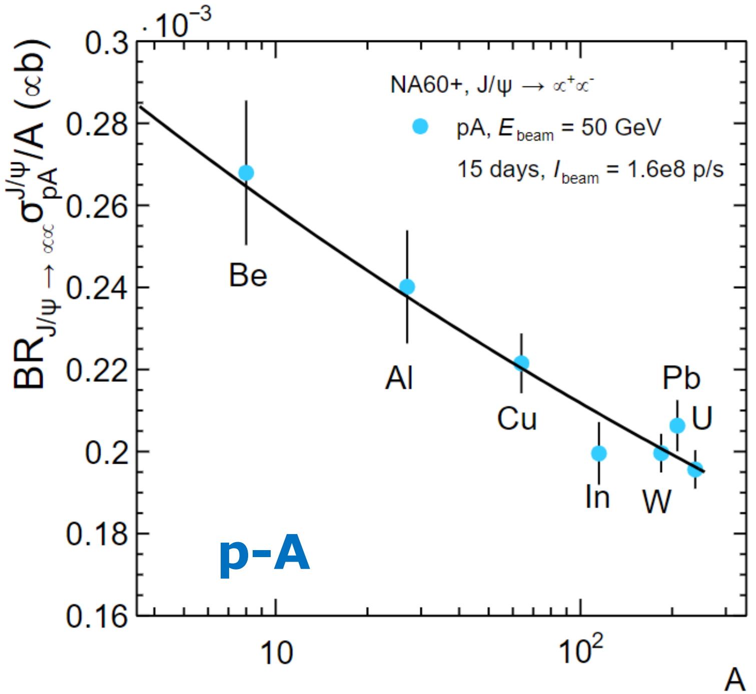
Excellent performance for strange hadrons
→ Very large statistical significance
→ Good prospects for measurement of Ξ and Ω hyperons

J/ψ: performance studies

- **Quarkonium measurements** in the dimuon channel







- 4mm Pb target and 1 month data taking → L_{int} =17 nb^{-1}

  NA60+ can aim at
  - **~O(10^4) J/ψ at 50 GeV**
  - **~O(10^5) J/ψ at 158 GeV**

- Allows detection of onset of anomalous suppression effects down to low SPS energy
- p-A data taking mandatory (few weeks/year), to calibrate CNM effects
- ψ(2S) also within reach, down to E=100-120 A GeV

Plans

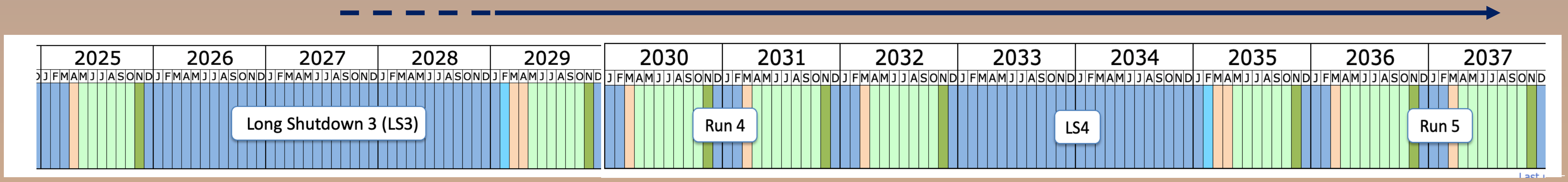
Timeline

- The project is part of the **Physics Beyond Colliders** CERN initiative since 2016 (QCD study group) and receives a substantial support on several technical aspects, including integration, RP and beam studies, and the project of the toroidal magnet

- An **Expression of Interest** (https://cds.cern.ch/record/2673280) was submitted in 2019 to the CERN SPSC

- A **Letter of Intent** is currently in (advanced) preparation, to be submitted in the first half of 2022

- Goal
  - 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 yrs** of data taking (one energy point per year with p-A and Pb-Pb)



Conclusions

- Precision studies of **electromagnetic and hard probes** in the region $6<\sqrt{s_{NN}}< 17$ GeV are currently lacking

- The CERN NA60 experiment had obtained measurements with unsurpassed precision in the study of dilepton production at top SPS energy ($\sqrt{s_{NN}}$ =17.3 GeV)

- **NA60+: a new dimuon experiment** with a similar concept but based on state-of-the-art technology choices may collect a factor ~20 larger statistics for several collision energies at the SPS

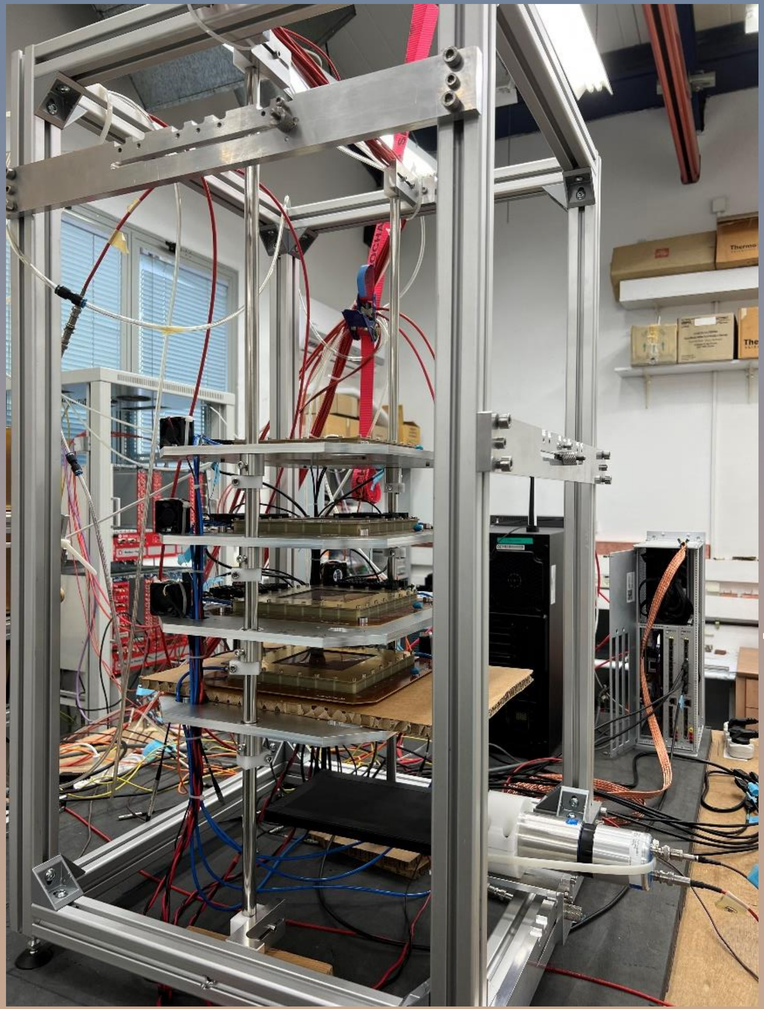
- Expected physics performance → possible **breakthrough** on several hot topics

- From **design to realization**: R&D studies ongoing, CERN test beam periods from 2022

A Collaboration is being built and still needs to be strengthened in order to bring the project to approval → you are welcome to contact us for discussions!

Backup slides

Muon tracker – Test and construction facility



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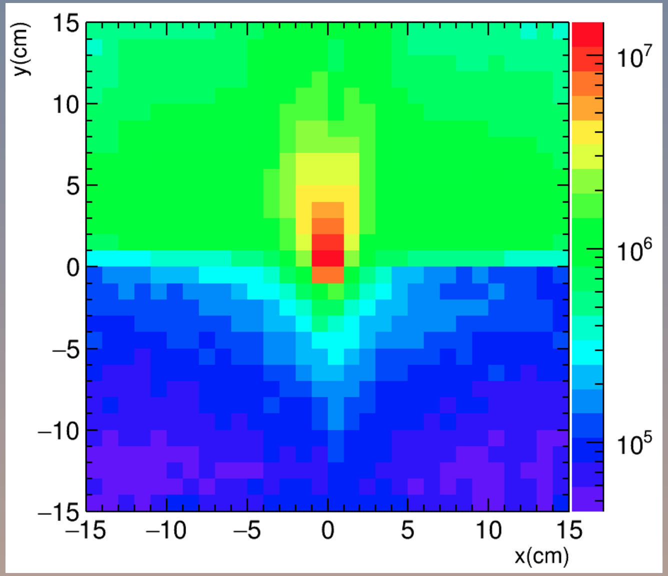
<40 μm resolution
→ Ideal testbench for test of NA60+ prototypes

Tracking telescope based **on triple GEM stations**
(100x100 mm^2, 2D readout, 256 strips, 400 μm pitch)

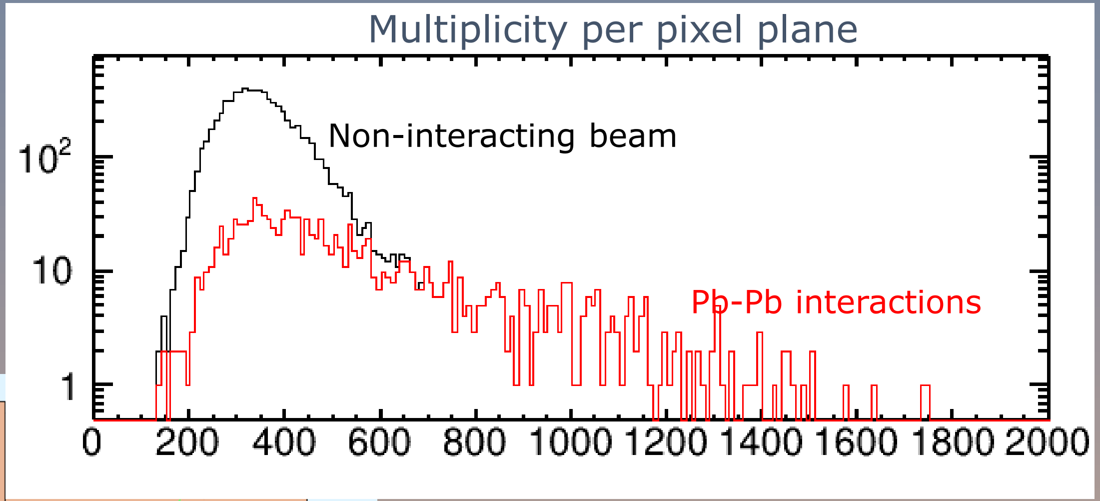
Weizmann Institute
World-class detector construction facility
(500 m^2 working area, clean rooms,
robotic-control winding machine,
X-ray scanner, electronic lab)

Operation conditions for vertex spectrometer

- Based on **FLUKA simulations** implementing a detailed experiment geometry
- 40 A GeV Pb beam on 5 Pb targets, 10^6 Pb/s

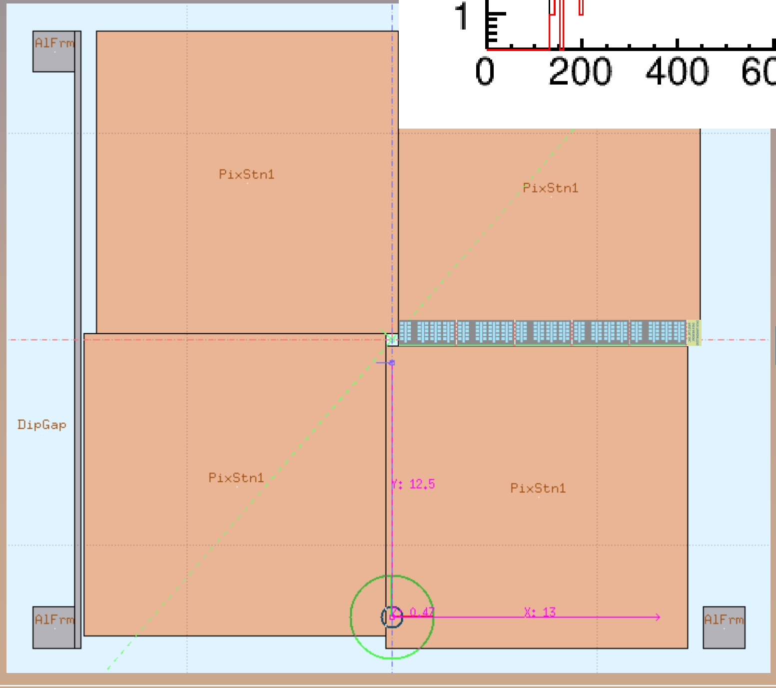


Upstream MAPS plane
(7.1 cm from last target)



Fluences up to 10^7/s close to the beam axis

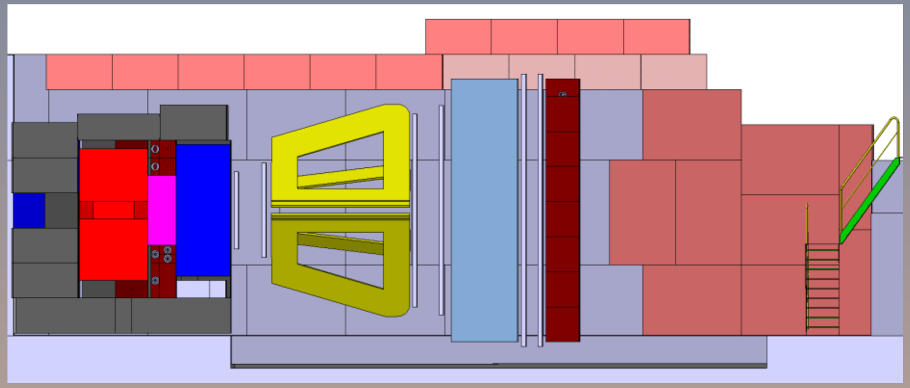
Significant contribution from δ-ray production (upward bent by dipole magnet)



Most "exposed" sensors get a 10-15 MHz rate
→ 20-30 MB/s data throughput

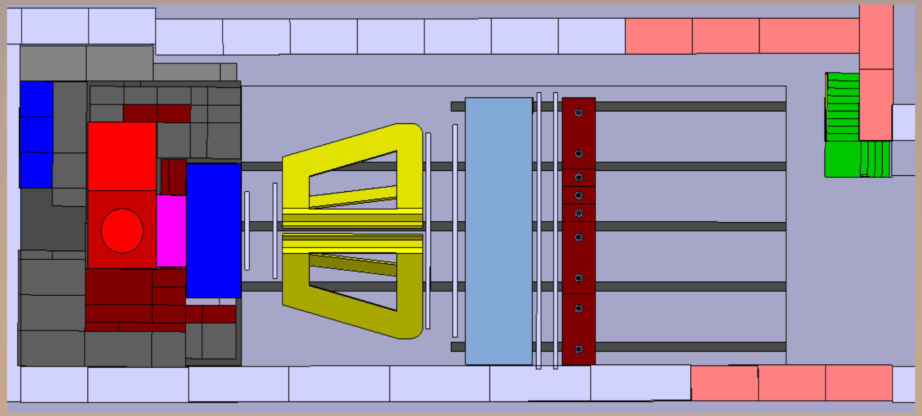
Integration, beam and RP studies

- Studies on three main aspects
  - Compatibility of the set-up with the proposed zone
  - Radiation protection studies ← delicate due to high beam intensity!
  - Development of beam optics

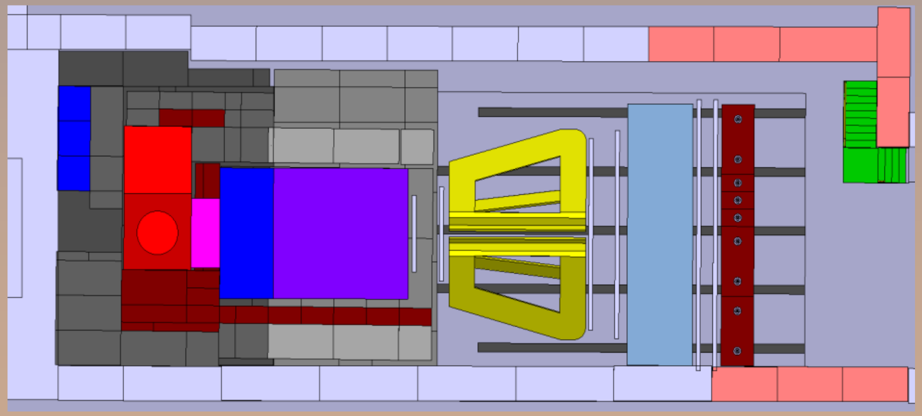


Side view

Installation and positioning of services under discussion



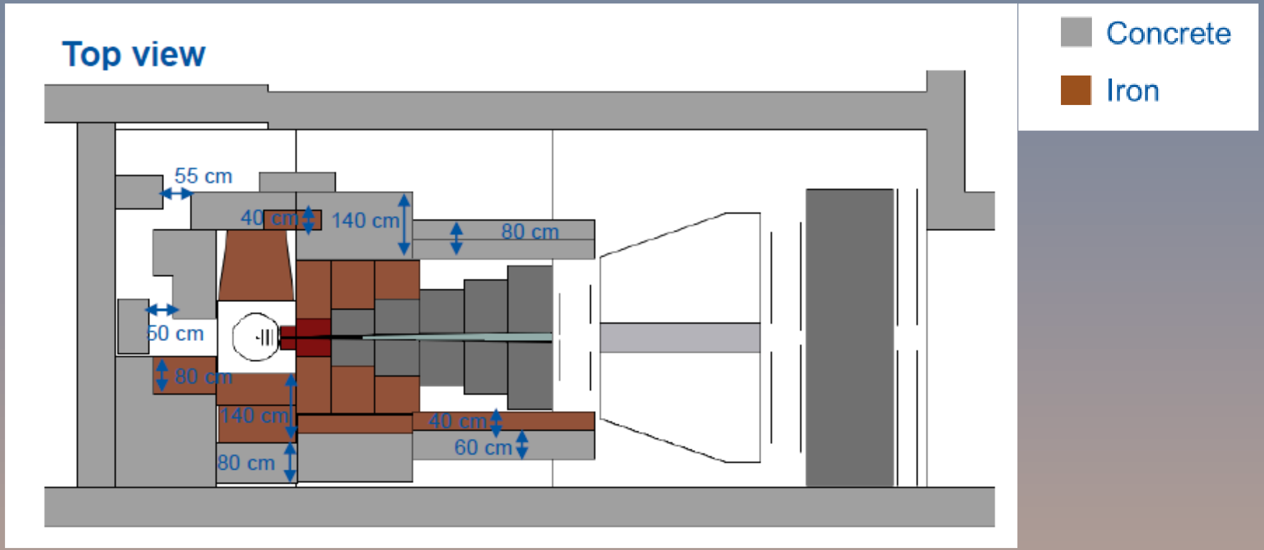
Top view (low-energy setup)

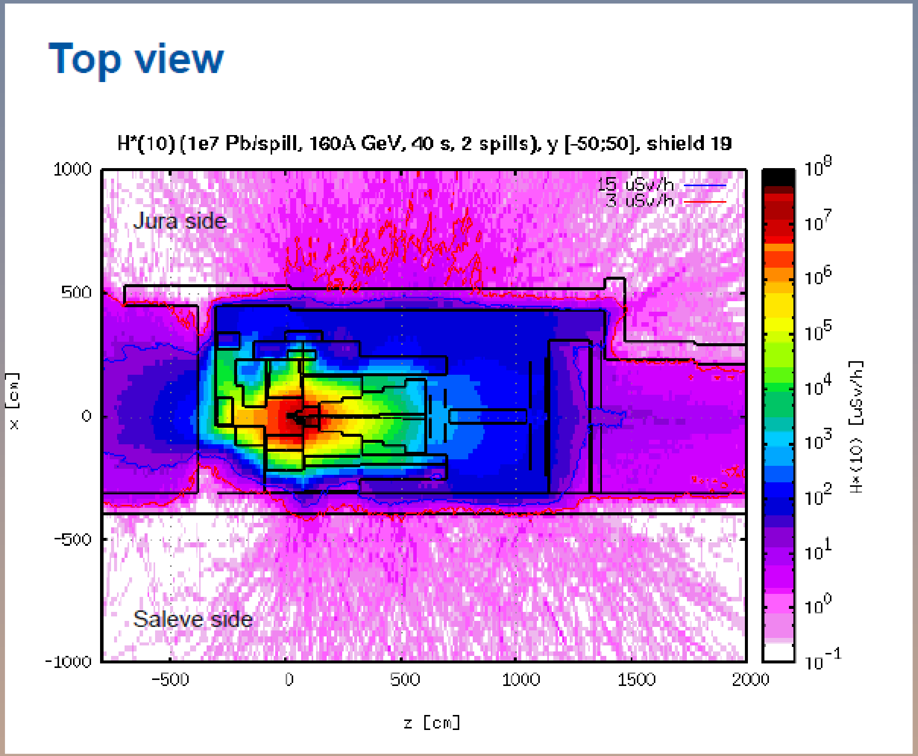


Top view (high-energy setup)

Integration, beam and RP studies

- ❑ Studies based on FLUKA geometry of the NA60+ set-up





- ❑ Installation on a surface zone implies strict requirements on radiation safety
- ❑ Dose has to be:
  - ❑ <3 μSv/h in permanent workplaces external to the experimental hall
  - ❑ <15 μSv/h in low occupancy regions

→ A thick shielding is necessary!

5. Conclusions: Feasibility Evaluation and Cost Estimation

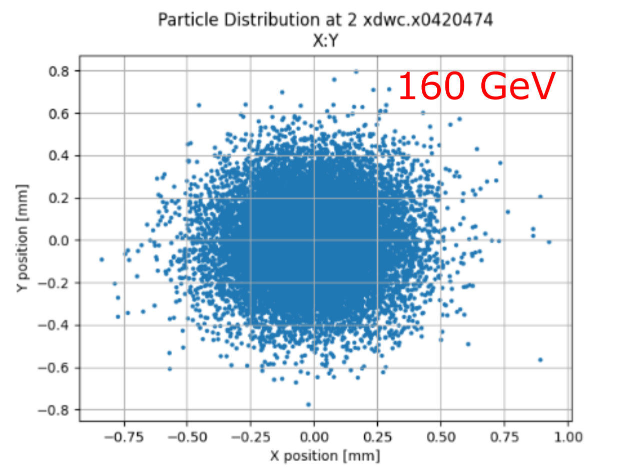
The potential integration of the NA60+ experiment in user zone PPE138 of EHN1 has been examined concerning beam physics requirements (Chapter 2), the infrastructure integration (Chapter 3) and radiation protection (Chapter 4). **The experiment is deemed to be feasible** with regard to these aspects. The aspects of general infrastructure, detector design, data acquisition and analysis as well as the physics reach have not been evaluated.

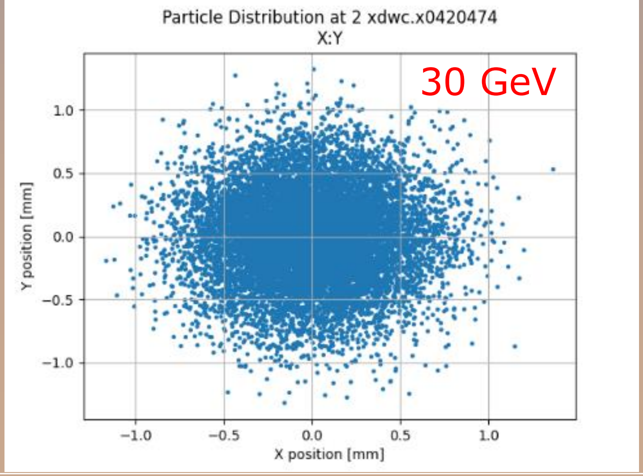
Integration, beam and RP studies

- Collimated beam ($\sigma \sim$ 1mm) needed from low to high SPS energy, keeping at the same time a high beam intensity (goal 10^7/spill)
  → Vertex spectrometer central hole, ∅ ~ 0.6 cm

- Low-energy is more critical: beam dimension increases, and collimators decrease transmission
  → Optics was re-designed in order to avoid losses at magnet apertures (dominating factor)

Parameter in zone 138	160 GeV/c	30 GeV/c
σ_x (mm)	0.19	0.33
σ_y (mm)	0.19	0.36
Transmission from T4 (%)	32.43	23.5

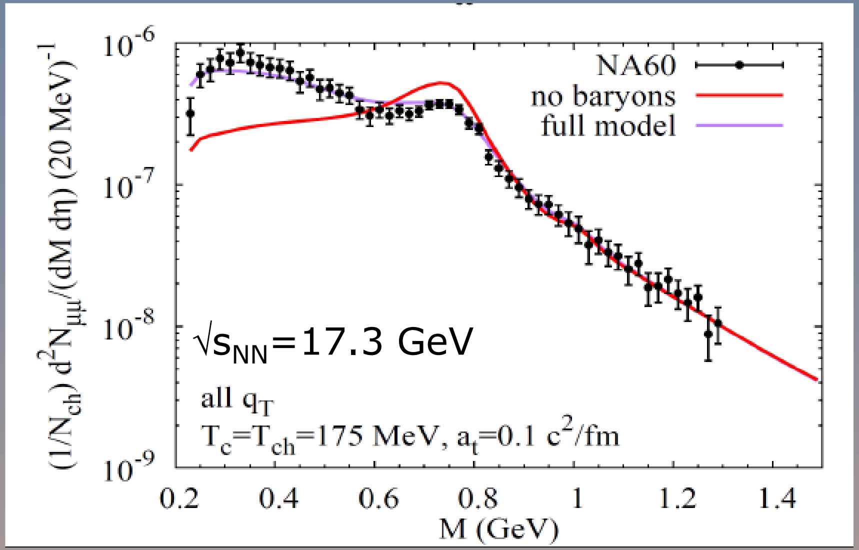




- Optics at the entrance of the H8 beam line (T4 target, 480 m upstream) based on estimates for another extraction (T2), as no data were available

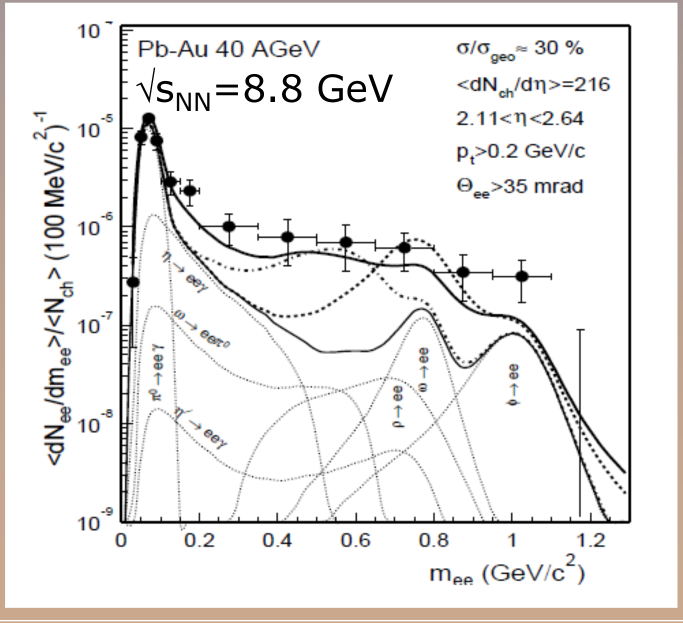
Test of new optics with real beams will take place in November 2022

Dilepton studies at CERN SPS energy



- NA60 → low- and intermediate-mass dileptons at top SPS energy
  - First precision measurement of
    - in-medium ρ modifications
    - Temperature via thermal dimuons in $1.5<m_{\mu\mu}<2.5$ GeV/c^2

R. Arnaldi et al. (NA60), EPJC 61(2009) 711

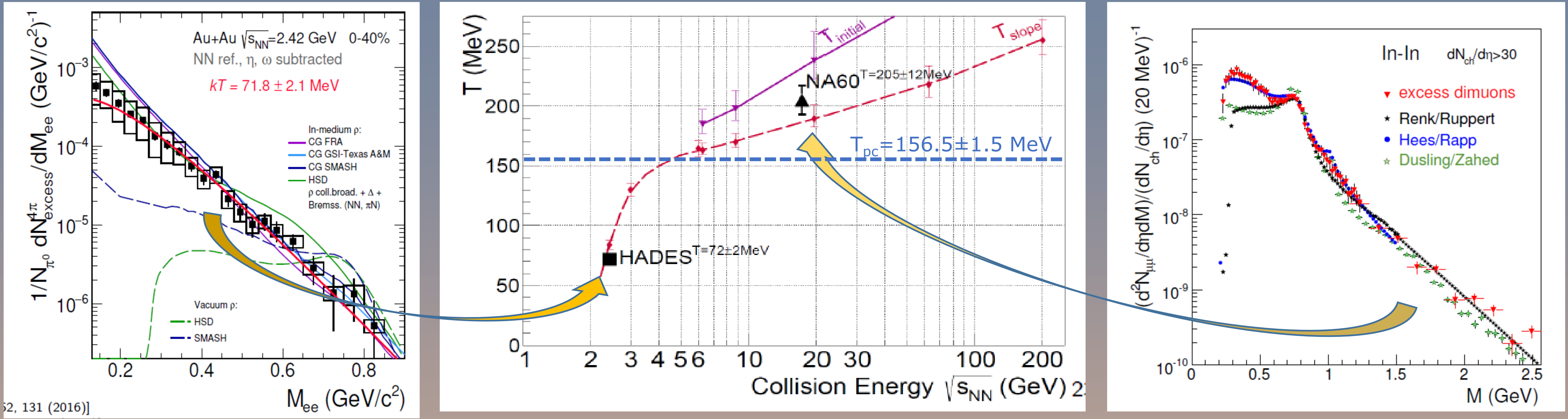


Region below top SPS energy almost unexplored

- Only a CERES measurement (low-mass dileptons at $\sqrt{s_{NN}}$=8.8 GeV)
  - **Dielectron excess** (central Pb-Au)
  - Indication (1.8 σ) for excess due to in-medium modifications of ρ spectral function

D. Adamova et al. (CERES), PRL91 (2003)042301

Study of dilepton production at low energy



HADES, Nature Phys. 15(2019) 1040

Adapted from T. Galatyuk

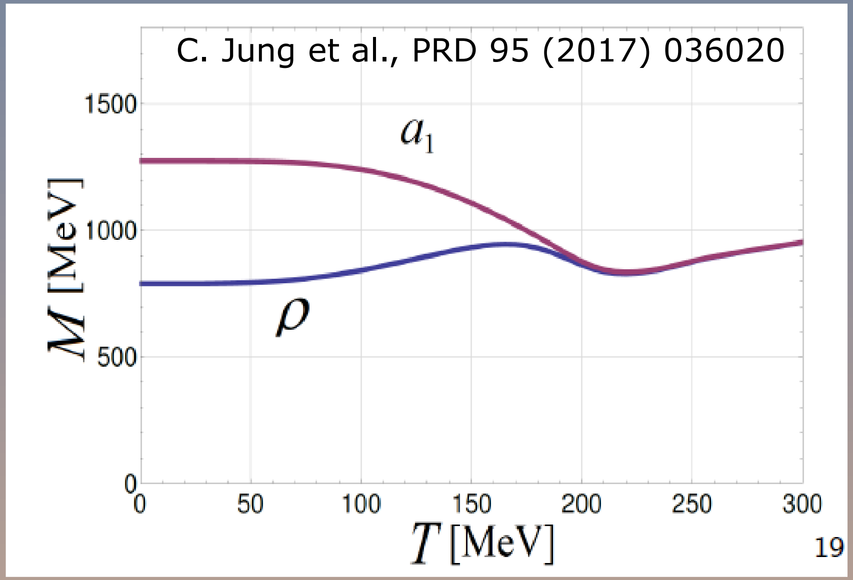
R. Arnaldi et al. (NA60), EPJC 61(2009) 711

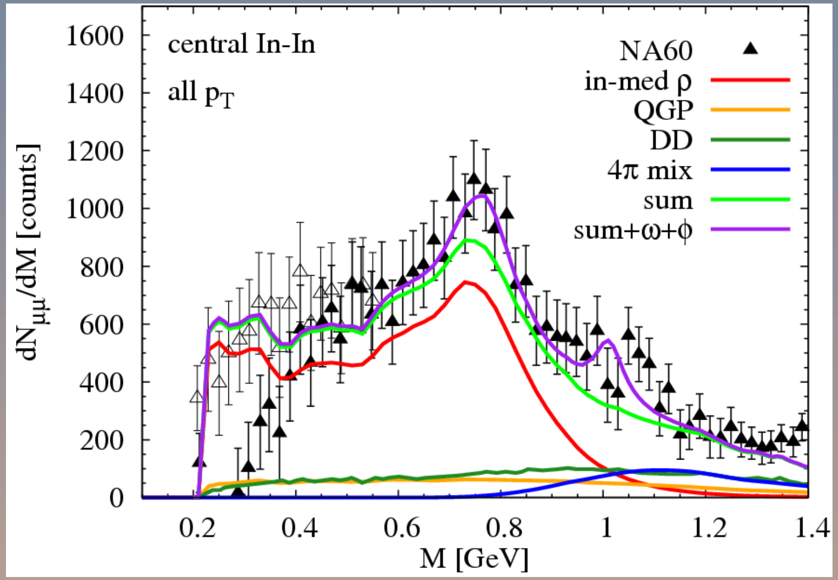
- ❑ HADES (SIS) and NA60 (SPS) have provided dilepton T_{slope} measurements
- ❑ A study of the T_{slope} evolution in $\sqrt{s_{NN}}$ ~3-20 GeV may provide accurate information on the region of the "transition temperature" associated with the change in the degrees of freedom of the system

→ Strong motivation for a measurement of a caloric curve T_{slope} vs $\sqrt{s_{NN}}$ with a few percent accuracy

Dilepton spectrum and chiral symmetry restoration

- Broadening of ρ-meson spectral function is qualitatively consistent with chiral symmetry restoration → need to investigate the chiral partner a_1





R. Rapp et al., arXiv:0901.3289

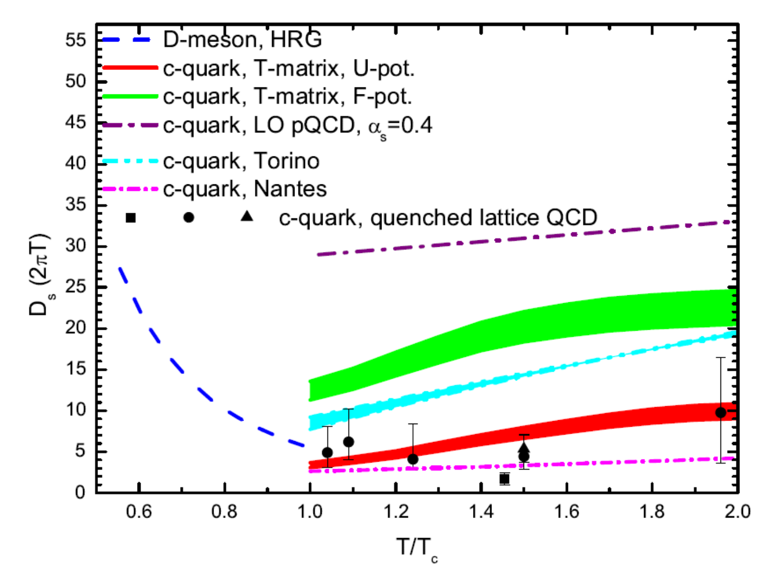
- No direct coupling of axial states to the dilepton channel
  → in vacuum the ($e^+ e^- \rightarrow$ hadrons) cross section has a dip in the a_1 mass range

- Chiral symmetry restoration → mixing of vector (V) and axial-vector (A) correlators
  → enhancement of the dilepton rate for $m_{\mu\mu}$ ~ 1-1.4 GeV/c^2
- Low-energy measurement expected to be more sensitive to chiral restoration effects
  → (Exponential) thermal dimuon yield from QGP becomes smaller
  → Contribution from open charm becomes relatively negligible

Open charm at SPS energy

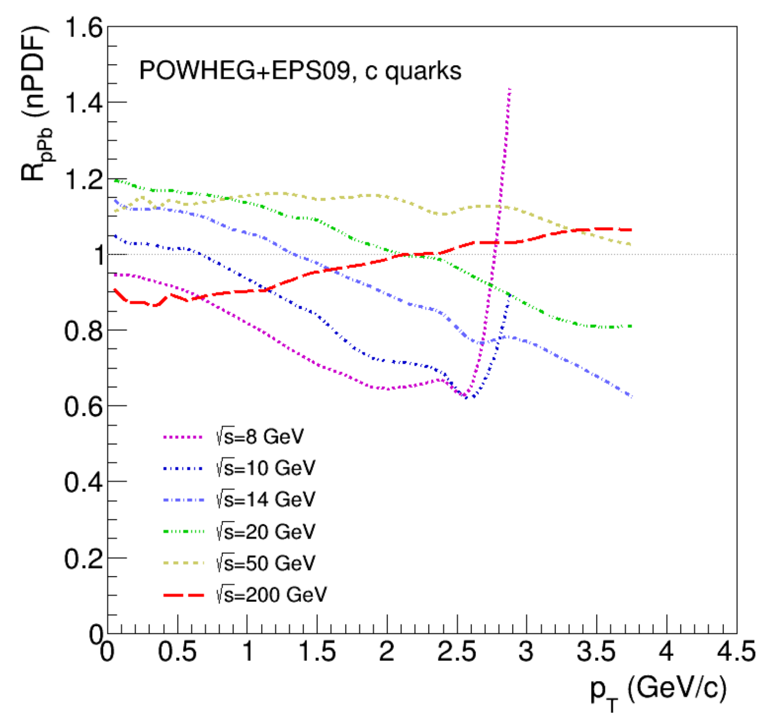
- ❑ No results available below top SPS energy

F. Scardina et al., PRC96 (2017) 044905



- ❑ Charm hadron yield and v_2 in Pb-Pb collisions
  - ❑ Constrain estimates of the charm diffusion coefficient D_s
  - ❑ Charm quark thermalization in a short-lived QGP
  - ❑ Insight into hadronization mechanisms
    → enhanced D_s^+/D, Λ_c/D ratios in case of quark recombination
- ❑ Charm cross section sensitive to chiral symmetry restoration restoration, due to possible lowering of DD threshold

- ❑ **Charm** production in pA
  → Sensitive to nPDFs
  → $Q^2 \sim 10–40$ GeV^2 and $0.1<x_{Bj}<0.3$ ($p_T<3$ GeV/c) (from anti-shadowing to EMC region)
  → Possible sensitivity to intrinsic charm



Charm production at SPS energy is an uncharted territory!

Charmonium at SPS energy

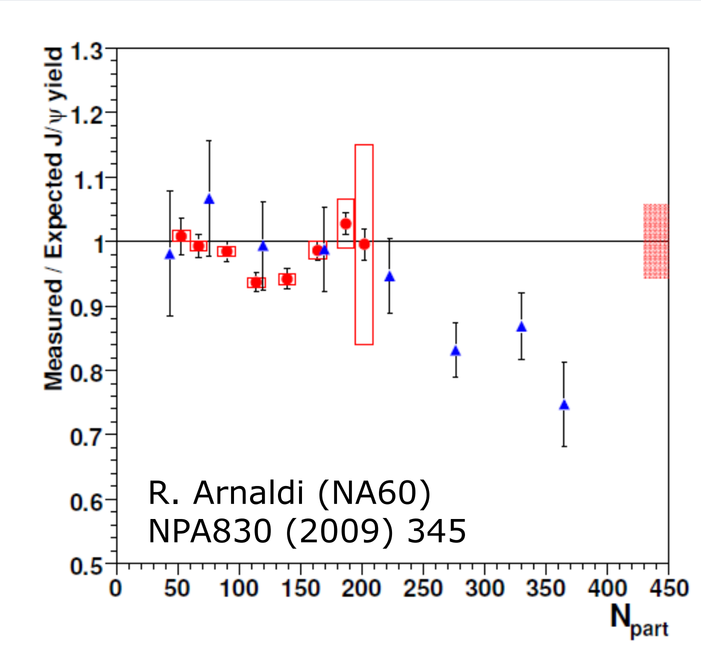
- The only "hard probe" studied at (top) SPS energy

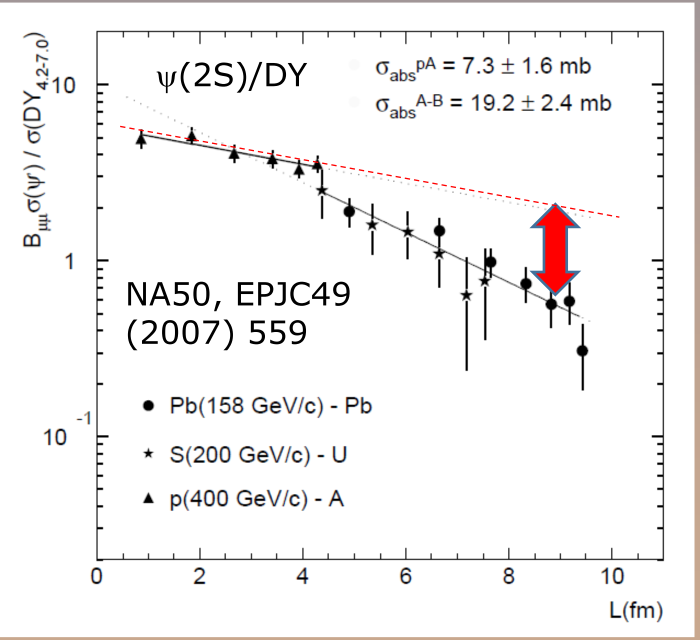
- J/ψ
- 30% suppression for central Pb-Pb events at top SPS energy, after accounting for CNM effects
  → Compatible with suppression of more weakly bound χ_c and ψ(2S) states decaying to J/ψ

- ψ(2S)
- Exhibits strong suppression already in peripheral Pb-Pb collisions, up to a factor ~5 for central collisions
  → sensitivity to the hadronic phase

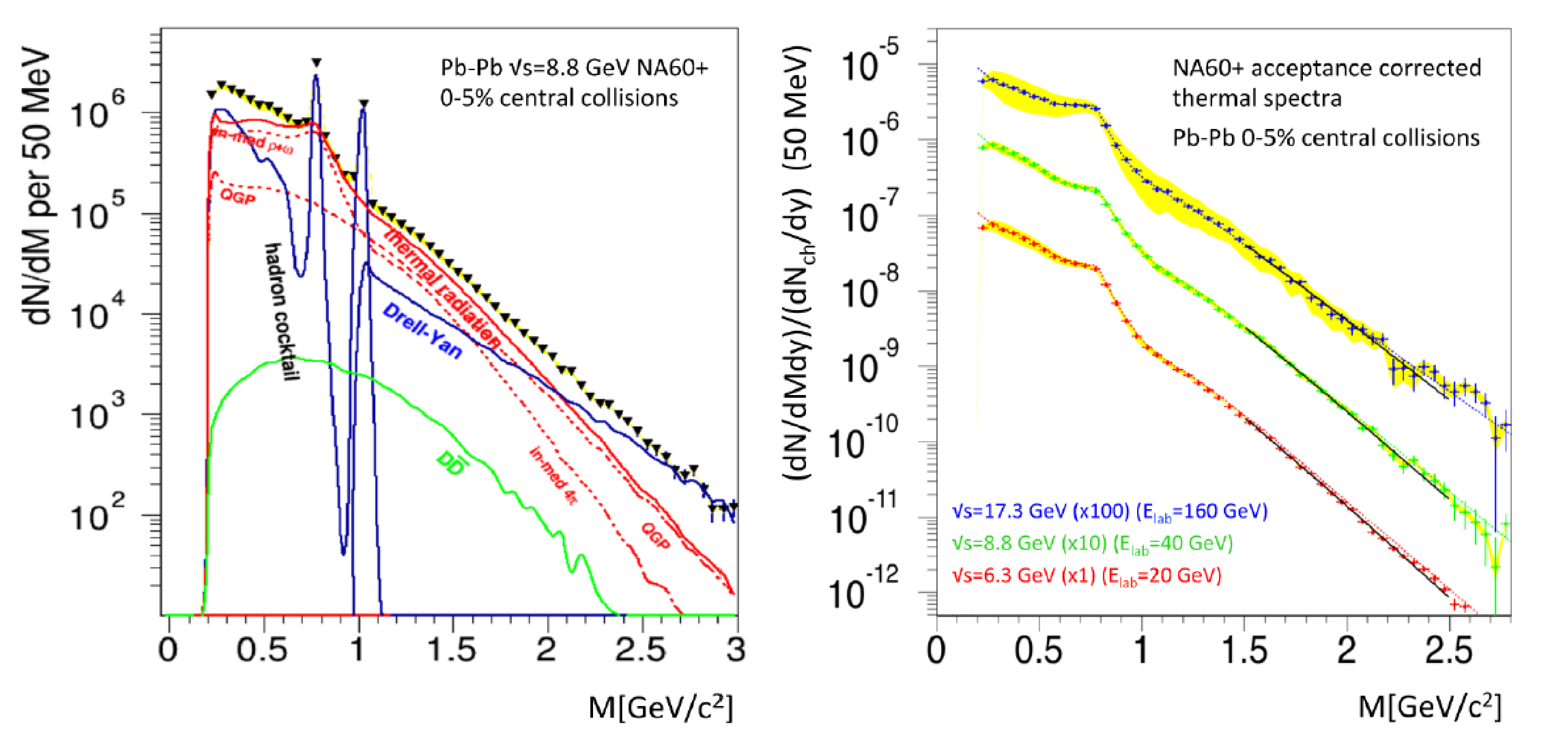
- Energy scan towards low SPS energy
  → Detect suppression threshold and correlate with T via thermal dimuons
  → Study elliptic flow, sensitive to medium properties
  → Detect suppression threshold and correlate with T via thermal dimuons
  → Strong variations of the ratio J/ψ/D at deconfinement threshold ?

Quarkonium physics not studied below top SPS energy!





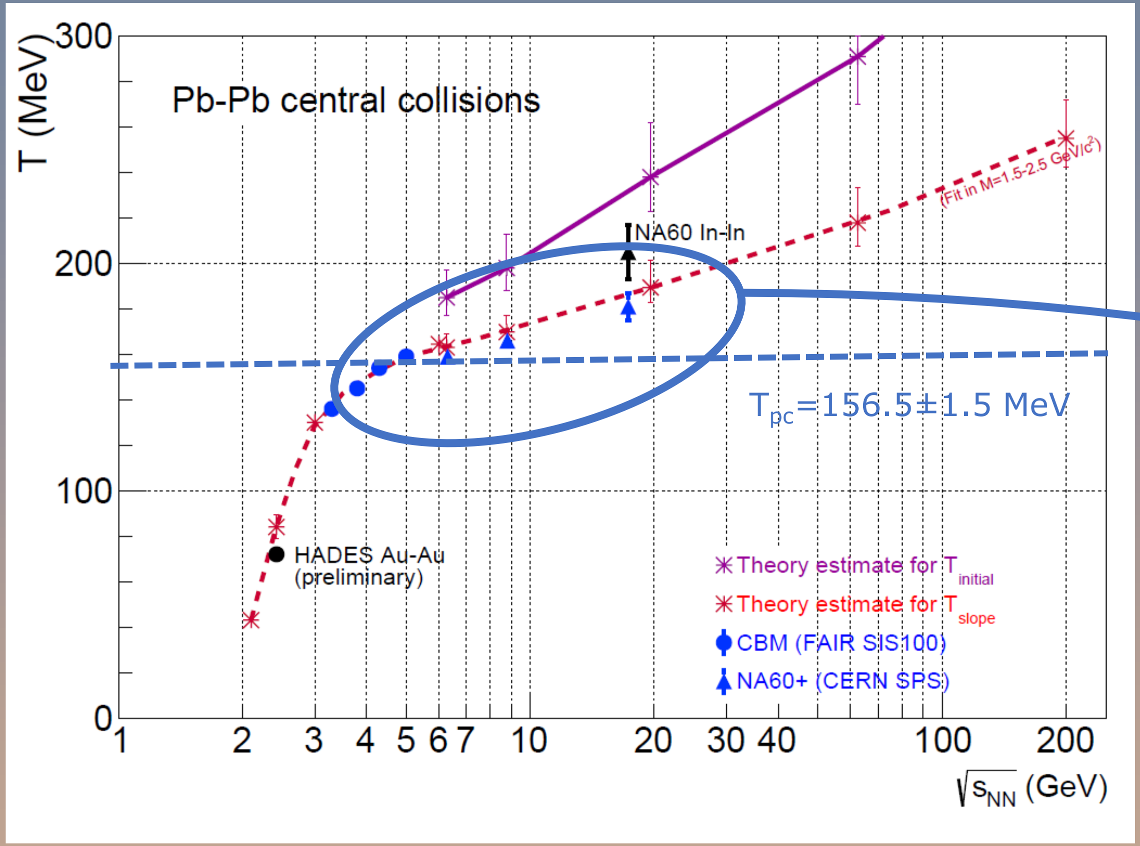
T_{slope} measurement



- Thermal radiation yield
  - Dominated by ρ contribution at low mass
  - Accessible up to $M=2.5\text{-}3$ GeV/c^2
- Drell-Yan contribution
  → to be also estimated via p-A measurements

- Acceptance-corrected signal spectra fitted with $dN/dM=M^{3/2}\exp(-M/T_s)$ in the interval $1.5<M<2.5$ GeV/c^2

T_{slope} measurement



T_{pc}=156.5±1.5 MeV

T_{slope} values from thermal yields in 1.5<M<2.5 GeV/c^2

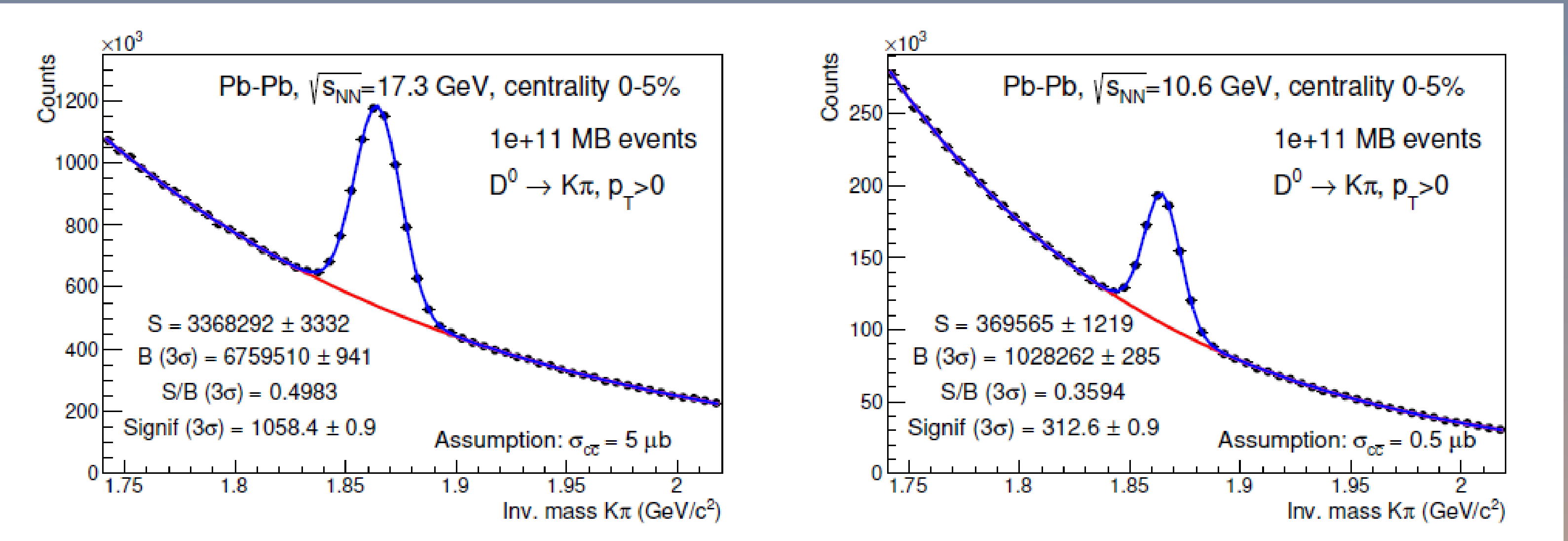
Theory
- √s>6 GeV, R. Rapp, PLB 753 (2016) 586
- √s<6 GeV, T. Galatyuk, EPJA 52 (2016) 131

A few MeV accuracy can be reached (1.4 to 5 MeV for $\sqrt{s_{NN}}$ to 6.3 to 17.3 MeV) on T_{slope}

Accurate mapping of the region where the pseudocritical temperature is reached !
Sensitive to potential effects expected in case of 1st order phase transition!

Hard probes: open charm

- ❑ Hadronic decays of charmed particles can be reconstructed in the vertex spectrometer (no PID)



- ❑ $D^0 \to K^+\pi^-$ (POWHEG-BOX+PYTHIA6)
- ❑ Background from NA49 light hadron production data

- ❑ 0-5% Pb-Pb, $\sqrt{s_{NN}}$=17.3 GeV
  - ❑ 1200 p,K,π per event
  - ❑ 8×10^3 candidates in $m_D\pm60$ MeV
  - ❑ S/B~10^{-7}, enhanced with kinematic and geometric selections

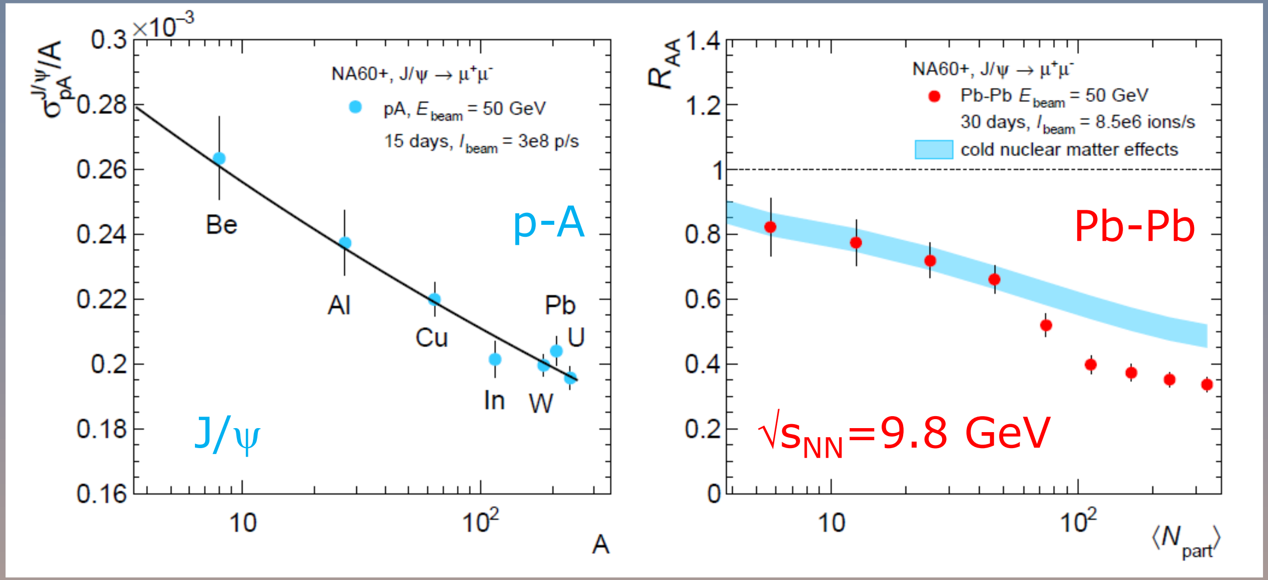
(equivalent to 30 days data taking at 150 kHz)

- ❑ Measurement for $\Lambda_c \to pK\pi$ more challenging → 3-particle decay, S/B~ 10^{-10}
- ❑ Alternatively, $\Lambda_c \to pK^0_S$ $K^0_S \to \pi\pi$ (lower BR, lower background)
- ❑ Measurement of $D^+_S \to KK\pi$

} in progress

Good prospects for a first low-energy measurement of charm in nuclear collisions!

Hard probes: charmonium

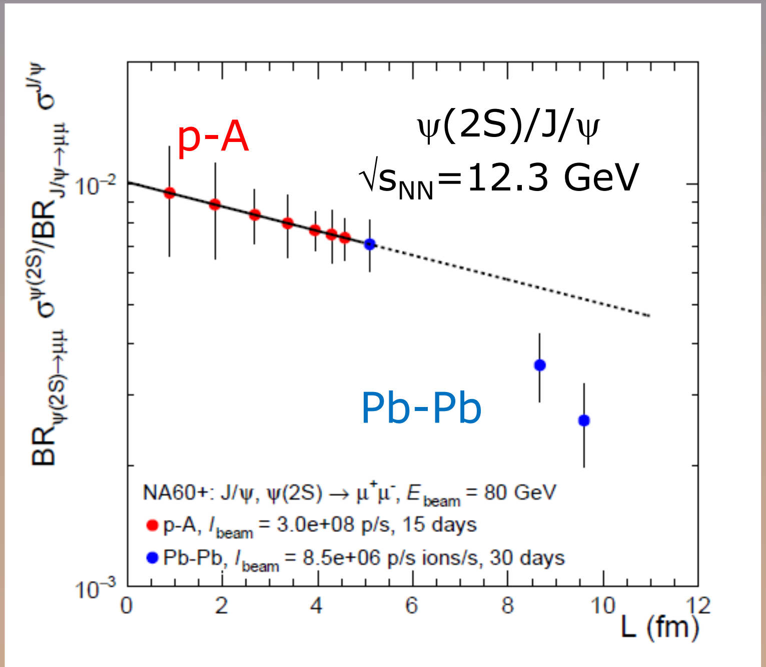


- p-A measurement → calibrate CNM effects (assume same effect as measured by NA60 at $\sqrt{s_{NN}}$=17.3 GeV)
- Extrapolate CNM effect to Pb-Pb and compare with a scenario where anomalous suppression sets in at N_{part} ~50 and reaches 20% (was ~30% at $\sqrt{s_{NN}}$=17.3 GeV)
- Assume 30 days of Pb beam and ~ 10^7 Pb/s

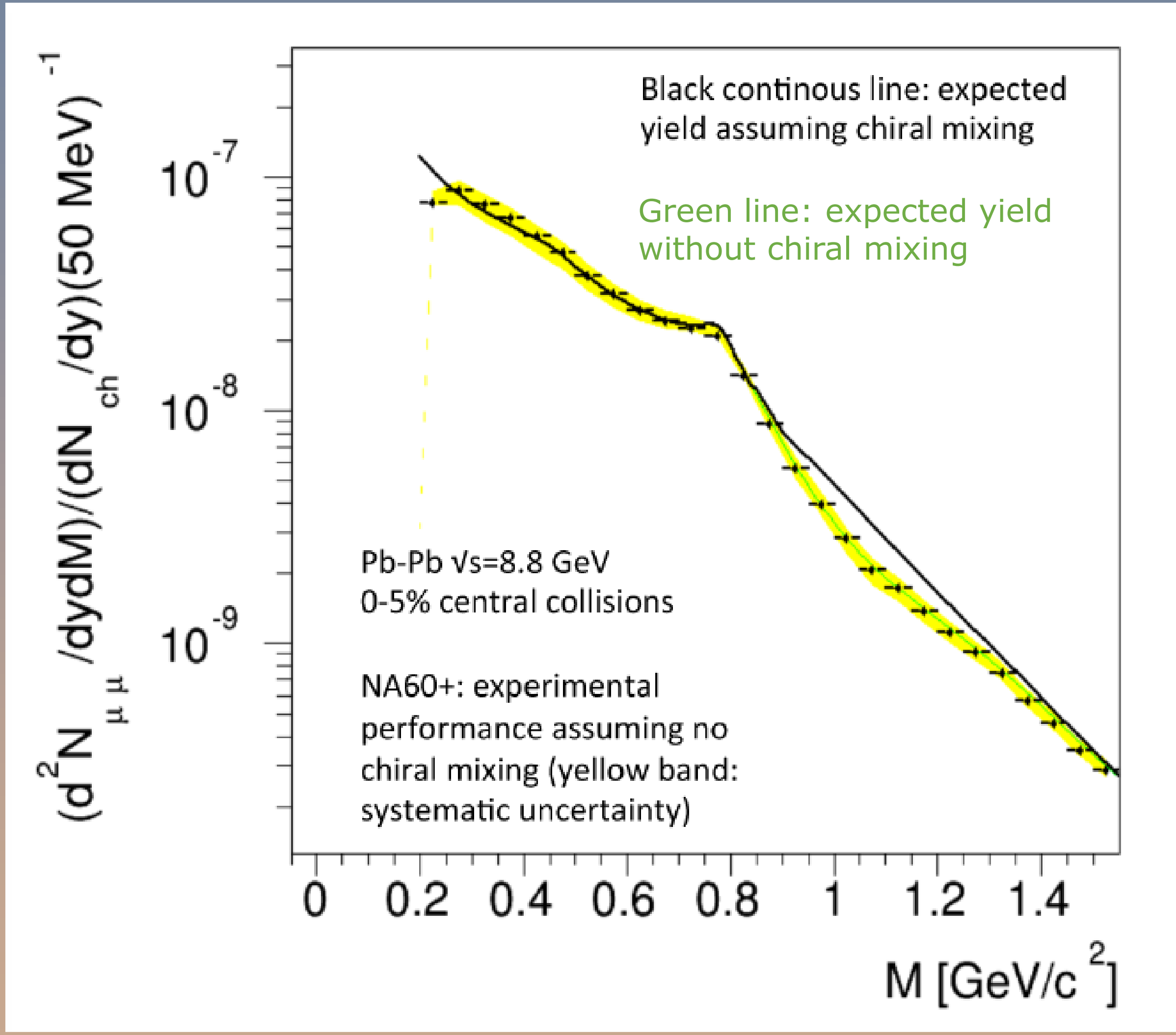
Good sensitivity to J/ψ suppression onset

ψ(2S)
pA → assume stronger suppression for ψ(2S) relative to J/ψ (as measured by NA50 at $\sqrt{s_{NN}}$=29 GeV)
Pb-Pb → assume factor ~2 stronger suppression for ψ(2S)

Look for the onset of ψ(2S) suppression



Sensitivity to chiral symmetry restoration



- ❑ Simulations carried out by considering
  - ❑ No chiral mixing (dip in $1<M<1.4$ GeV/c^2)
  - ❑ Full ρ-a_1 chiral mixing

(modeled from Rapp, vanHees, PLB753 (2016) 586)

- ❑ A 20-30% enhancement is expected in case of full mixing

With the foreseen accuracy of the measurement the effect can be clearly detected!

NA60+ Expression of Interest

http://cds.cern.ch/record/2673280

Signed by 82 physicists from France, Germany, India, Italy, Japan, Switzerland, USA

The NA60+ Collaboration

M. Agnello[14,16], F. Antinori[12], H. Appelshäuser[2], M. Arba[7], R. Arnaldi[14], R. Bailhache[2], L. Barioglio[17,14], S. Beole[17,14], A. Beraudo[14], F. Bergsma[20], A. Bianchi[17,14], L. Bianchi[17,14], E. Botta[17,14], E. Bruna[14], S. Bufalino[16,14], E. Casula[7,8], F. Catalano[16,14], S. Chattopadhyay[6], A. Chauvin[7], C. Cicalo[7], M. Concas[15,14], P. Cortese[18,14], T. Dahms[4,5,i], A. Dainese[12], A. Das[6], D. Das[6], D. Das[6], I. Das[6], L. Das Bose[6], A. De Falco[7,8], N. De Marco[14], S. Delsanto[17,14], A. Drees[22], L. Fabbietti[5], P. Fecchio[16,14], A. Ferretti[17,14], A. Feliciello[14], M. Gagliardi[17,14], P. Gasik[5], F. Geurts[21], P. Giubilato[12,13], P.A. Giudici[20], V. Greco[9], F. Grosa[16,14], H. Hansen[1], J. Klein[14], W. Li[21], M.P. Lombardo[11] D. Marras[7], M. Masera[17,14], A. Masoni[7], P. Mereu[14], L. Micheletti[17,14], A. Mulliri[7,8], L. Musa[20], M. Nardi[14], H. Onishi[19], C. Oppedisano[14], B. Paul[7,8], S. Plumari[10], F. Prino[14], M. Puccio[17,14], L. Ramello[18,14], R. Rapp[23], I. Ravasenga[16,14], A. Rossi[12,13], P. Roy[6], B. Schmidt[20], E. Scomparin[14,i], S. Siddhanta[7], R. Shahoyan[20], T. Sinha[6], M. Sitta[18,14], H. Specht[3], S. Trogolo[17,14], R. Turrisi[12], M. Tuveri[7], A. Uras[1], G. Usai[7,8,i,ii], E. Vercellin[17,14], J. Wiechula[2], S. Winkler[5]

- Observables
- Requirements
- Experimental layout
- Detectors
- Physics performances
- Competition with other measurements

Expression of Interest for a new experiment at the CERN SPS: NA60+

NA60+ Collaboration

CERN-SPSC-2019-017 / SPSC-EOI-019
03/05/2019

Abstract

The exploration of the phase diagram of Quantum ChromoDynamics (QCD) is carried out by studying ultrarelativistic heavy-ion collisions. The energy range covered by the CERN SPS ($\sqrt{s_{NN}} \sim$ 5–17 GeV) is ideal for the investigation of the region of the phase diagram corresponding to finite baryochemical potential (μ_B), and has been little explored up to now. In this Expression of Interest, we describe the physics motivations and the exploratory studies for a new experiment, NA60+, that would address several observables which are fundamental for the understanding of the phase transition between hadronic matter and a Quark–Gluon Plasma (QGP) at SPS energies. In particular, we propose to study, as a function of the collision energy, the production of thermal dimuons from the created system, from which one would obtain a caloric curve of the QCD phase diagram that is sensitive to the order of the phase transition. In addition, the measurement of a ρ–a_1 mixing contribution would provide crucial insights into the restoration of the chiral symmetry of QCD. In parallel, studies of heavy quark and quarkonium production would also be carried out, providing sensitivity for transport properties of the QGP and the investigation of the onset of the deconfinement transition. The document defines an experimental set-up which couples a vertex telescope based on monolithic active pixel sensors (MAPS) to a muon spectrometer with tracking (GEM) and triggering (RPC) detectors within a large acceptance toroidal magnet. Results of physics performance studies for most observables accessible to NA60+ are discussed, showing that the results of the experiment would lead to a significant advance of our understanding of (non-perturbative) strong interaction physics. It is also shown that beam intensities of the order of 10^7 lead ions/s are required in order to obtain meaningful results on the various physics topics. Such intensities can presently be reached only in the ECN3 underground hall of the SPS. In addition, the support and engagement of CERN for the development, construction and operation of the toroidal magnet is considered crucial for the success of the project.

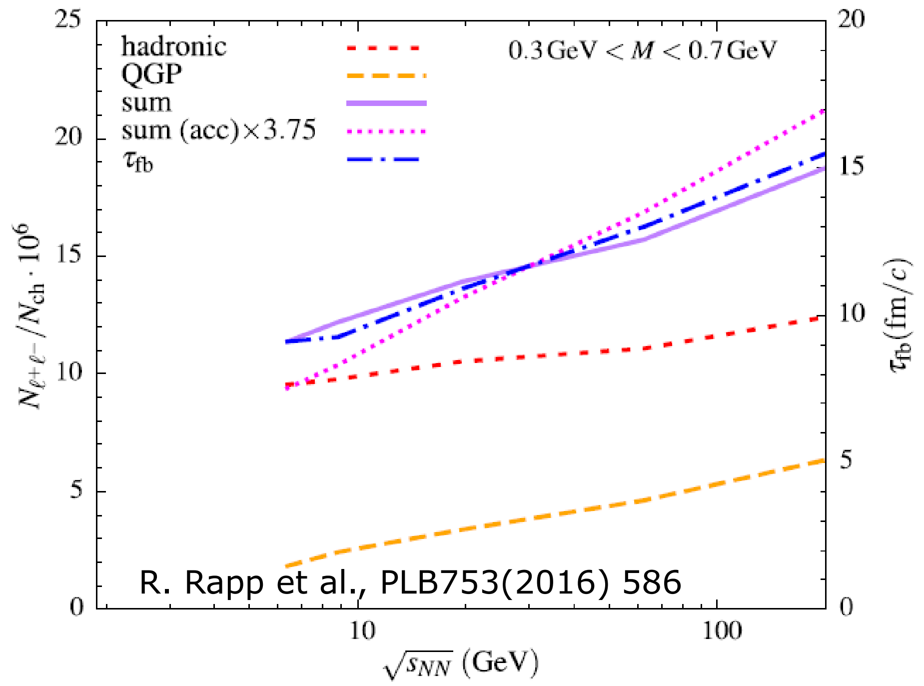
May 3, 2019

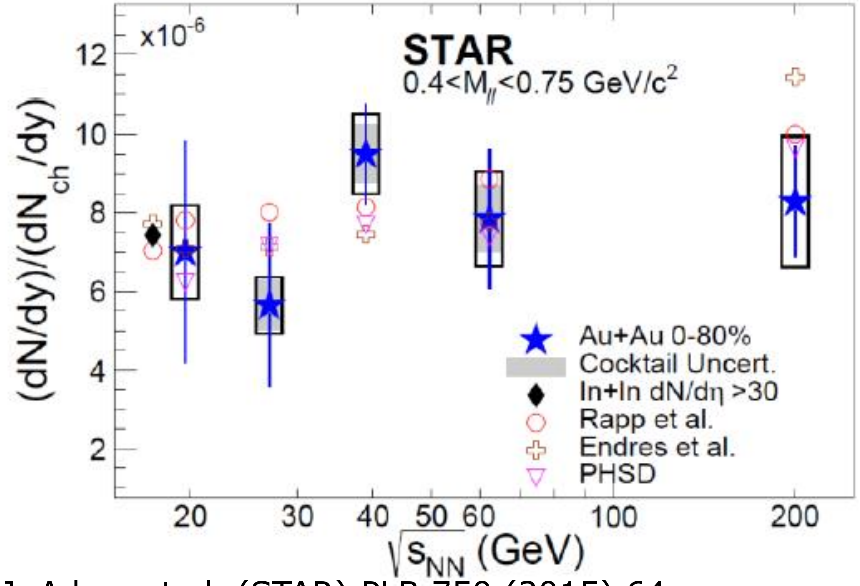
Dilepton excitation function and fireball lifetime

- Fireball lifetime directly related to acceptance corrected low-mass dilepton yield in 0.3>M>0.75 GeV
  → promising tool to detect "anomalous" variations as a function of collision energy

- Such variations could be triggered by the presence of a soft mixed phase during a first order transition
  → fireball lifetime anomalously increased due to the burning of latent heat
  → appearance a plateau in the thermal dilepton yield vs collision energy

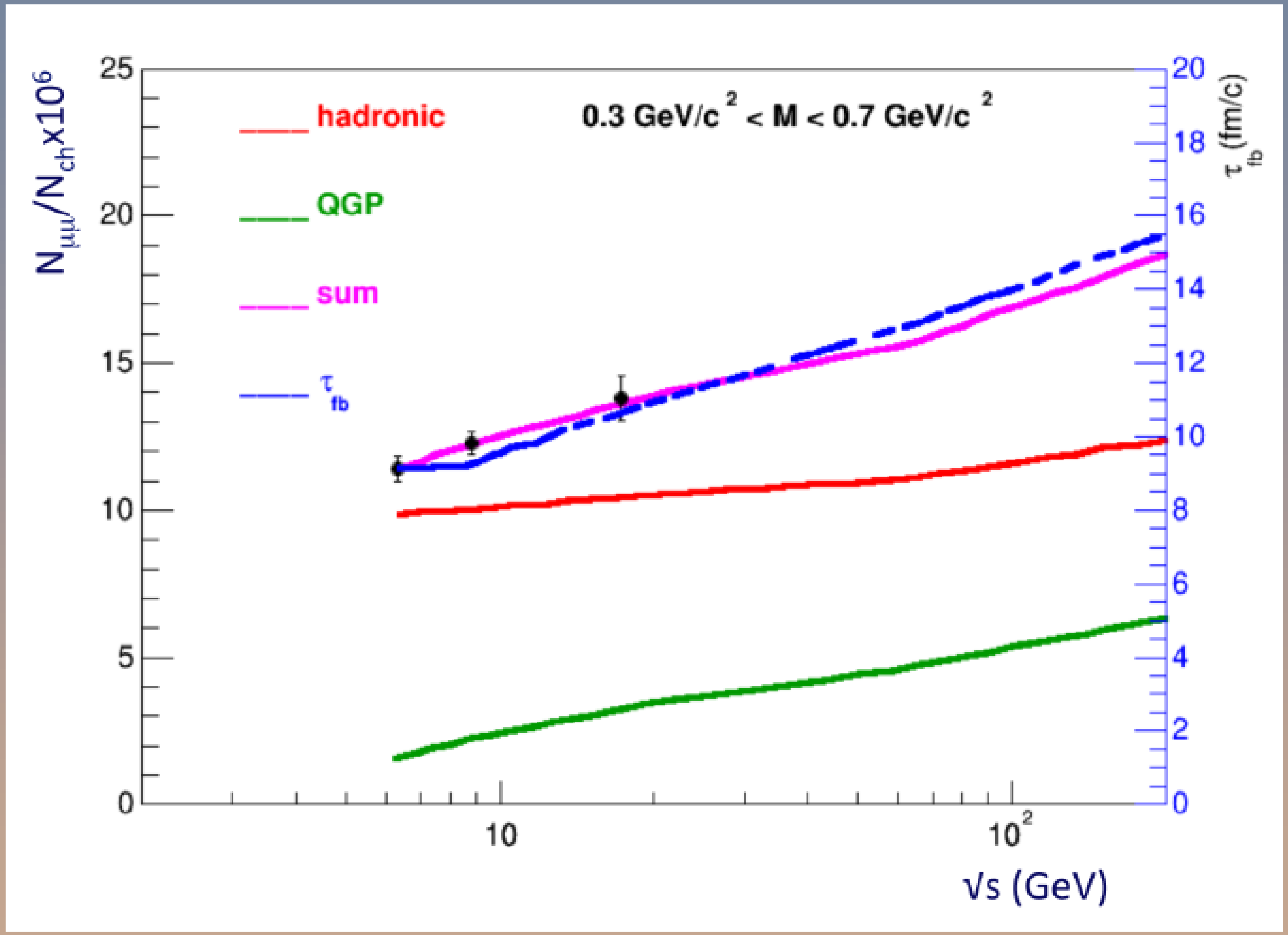
Needs a precision measurement at energies below top SPS!





J. Adam et al. (STAR) PLB 750 (2015) 64

Thermal dimuons as a fireball chronometer

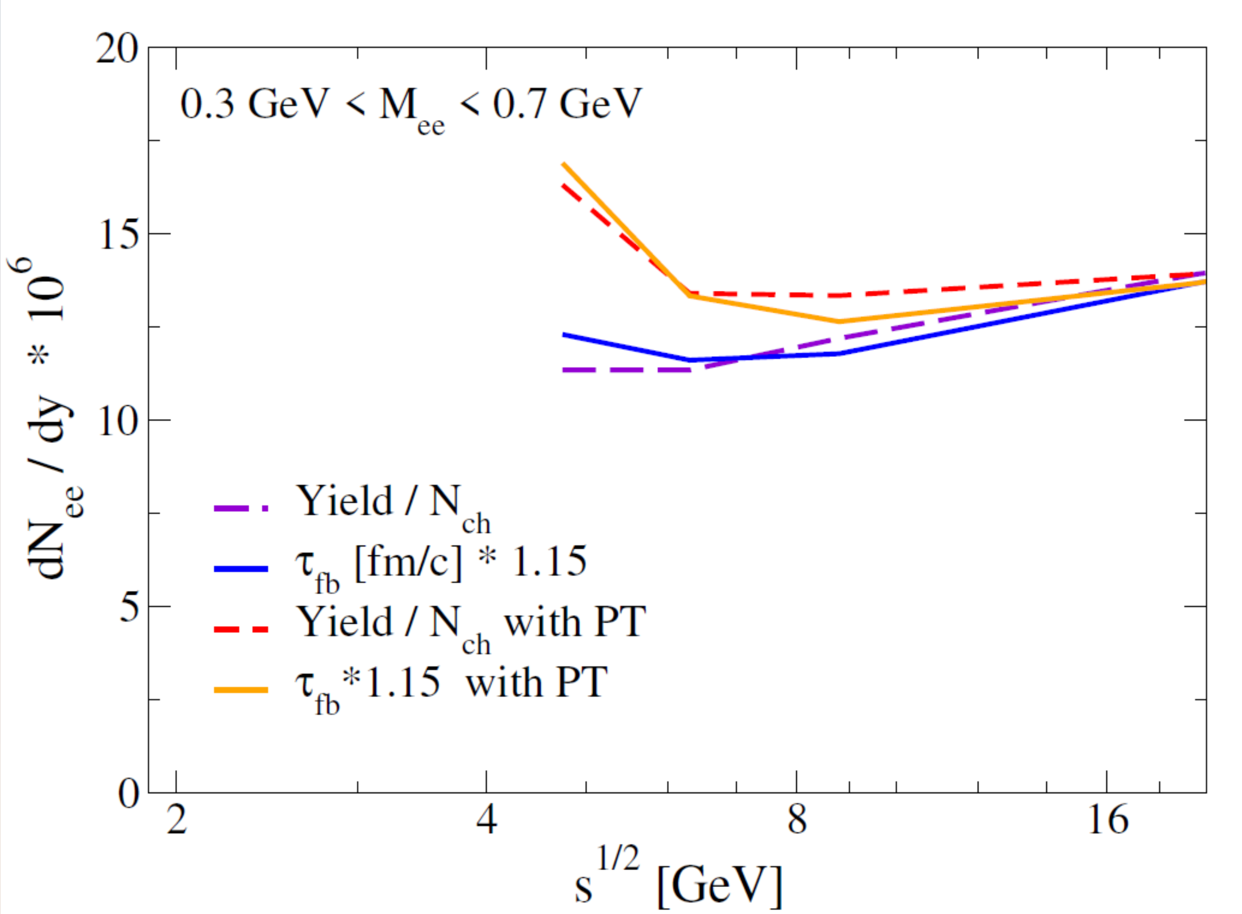


- Measurement of the thermal yield in $0.3<M<0.7$ GeV/c^2
- Excellent accuracy → may allow a precise estimate of the fireball lifetime

"Anomalous" variations in the yields as a function of $\sqrt{s_{NN}}$, due to the burning of latent heat, could represent a promising to detect the presence of a first order phase transition

Dilepton Emission with 1st-Order Transition I

Fireball Lifetime Excitation Function



- Clear signature in low-mass yield due to lifetime increase