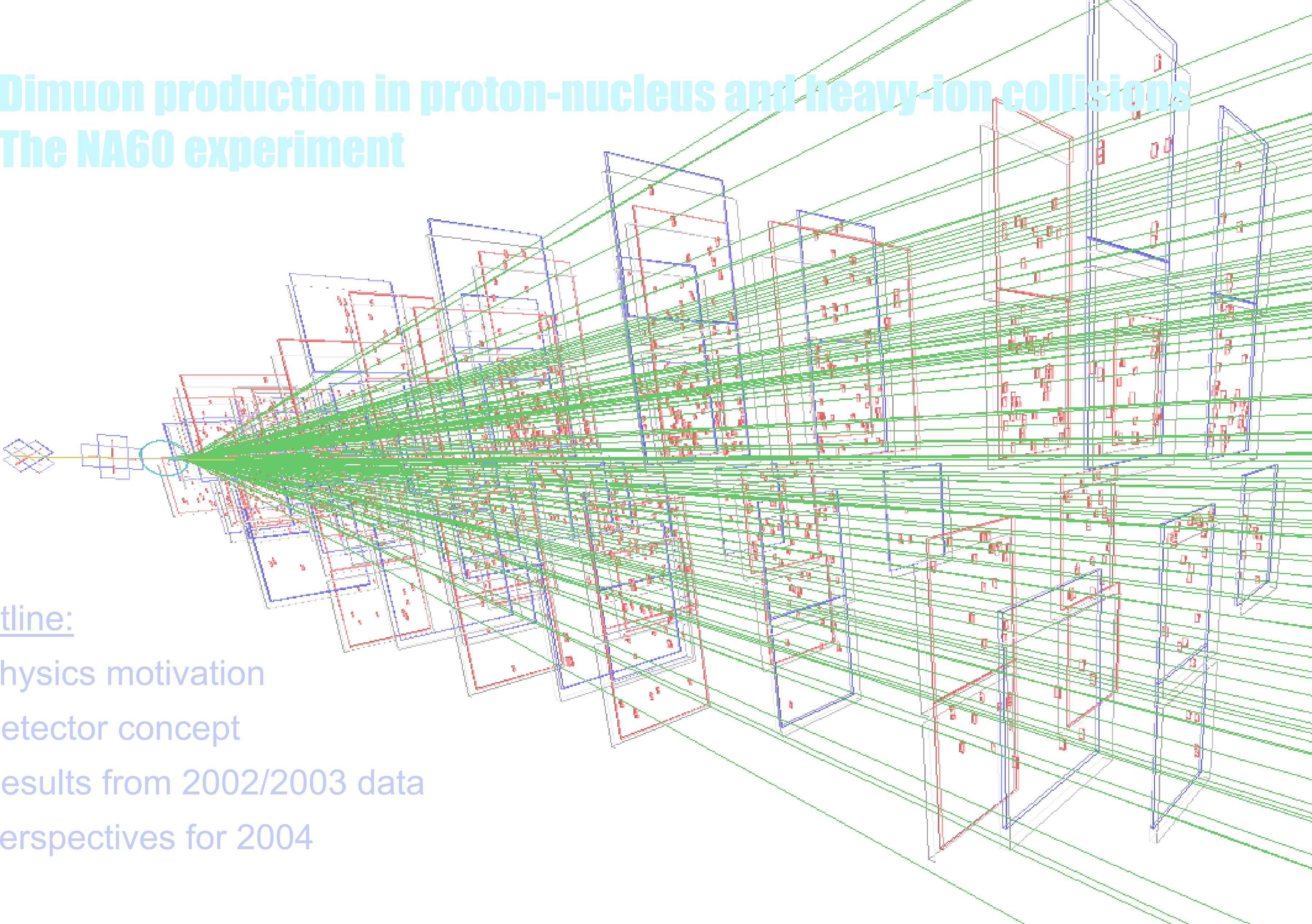
Dimuon production in proton-nucleus and heavy-ion collisions
The NA60 experiment



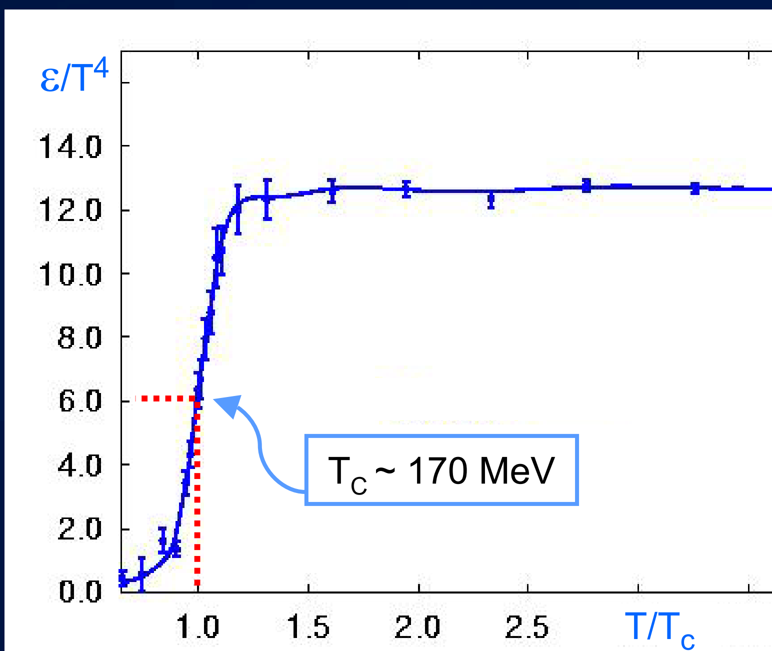
Outline:

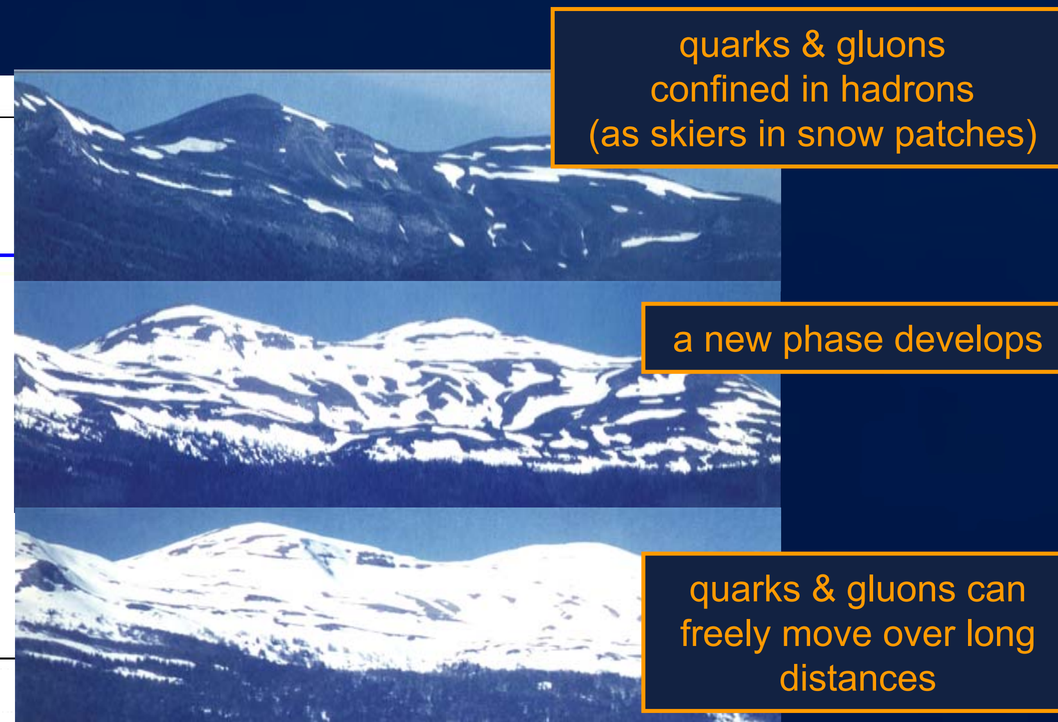
- Physics motivation
- Detector concept
- Results from 2002/2003 data
- Perspectives for 2004

Hermine Wöhri, CERN-PH & IST Lisbon (on behalf of the NA60 collaboration)
Results and Perspectives in Particle Physics, La Thuile, Italy

The QCD phase transition

Lattice QCD calculations predict that, above a certain temperature or energy density, strongly interacting matter should undergo a phase transition from a gas of hadrons to a deconfined state of quarks and gluons, where chiral symmetry is restored

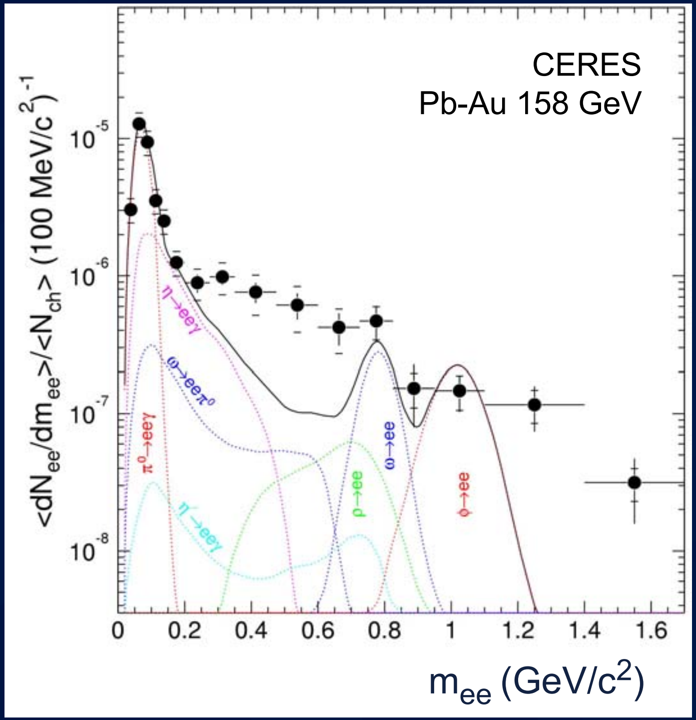


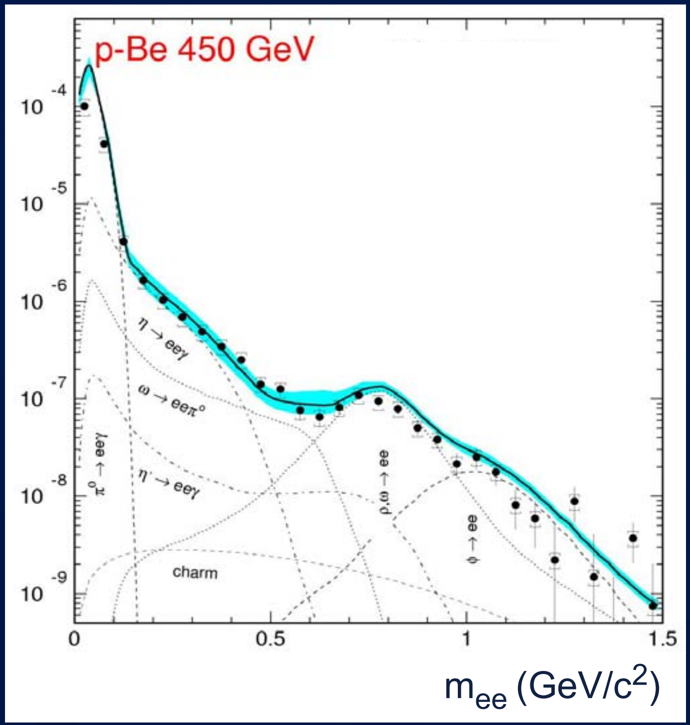


Many experiments probed high energy nuclear collisions at the CERN SPS, since 1986, to look for signatures of the deconfinement of quarks and gluons: interesting results were found but several important questions remain open

Questions left open by previous dilepton experiments

The heavy-ion data collected by the CERES experiment exceeds the sum of meson decays, which explains quite well the p-Be data





- Is the ρ meson modified by the medium produced in nuclear collisions?
- Because of chiral symmetry restoration?

New measurements are needed, with:

$\Rightarrow$ Much more statistics

$\Rightarrow$ Better mass resolution and signal to background ratio

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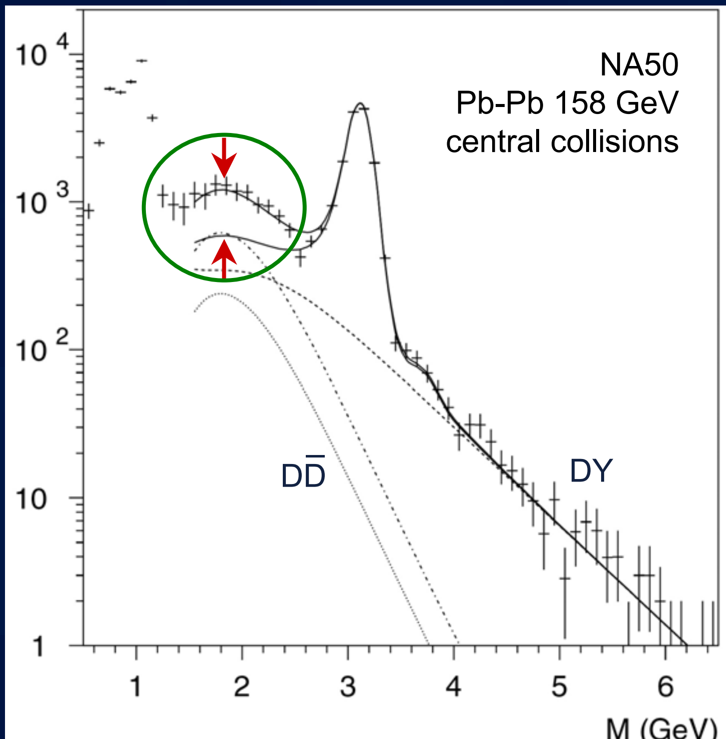
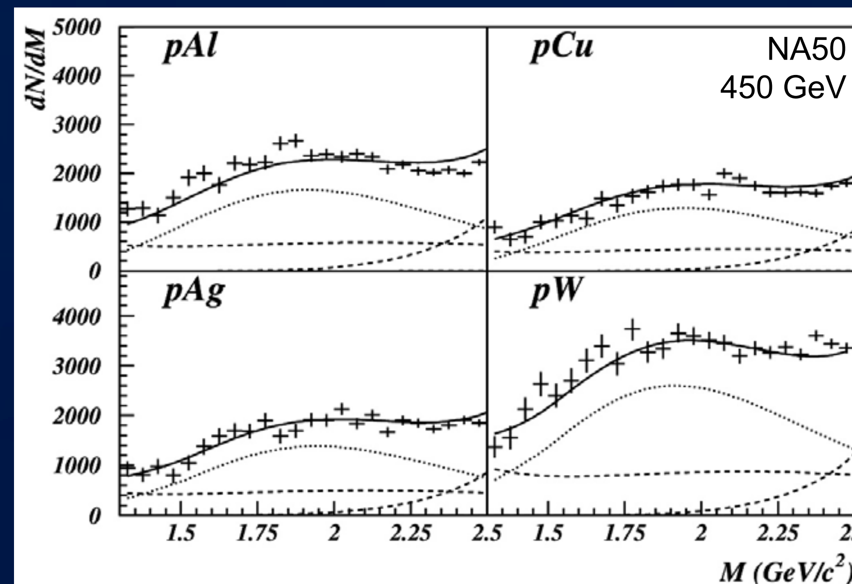
Questions left open by previous dilepton experiments

The yield of intermediate mass dimuons produced in heavy-ion collisions exceeds the superposition of the expected sources : Drell-Yan and D meson decays (which describe the proton data)





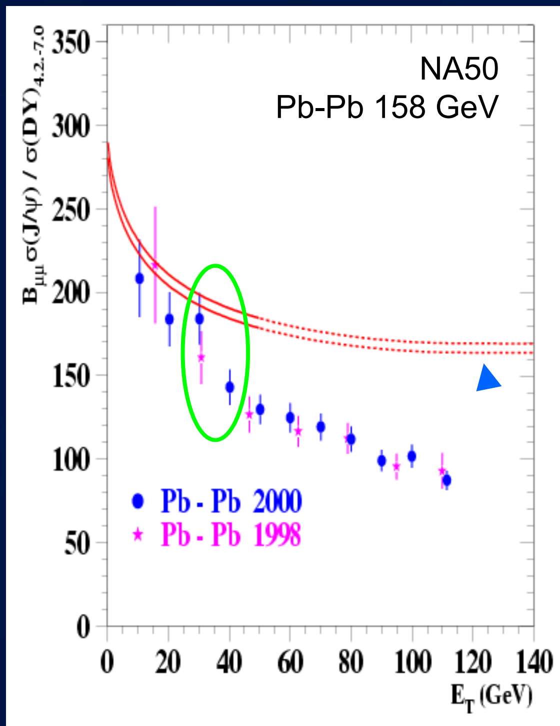
- Is the excess due to the production of thermal dimuons from a quark-gluon plasma?
- Is the open charm yield enhanced in nucleus-nucleus collisions?

New measurements are needed, able to:

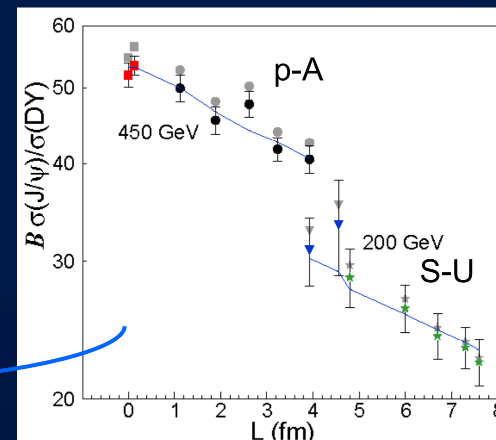
$\Rightarrow$ Measure secondary vertices with 50 μm precision

Questions left open by previous dilepton experiments

The production of J/ψ and ψ’ mesons is suppressed in heavy-ion collisions with respect to the yields extrapolated from proton-nucleus measurements



J/ψ “normal nuclear absorption”



- Are the charmonium states broken by deconfined (free) quarks and gluons ?
- What is the impact of the χ_c feed-down on the observed J/ψ suppression pattern?

New measurements are needed:

⇒ Indium-Indium collisions to clarify origin of observations

⇒ χ_c production in p-A collisions

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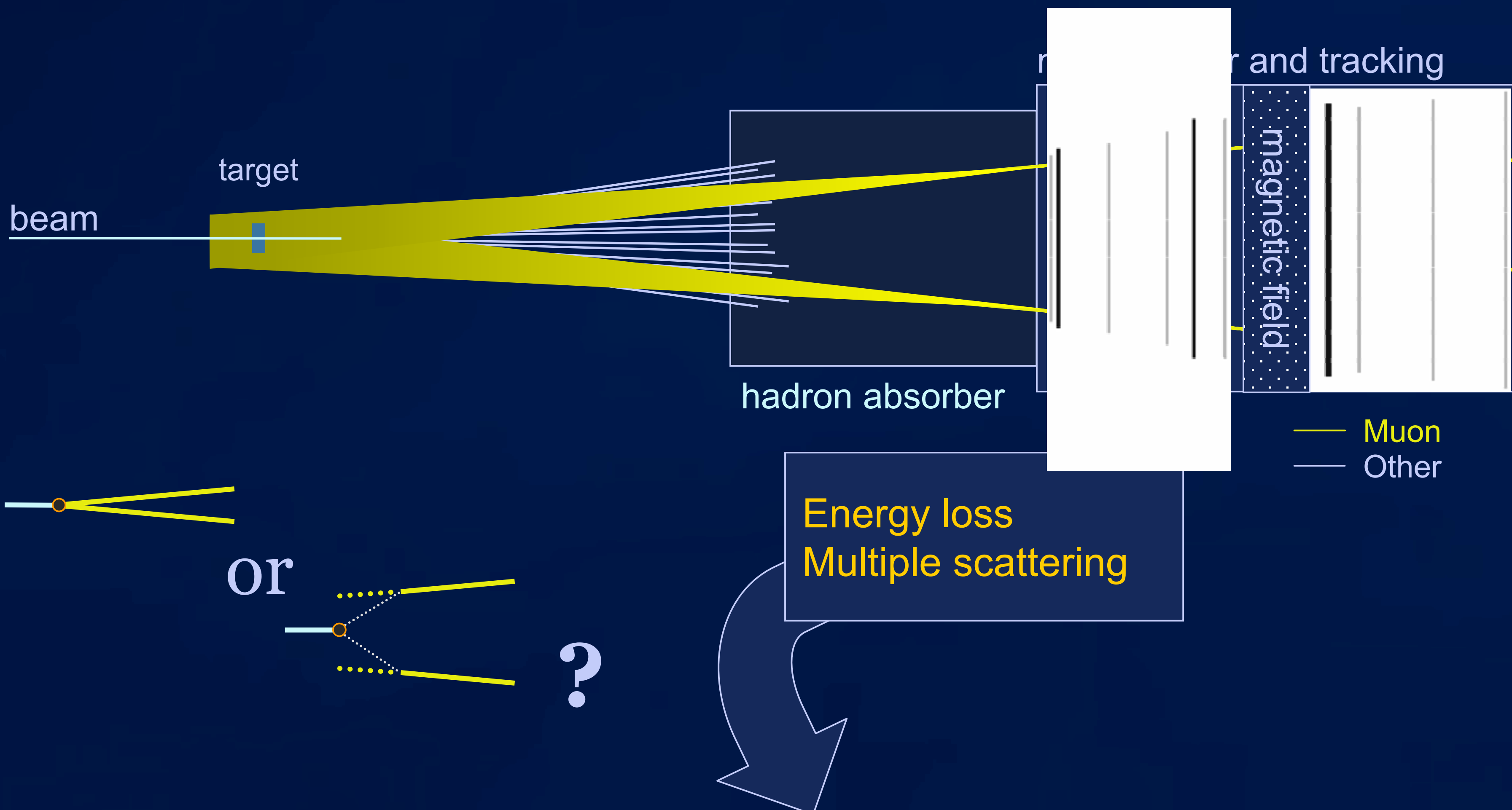
Standard way of measuring dimuons

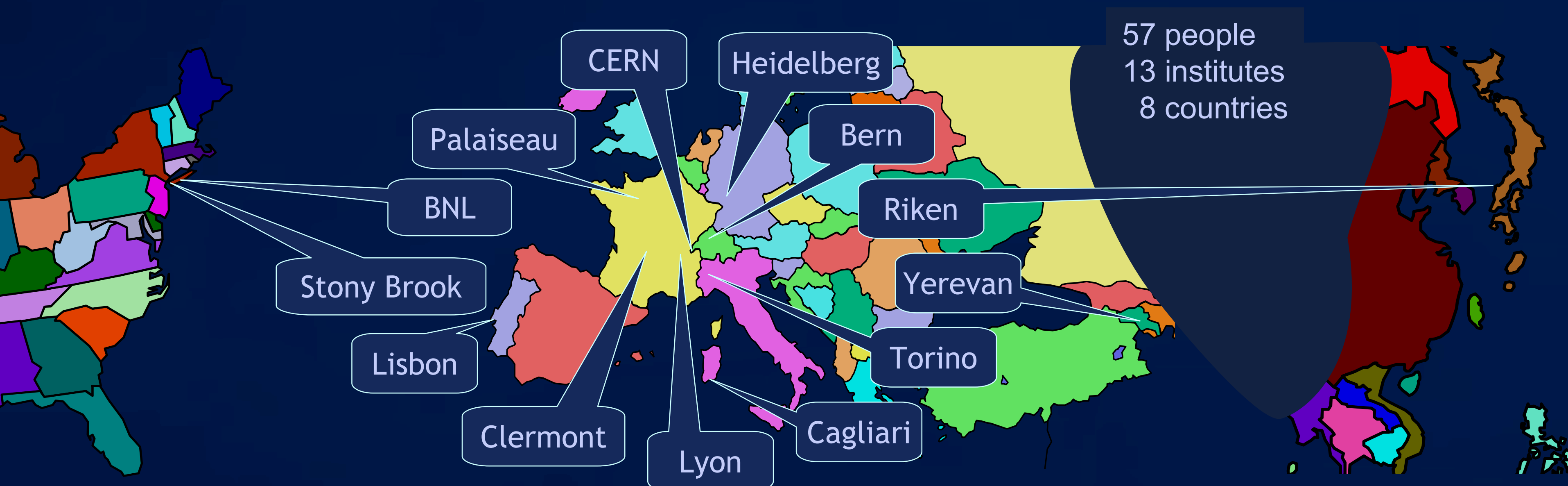


- Cannot distinguish prompt dimuons from decay muons
- Degraded dimuon mass resolution

The NA60 Experiment

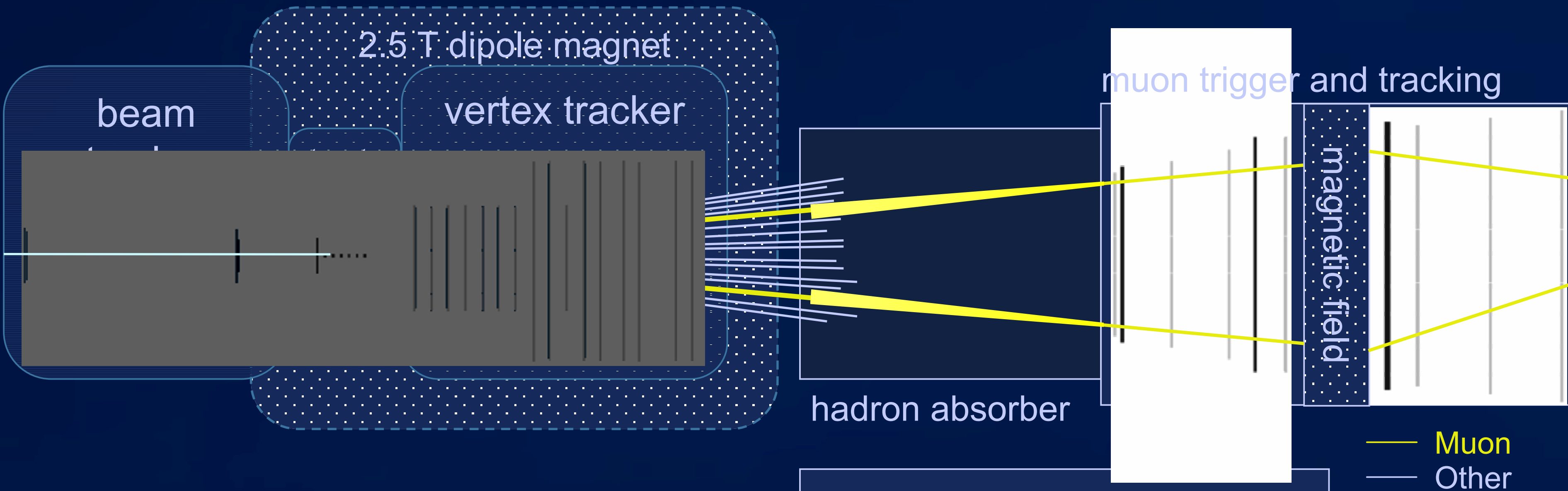
http://cern.ch/na60

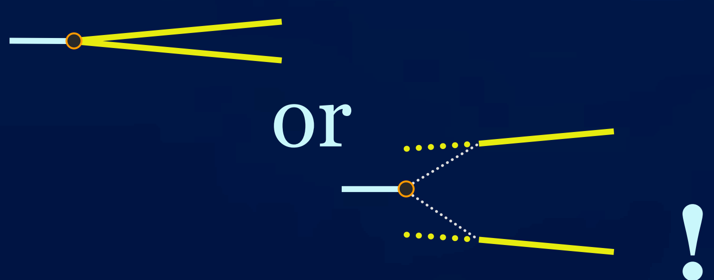
"Place a *high granularity* and *radiation-hard* silicon tracking telescope in the vertex region to measure the muons before they suffer multiple scattering and energy loss"



R. Arnaldi, R. Averbeck, K. Banicz, K. Borer, J. Buytaert, J. Castor, B. Chaurand, W. Chen, B. Cheynis, C. Cicalò, A. Colla, P. Cortese, S. Damjanovic, A. David, A. de Falco, N. de Marco, A. Devaux, A. Drees, L. Ducroux, H. En'yo, A. Ferretti, M. Floris, P. Force, A. Grigorian, J.Y. Grossiord, N. Guettet, A. Guichard, H. Gulkanian, J. Heuser, M. Keil, L. Kluberg, Z. Li, C. Lourenço, J. Lozano, F. Manso, P. Martins, A. Masoni, A. Neves, H. Ohnishi, C. Oppedisano, P. Parracho, G. Puddu, E. Radermacher, P. Ramalhete, P. Rosinsky, E. Scomparin, J. Seixas, S. Serci, R. Shahoyan, P. Sonderegger, H.J. Specht, R. Tieulent, G. Usai, H. Vardanyan, R. Veenhof, D. Walker and H. Wöhri

Measuring dimuons in NA60: concept



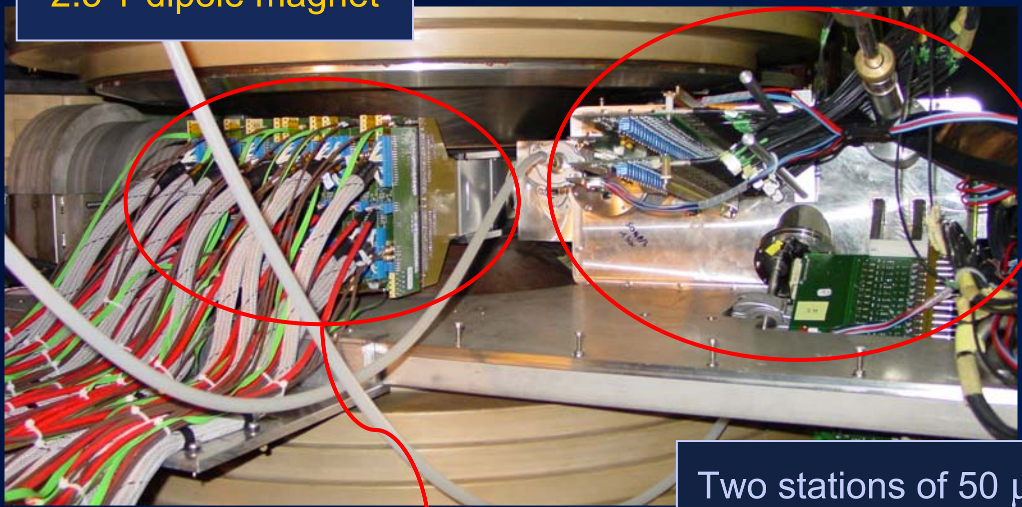


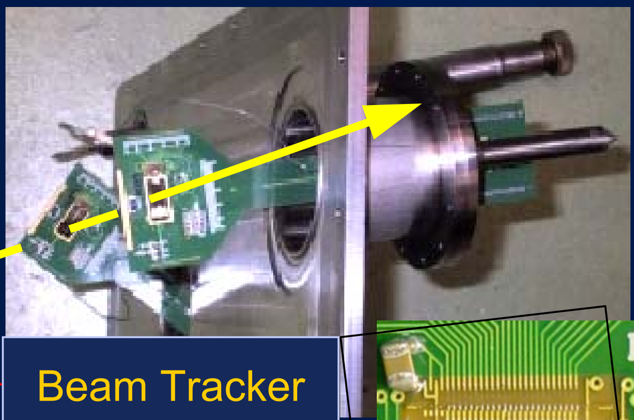
Matching in coordinate <u>and</u> momentum space

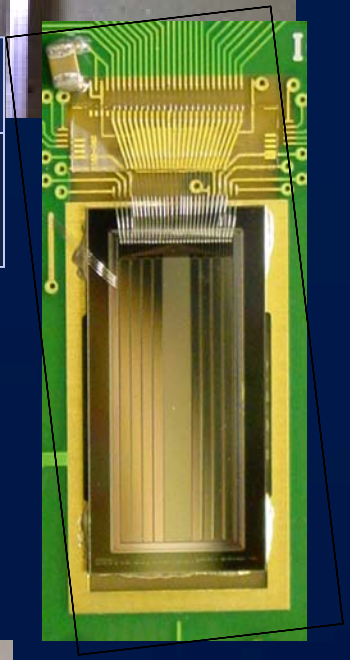
- Origin of muons can be accurately determined
- Improved dimuon mass resolution

The target region: reality

2.5 T dipole magnet



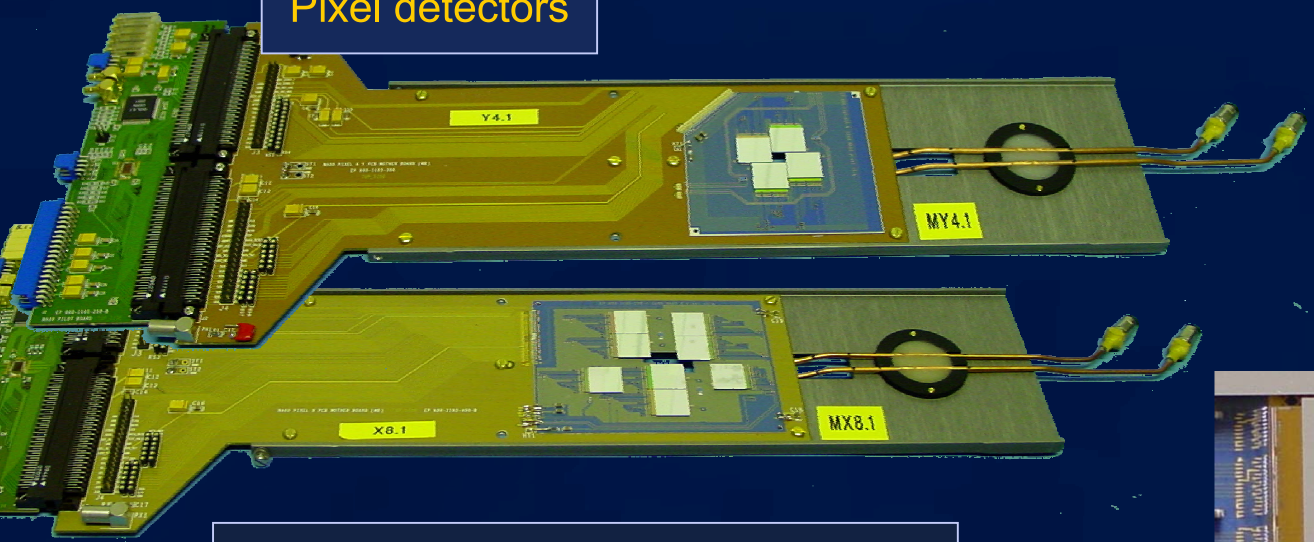




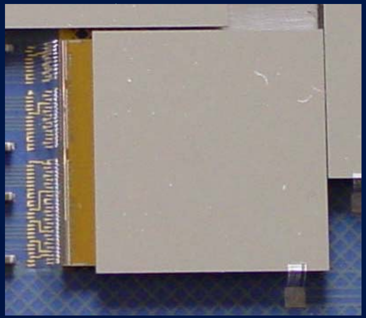
Beam Tracker

Two stations of 50 μm pitch micro-strip detectors
Operated at 130 K → increased radiation hardness

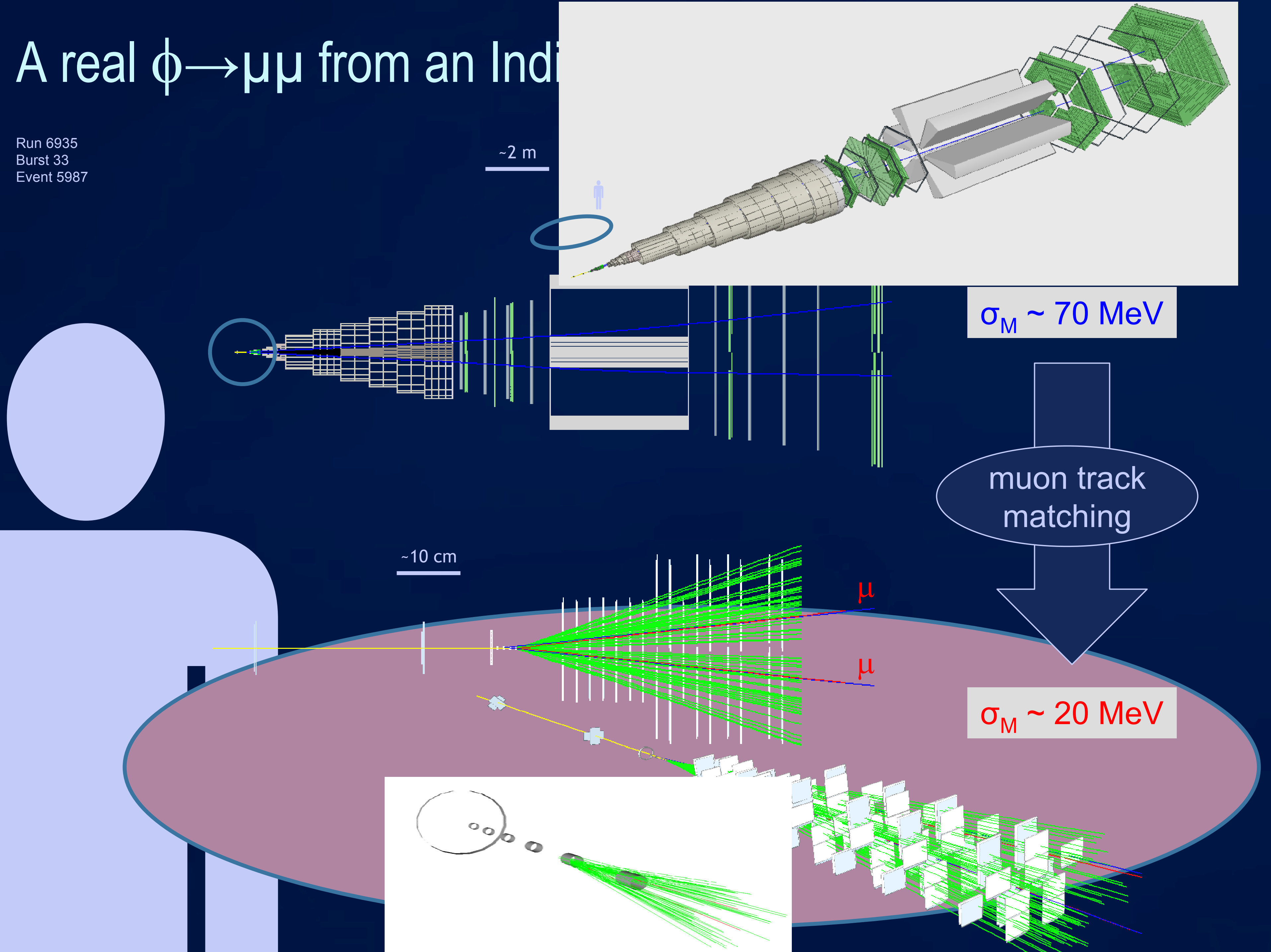
Pixel detectors



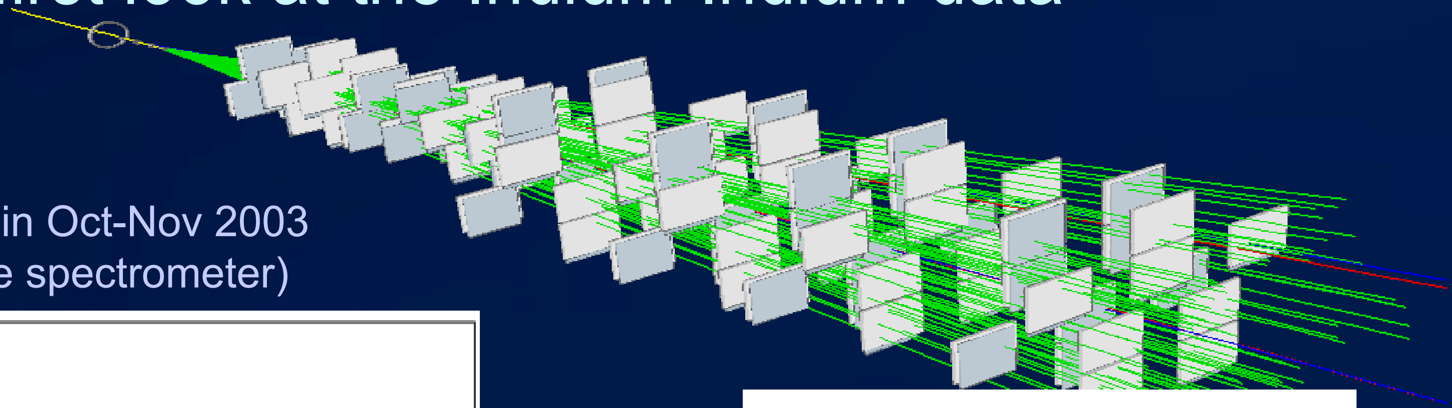
~ 100 pixel detectors (radiation tolerant)
in 11 tracking planes; cells = 50 × 425 μm^2



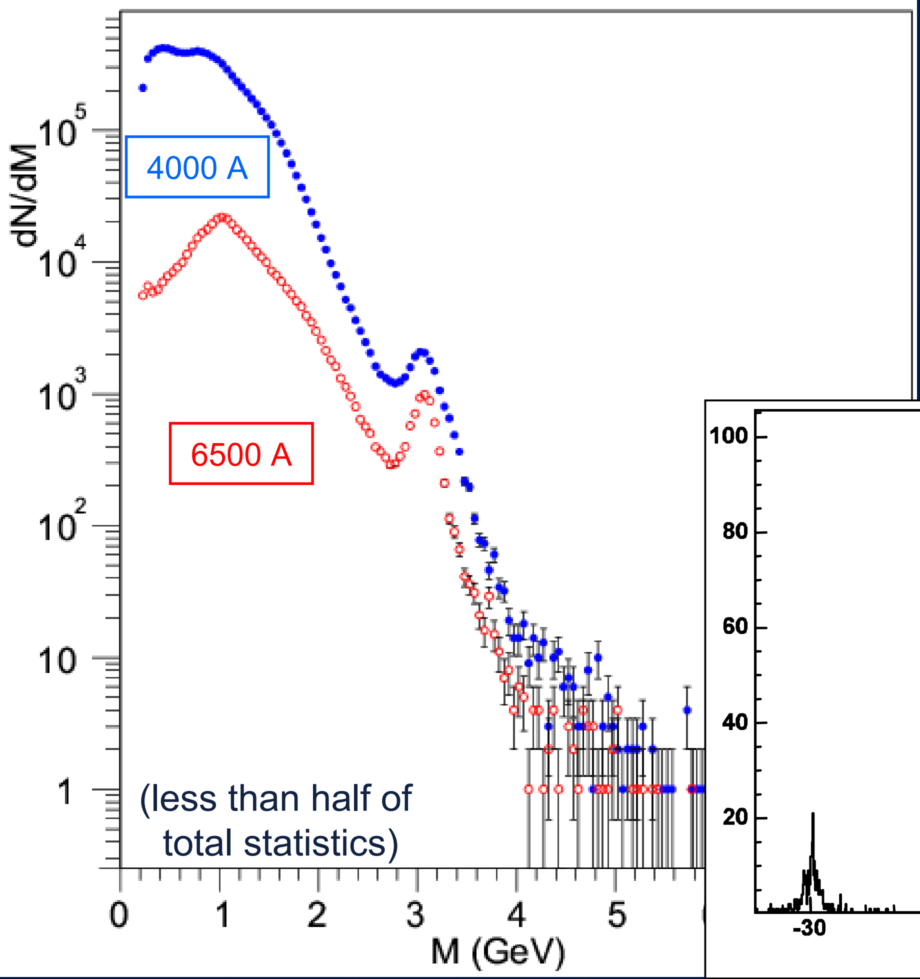
A real $\phi \rightarrow \mu\mu$ from an Indi

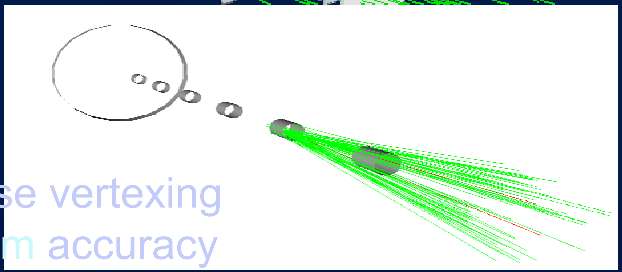


A first look at the Indium-Indium data

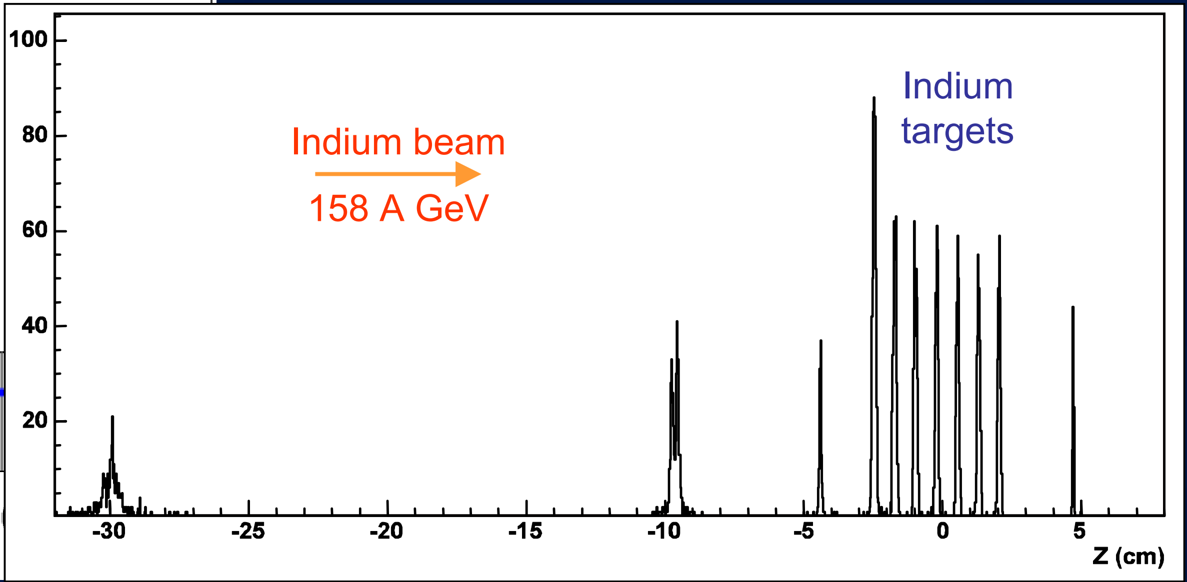


Dimuon data collected in Oct-Nov 2003
(with two settings of the spectrometer)



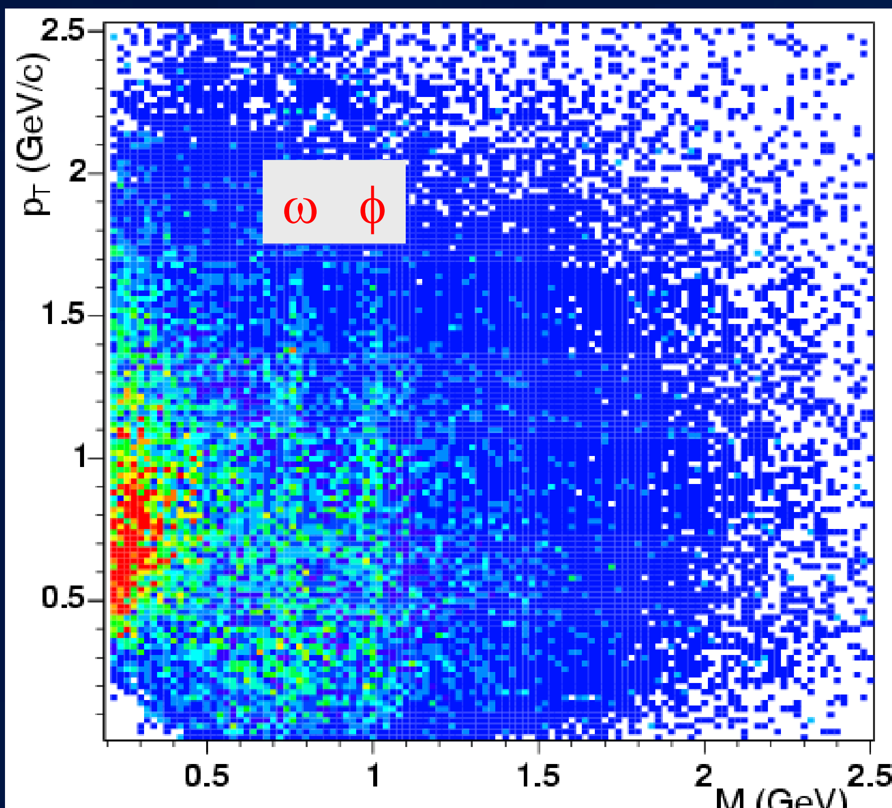


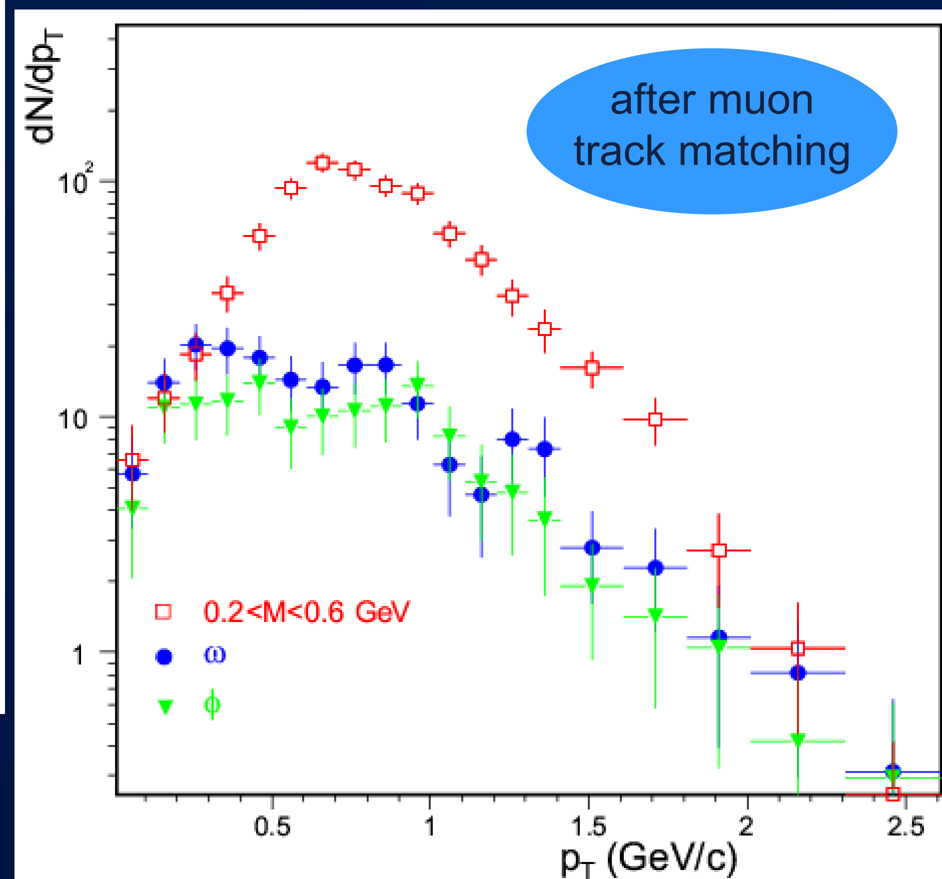
Transverse vertexing
with 20 μm accuracy
(and < 200 μm in Z)



Phase space coverage for low mass dimuons

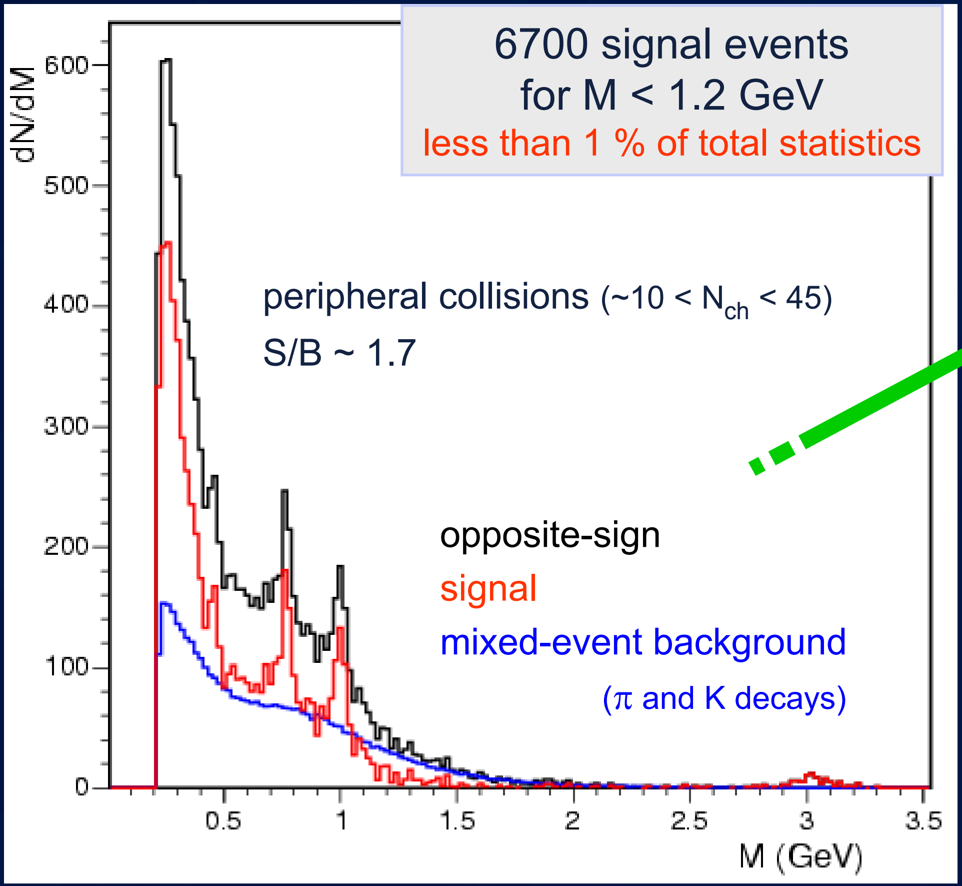
Excellent p_T coverage down to very low dimuon masses
(previous dimuon measurements had a p_T cut at ~ 1GeV/c
and were not competitive with respect to dielectrons)

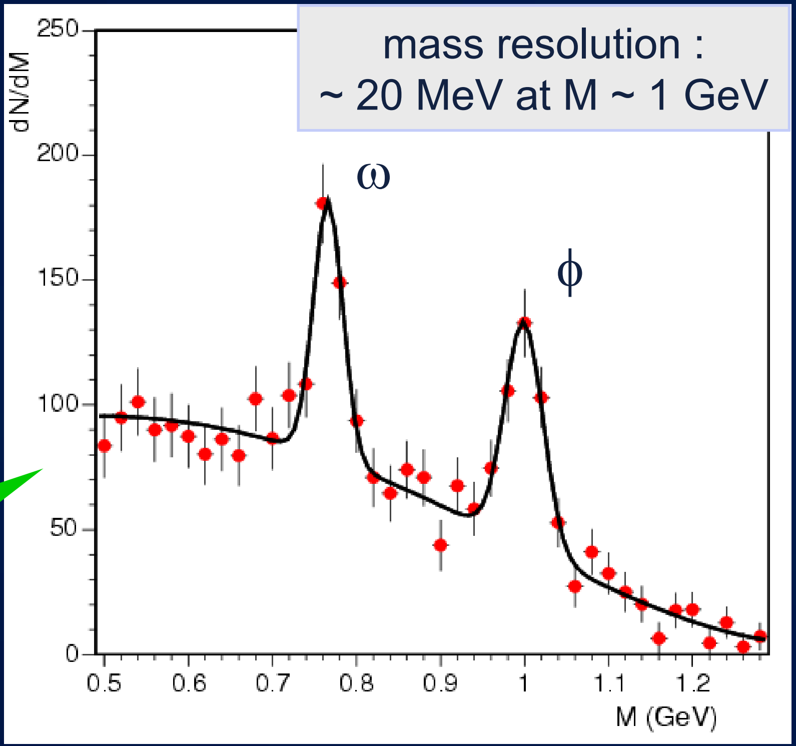




Low mass dimuons produced in Indium-Indium collisions

… from a very fast analysis of
a very small event sample …





> 100 000 $\phi \to \mu\mu$ decays in the full data sample

$\phi \to K^+K^-$ decays also under analysis

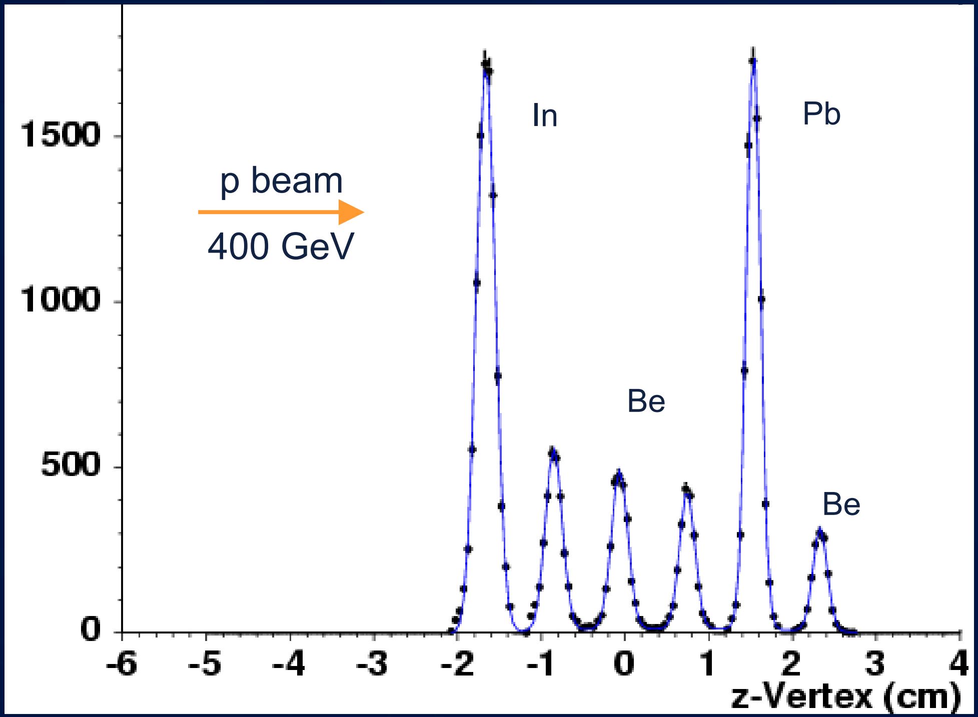
With respect to CERES data:

- Higher statistics by factor ~100
- Signal / noise improved by factor ~10
- Better mass resolution
- Completely different systematical uncertainties

Getting reference data from proton-nucleus collisions

To understand the results obtained with heavy-ion collisions, it is crucial to establish a solid reference baseline using proton-nucleus results

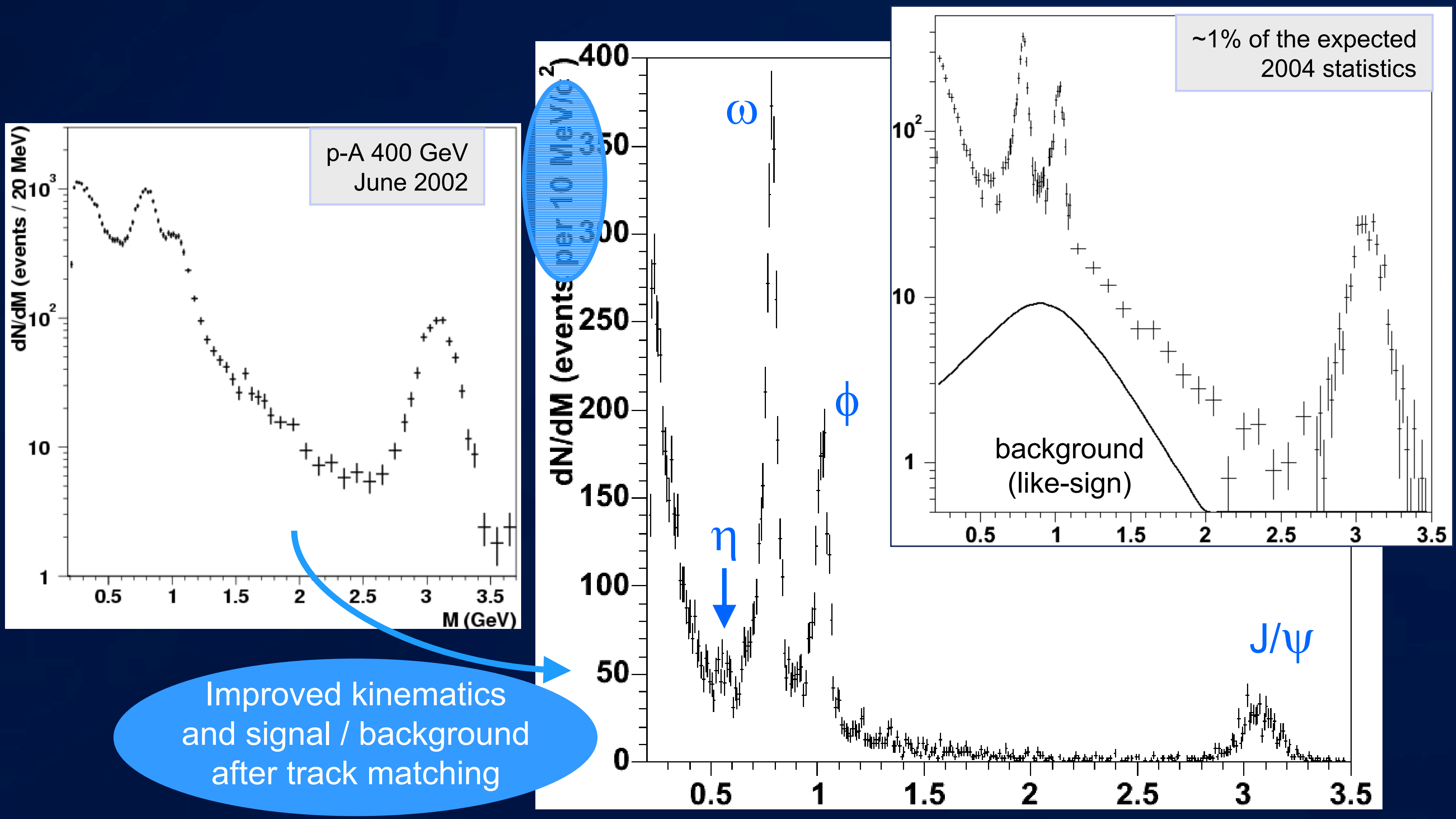
- The “real proton run” takes place in 2004 (around 70 days, with 7 different nuclear targets)
- A *very small* data sample was collected in 2002, during 4 days, at low beam intensity
- After muon track matching and vertex selection cuts we are left with ~ 25 000 dimuons



Z-vertex resolution ~ 600–900 μm
⇒ allows us to clearly separate the individual targets (2 mm thick) simultaneously placed on the beam line

Dimuon mass distributions from p-A collisions

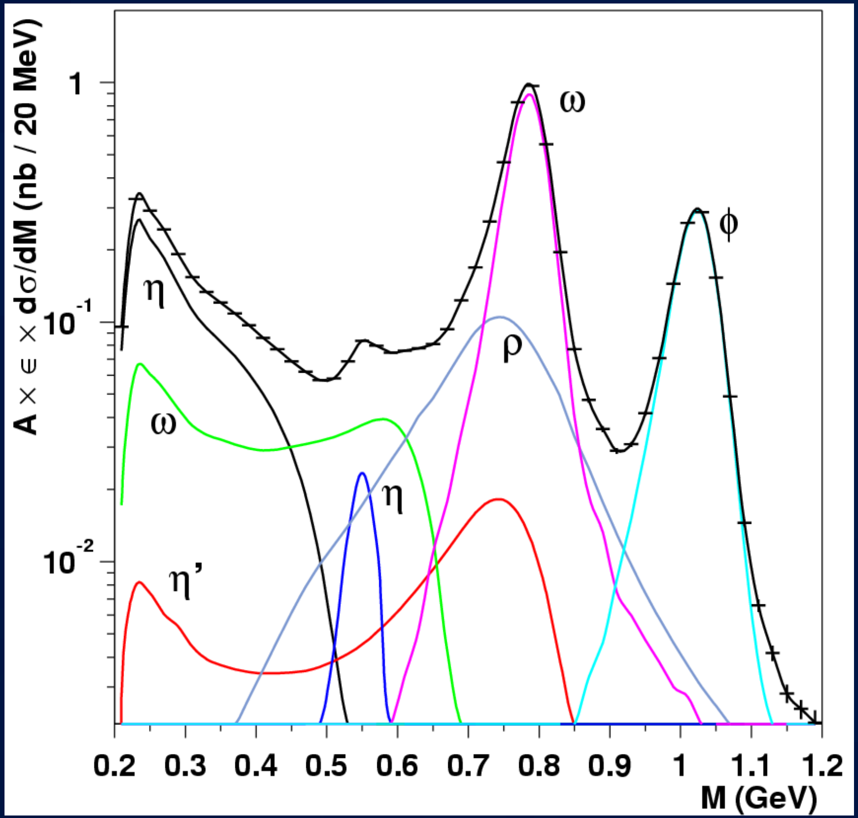
- Like-sign / opposite-sign muon pairs : ~ 25% ⇒ ~ 7% after track matching
- Mass resolution in the ω/ϕ mass region : 70 MeV ⇒ 25–30 MeV
  and in the J/ψ peak : 125 MeV ⇒ 90 MeV

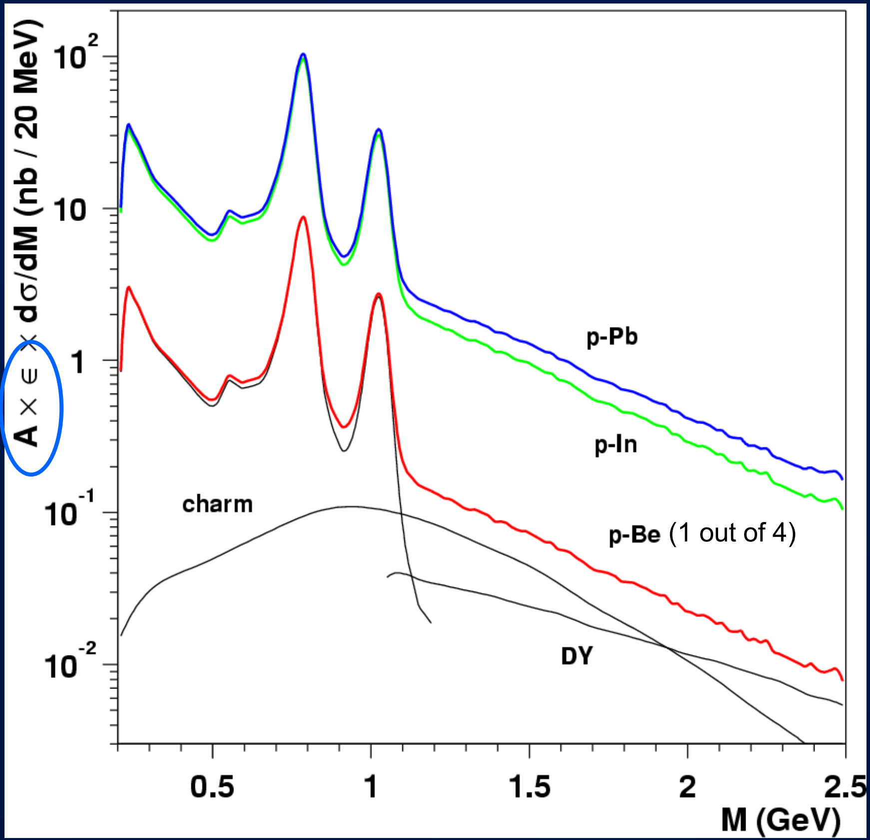


Expected dimuon sources

Detailed Monte-Carlo simulation (with Geant) of the expected signal dimuon sources

- ✓ $\mu^+\mu^-$ and Dalitz decays of the η, η', ρ, ω and ϕ mesons (with Genesis/Venus)
- ✓ Charm (semi-muonic decays), Drell-Yan and J/ψ production (with Pythia)

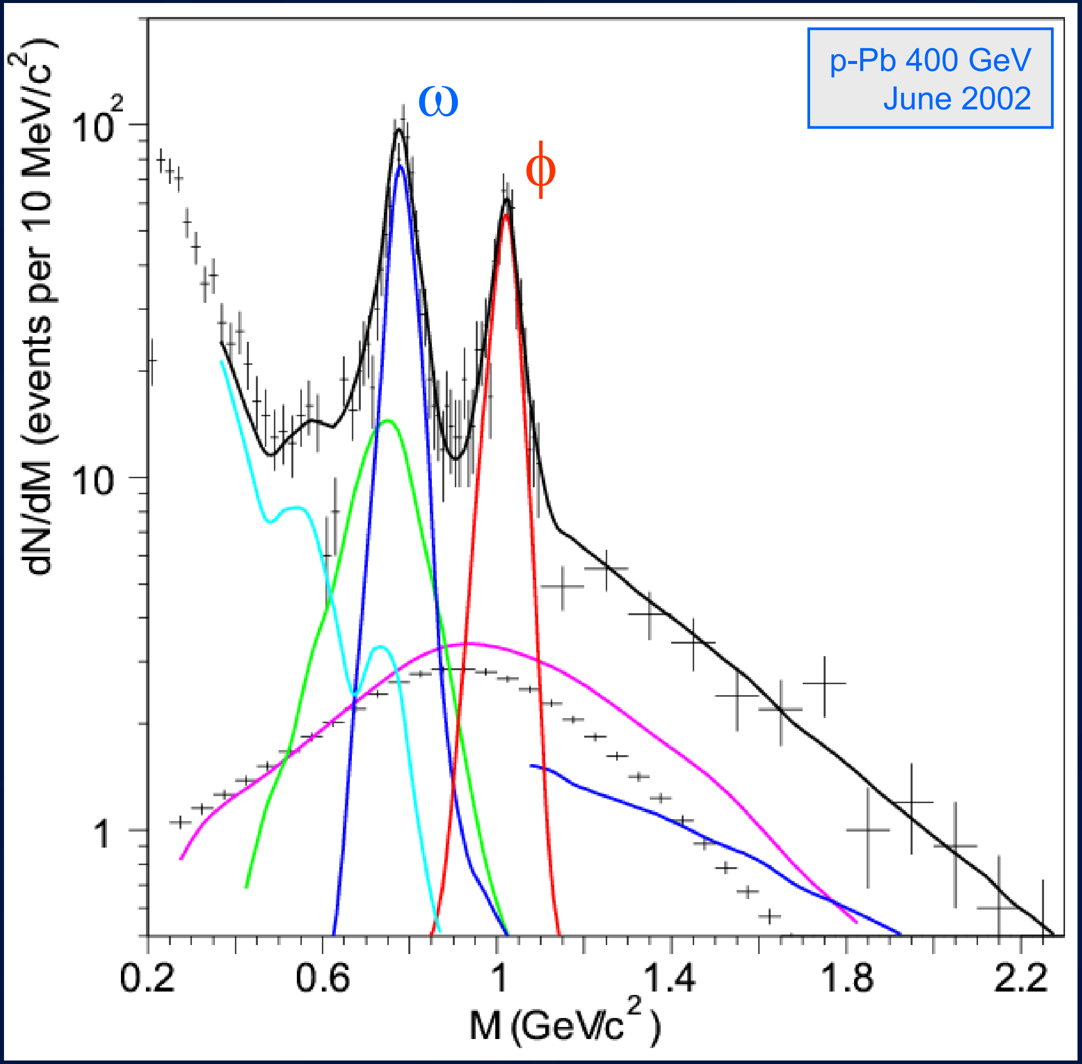




curves include acceptances and reconstruction efficiencies

A first look at dimuon production in p-A collisions

Comparing the dimuon mass distributions from the several target materials, we can extract the nuclear dependences of the production cross-sections of several dimuon sources, such as the ω, φ and J/ψ mesons



$$\sigma_{pA} = \sigma_0 \, A^{\alpha}$$

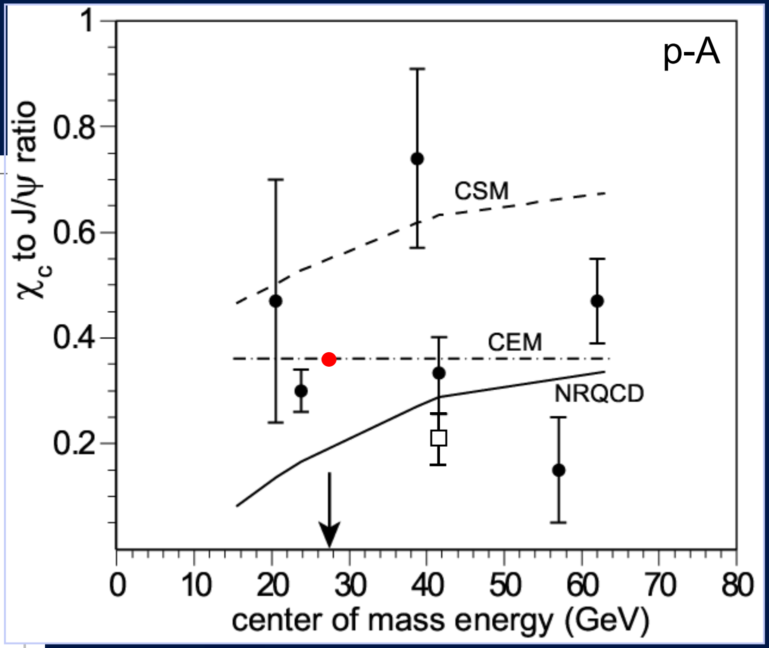
[A is the mass number of the nucleus]

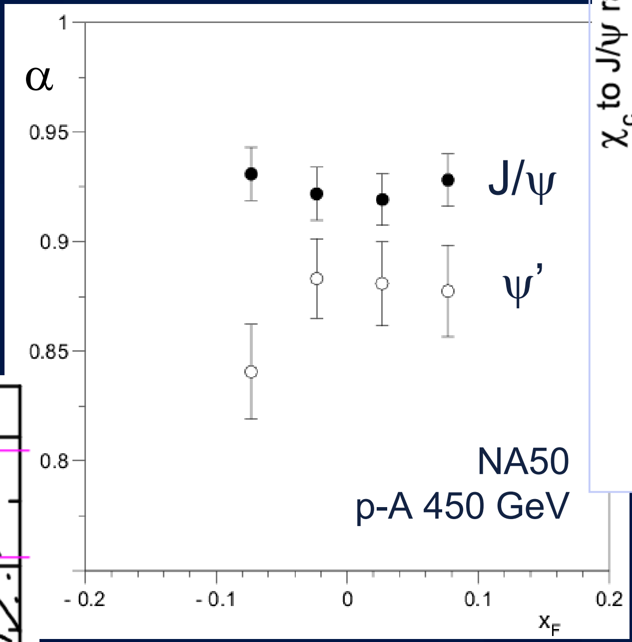
<u>From the data collected in 2002:</u>

- $\alpha(J/\psi) \sim 0.91$, both before and after muon track matching (nice cross-check)
- The extraction of the α values for the ω and φ is still in progress; very preliminary estimates indicate $\alpha(\omega) \sim 0.79$; $\alpha(\phi) \sim 0.86$ (expected accuracy ~ 2–3%)

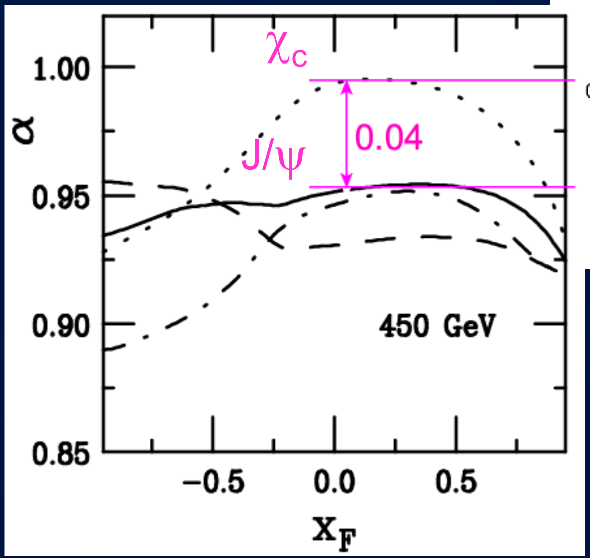
Impact of χ_c production on the study of J/ψ suppression

- A big fraction (~30 %) of the measured J/ψ yield results from χ_c decays: $\chi_c \rightarrow J/\psi + \gamma$
  $\Rightarrow$ maybe the observed J/ψ suppression is due to the melting of the χ_c
- What is the "normal nuclear absorption" of the χ_c ?
- The ψ' is more strongly absorbed (E866, NA50) and NRQCD predicts less absorption of the χ_c





NRQCD



In 2004, NA60 will track the converted photons and will measure $\alpha(\chi_c)$ and the χ_c to J/ψ ratio with ~ 2% accuracy

Summary and outlook

Harvest from the 5-week long Indium run in Oct.–Nov. 2003 :

- more than 100 000 reconstructed J/ψ events (before track matching)
- ~ 1 million signal low mass dimuons (after track matching)
- mass resolution ~ 20 MeV at the ω and ϕ masses
- signal to background ratio around 1:1 or 1:2 depending on collision centrality (a factor 4 better than before muon track matching)

Together with the proton run of 2004, NA60 should be able to :

- study the production of low mass dimuons, including the ρ, ω and ϕ resonances
- clarify the cause of the excess of intermediate mass dimuons in heavy-ion collisions
- improve the understanding of the production and suppression of charmonium states

Many other items on the physics menu of the 2004 proton run :

- nuclear dependence of charm production
- and of intermediate mass prompt dimuons (Drell-Yan)
- look for the $D^0 \to \mu^+\mu^-$ rare decay, among others

other ideas are welcome