Low Mass Dimuon Production in Indium-Indium Collisions at 158 GeV

Gianluca Usai (Cagliari University)
for the NA60 Collaboration

Outline:

The NA60 Experiment

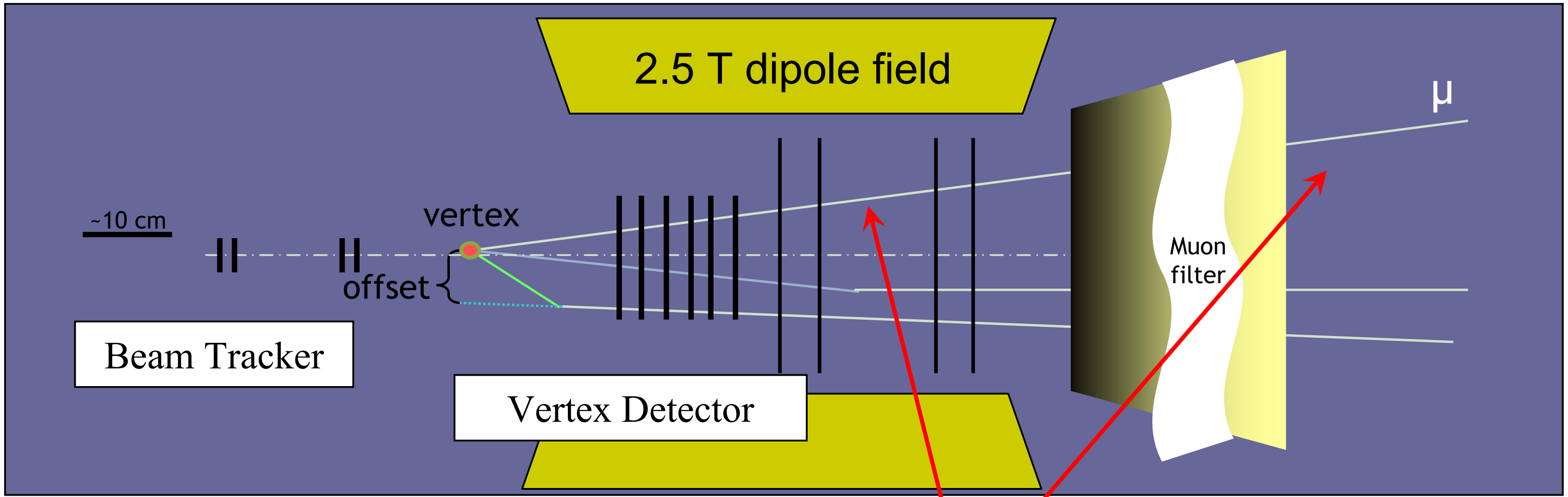
- The silicon vertex detector

Preliminary results from In-In collisions

- ϕ/ω cross section ratio
- ϕ p_T distributions
- ϕ mass

Hard Probes 2004
Ericeira, Nov 4 – 10, 2004

Matching muons



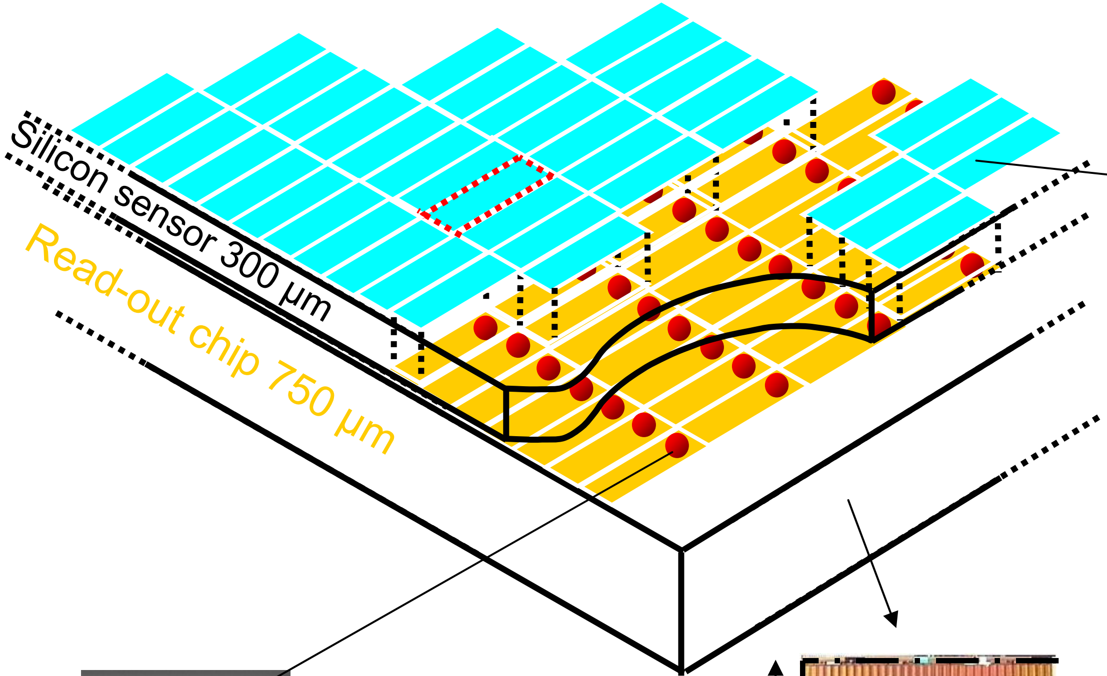
the muons in the vertex region are identified by matching the tracks in the vertex telescope to those in the muon spectrometer

both in coordinate and momentum space

- Better mass resolution
- Better S/N ratio
  - ✓ μ from π and K decays are rejected to a big extent
- Allows to distinguish between muons from D mesons *(open charm)* and prompt dimuons *(thermal?)*

Radiation Tolerant Pixels

- Radiation tolerant silicon pixel detectors became available only recently
- NA60 uses sensor + readout chips developed for the ALICE collaboration

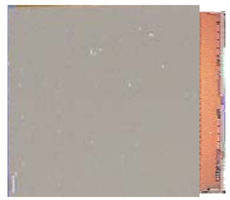


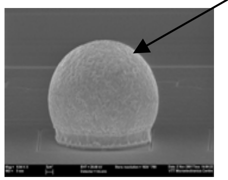
Pixel sensor

- 12.8 x 13.6 mm^2 active area
- 32 x 256 cell matrix
- 50 x 425 $µm^2$ cell size

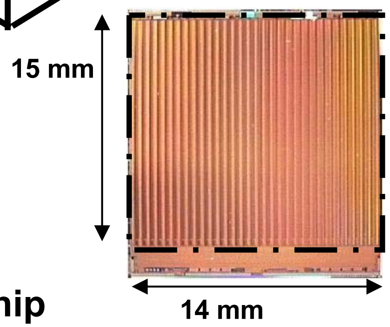
sensor

Assembly (sensor + R/O chip)





25 µm solder bump

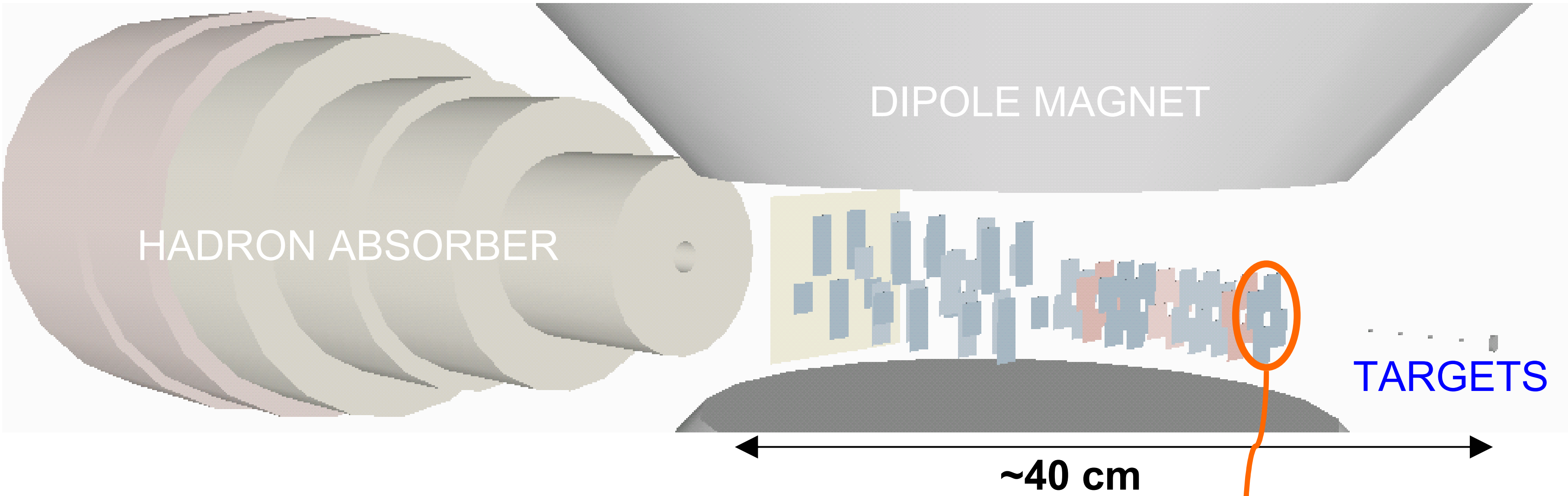


Read-out chip

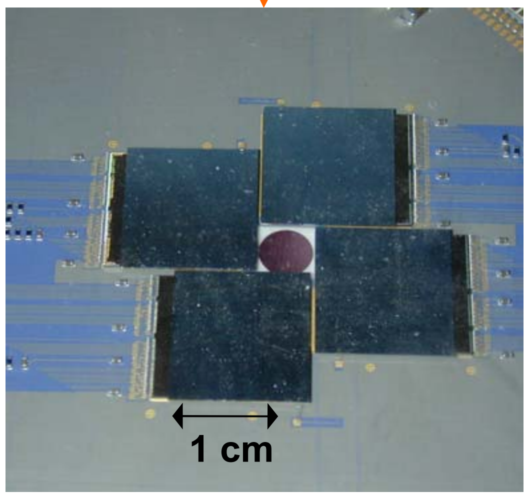
ALICE1LHCb read-out chip

- Operated at 10 MHz clock
- Radiation tolerant up to ~ 30 Mrad
- 32 columns parallel read-out

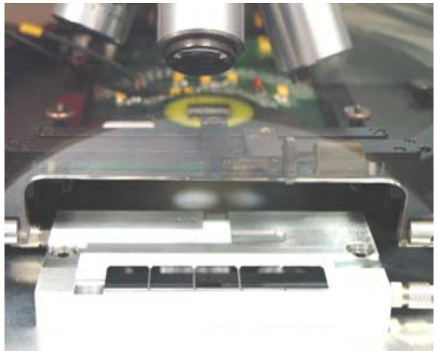
The NA60 Pixel Vertex Detector



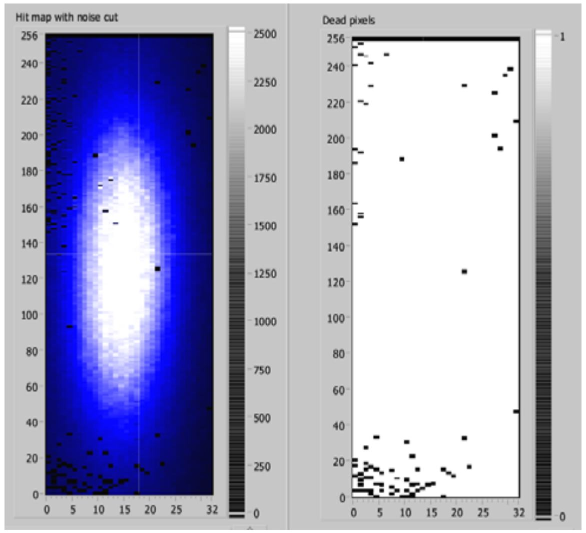
- **12 tracking points** with good acceptance
  8 “small” 4-chip planes, plus
  8 “big” 8-chip planes (4 tracking stations)
- **~ 3% X_0** per plane
  750 µm Si read-out chip
  300 µm Si sensor
  ceramic hybrid
- **800’000 R/O channels** - 96 pixel assemblies

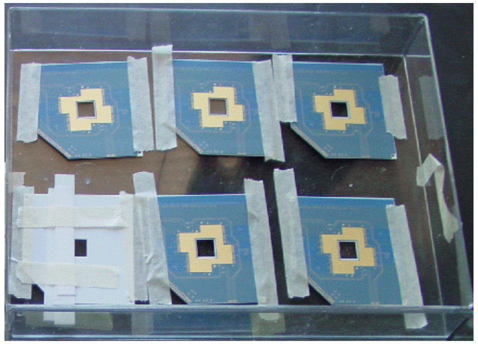


Pixel Planes Construction

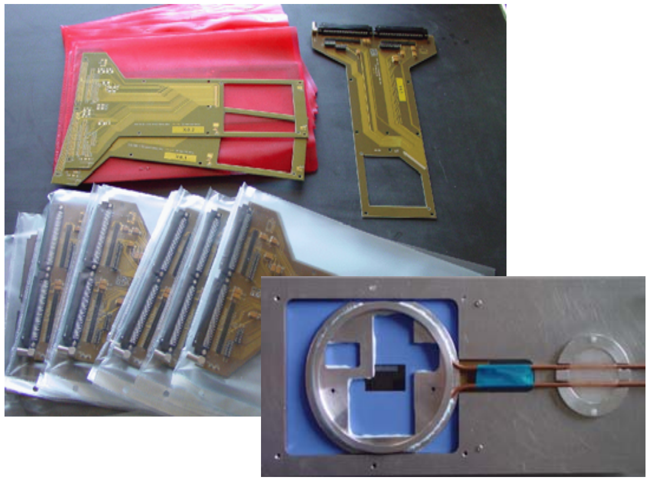


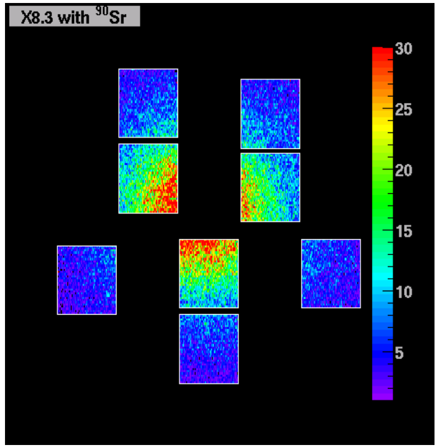
Test of the assemblies in the probe station (source scan, threshold scan, etc)



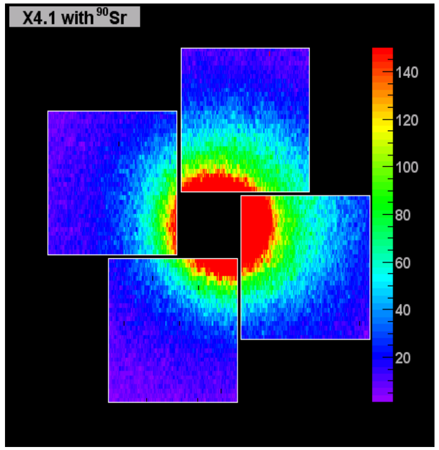


Good assemblies are glued on ceramic hybrids, mounted on PCBs and wire-bonded. Cooling rings are also mounted.





Final modules are tested and calibrated in the lab.

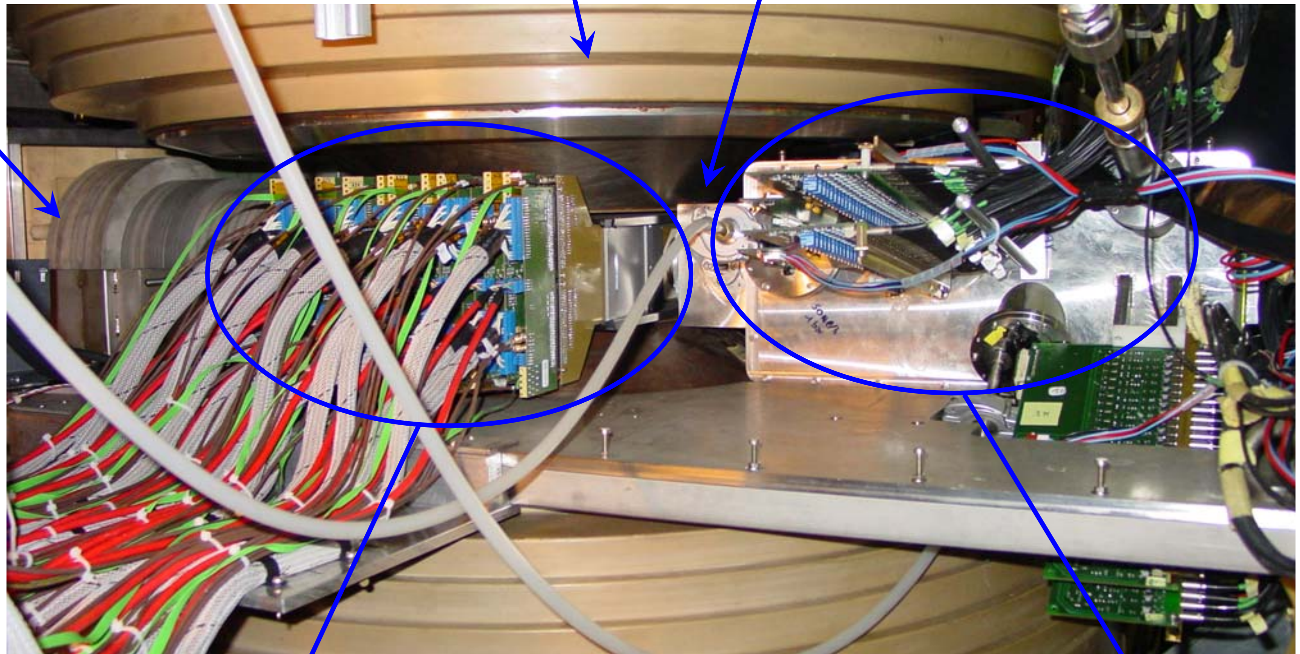


The NA60 Target Region

Dipole magnet

Target system

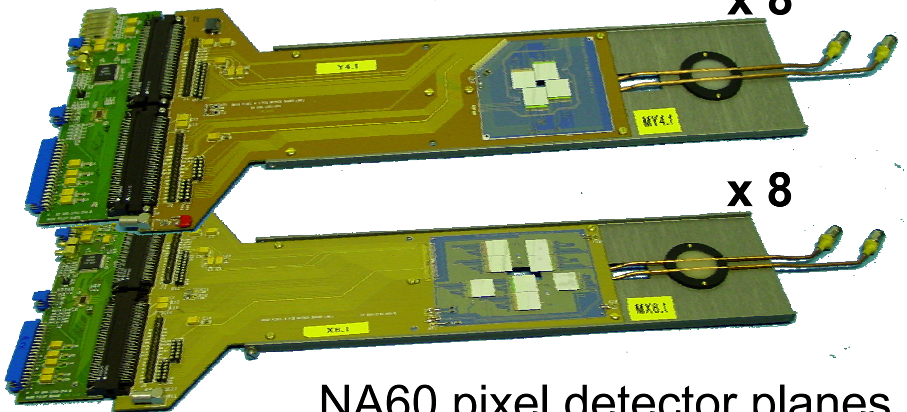
Absorber



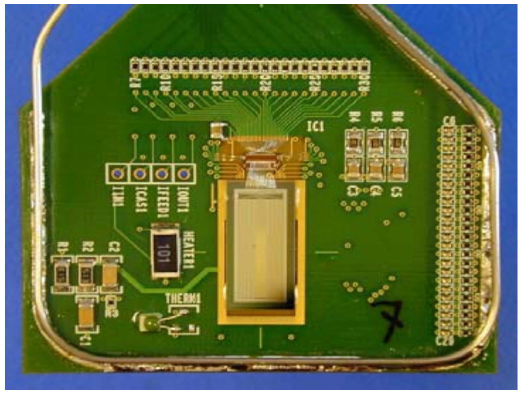
Beam Tracker (micro-strips operated at 130 K)

x 8

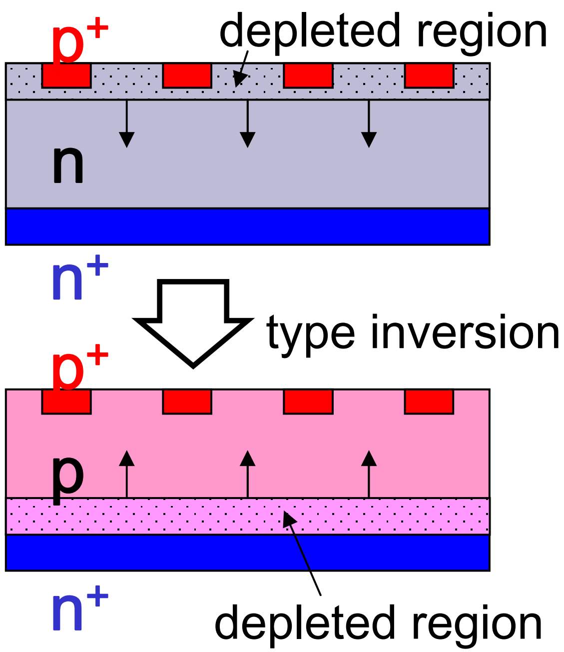
x 8



NA60 pixel detector planes



Record breaking radiation levels

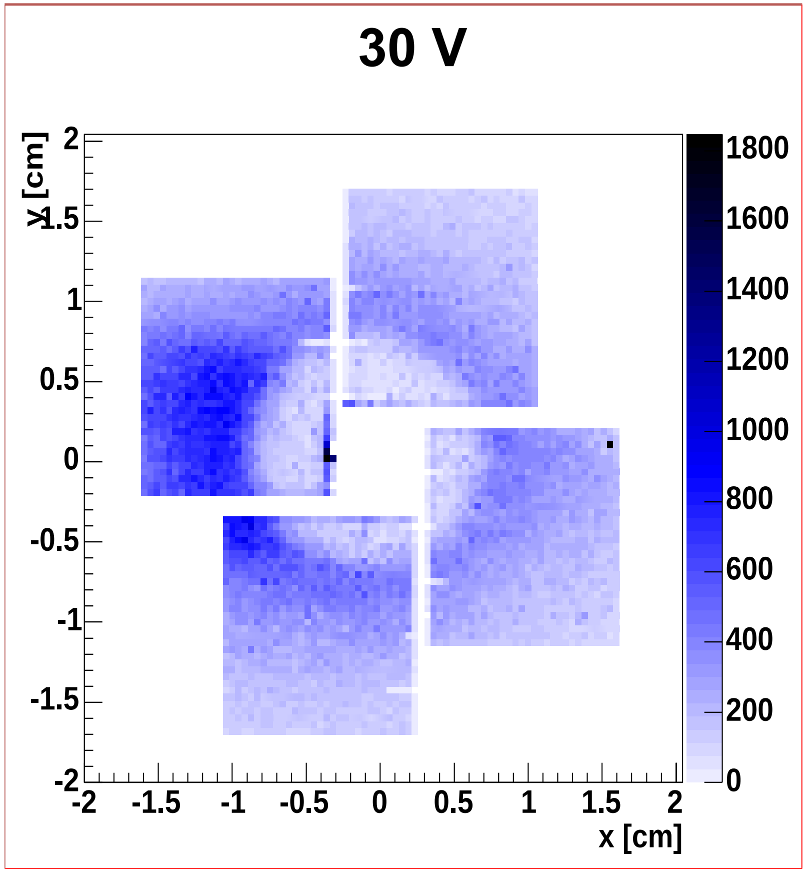


- pixels at small radii receive more fluence than those further away from the beam axis:

  ⇒ after type inversion we expect the depletion voltage to increase towards small radii

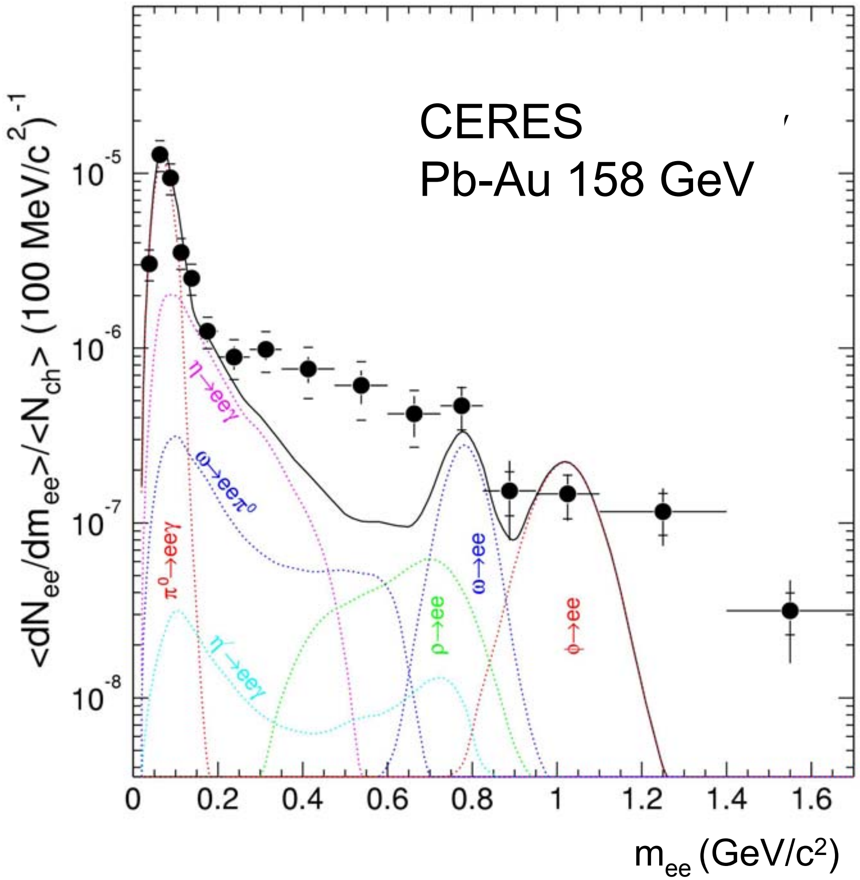
  ⇒ lowering the bias voltage should leave an ever larger area not fully depleted (i.e. very inefficient)

Hit maps taken during a bias voltage scan after 4 weeks



After 4×10^{12} ions delivered to the targets, pixels wounded but still alive and working well

Physics motivation (low mass dimuons)



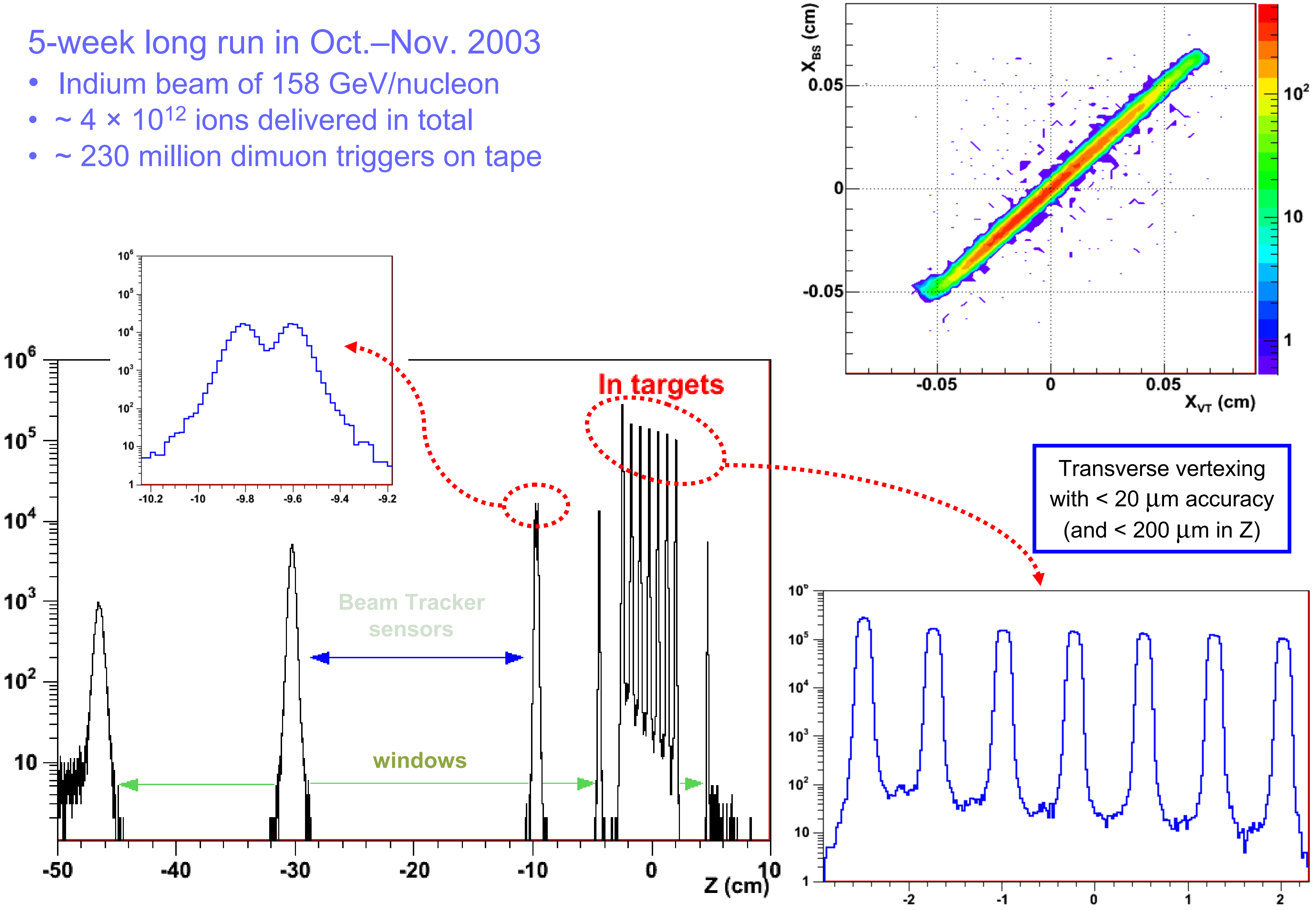
- Is the ρ meson modified by the medium produced in nuclear collisions?
- Because of chiral symmetry restoration?

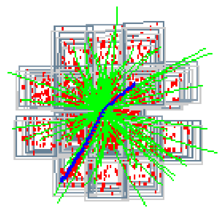
⇒ New measurement with high statistics, good signal to background ratio and dimuon mass resolution

Results from Indium-Indium data

5-week long run in Oct.–Nov. 2003

- Indium beam of 158 GeV/nucleon
- ~ 4 × 10^{12} ions delivered in total
- ~ 230 million dimuon triggers on tape





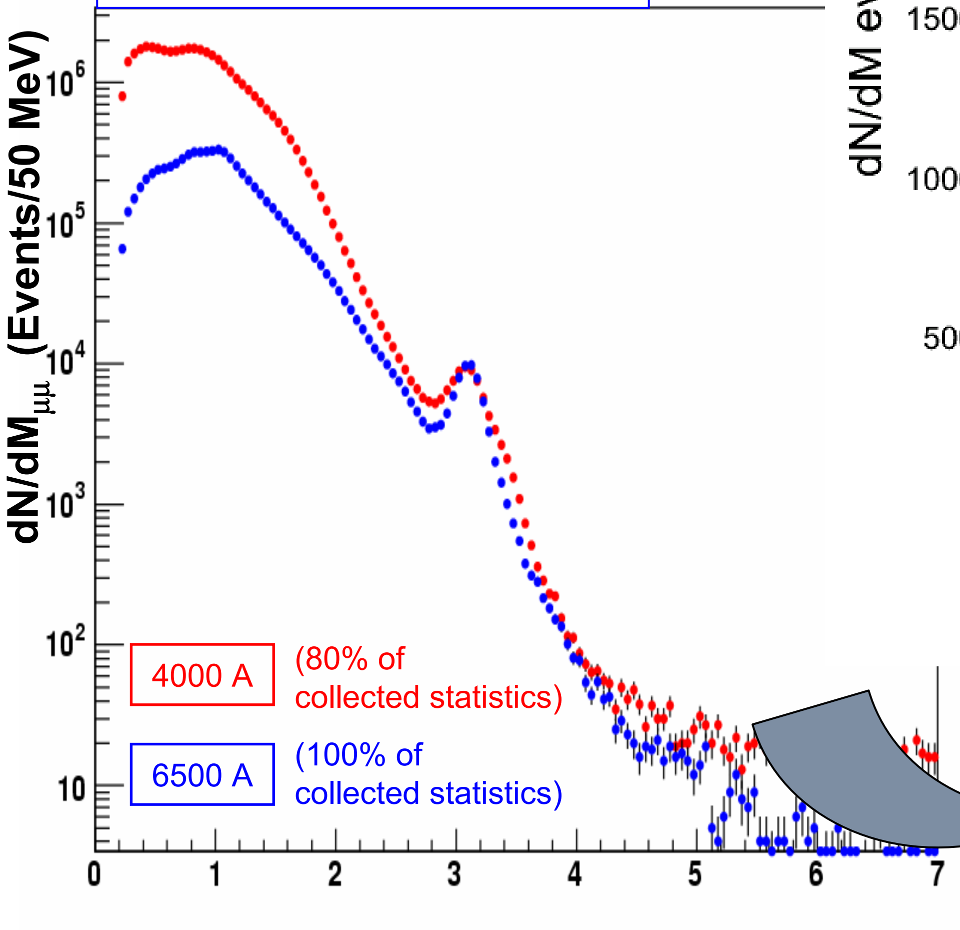
Steps in the analysis procedure

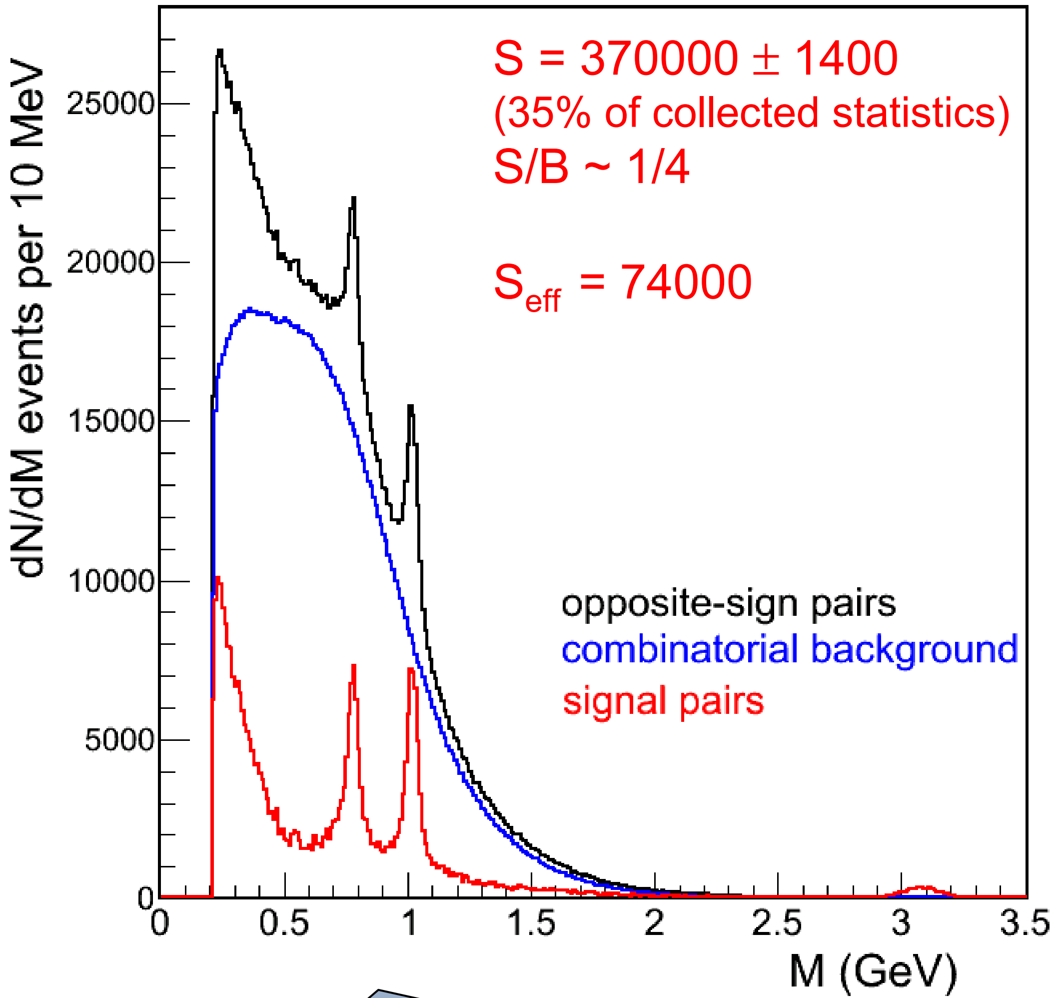
- Select only events with a clean vertex in the target system
- Track matching between muon spectrometer and vertex telescope in coordinate and momentum space
- The combinatorial background resulting from π and K decays is calculated through a mixed-event technique, using single muons from different like-sign muon pairs
- The fake matches are not yet subtracted

The data shown here correspond to ~35% of the total statistics

Dimuon mass spectra

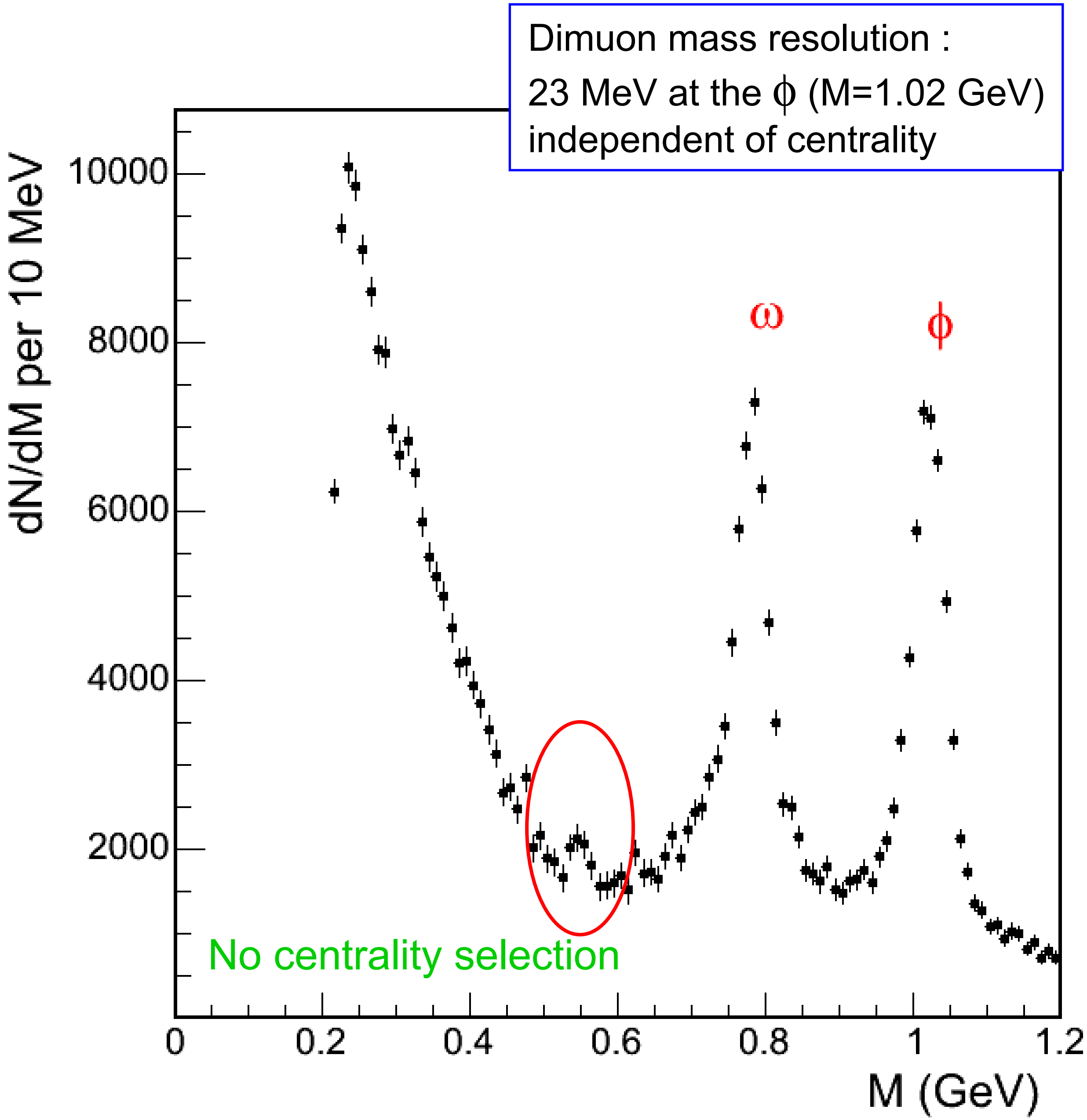
- Opposite-sign dimuon mass distributions
- **Before quality cuts**
- No muon track matching
- Two magnet settings





Vertex selection and muon track matching

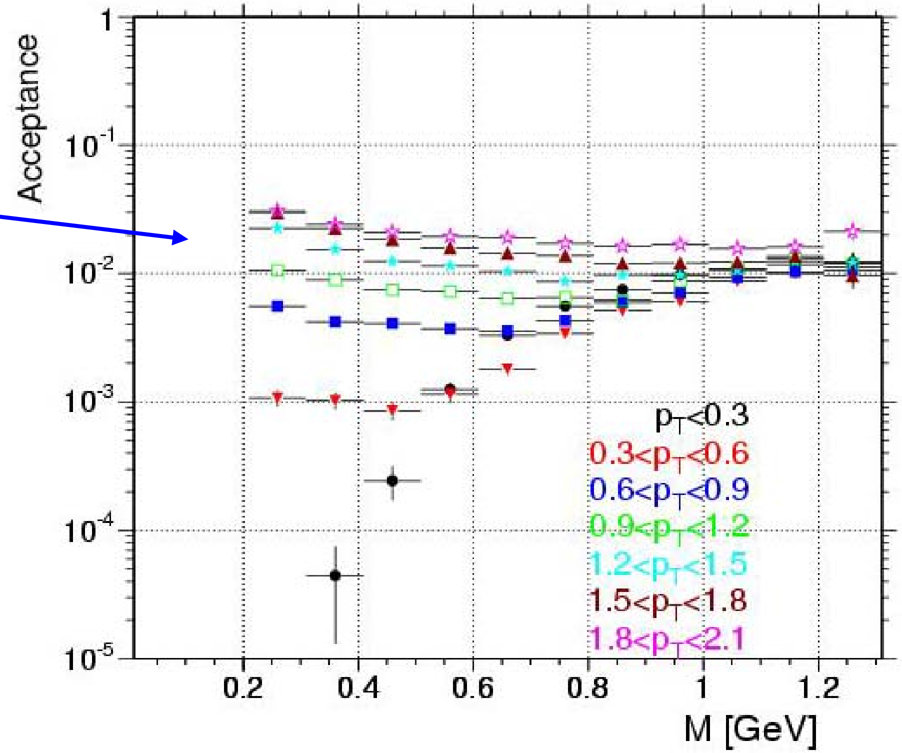
Signal spectrum in the low mass region

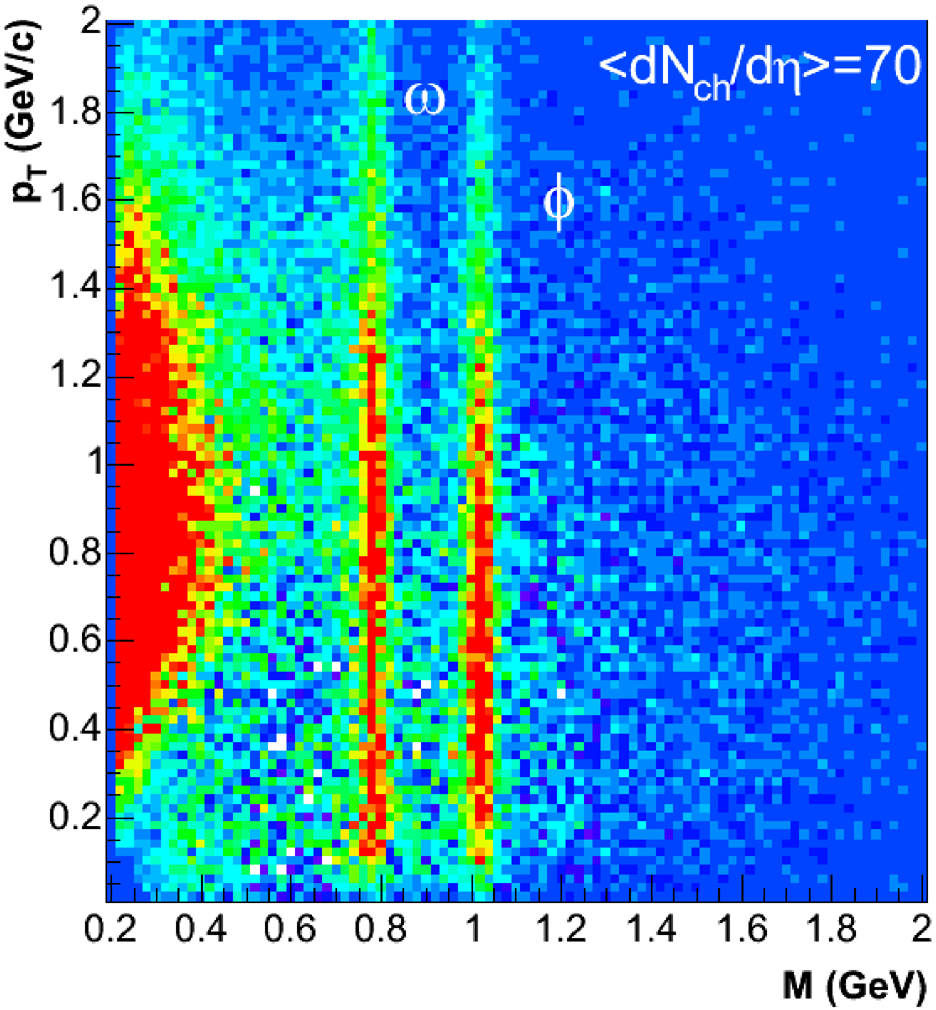


- 37000 ϕ events
- Similar ω statistics
- The $\eta \rightarrow \mu\mu$ channel is also visible (for the first time in nuclear collisions)
- This offers interesting possibilities for the future

Phase space coverage of low mass dimuons

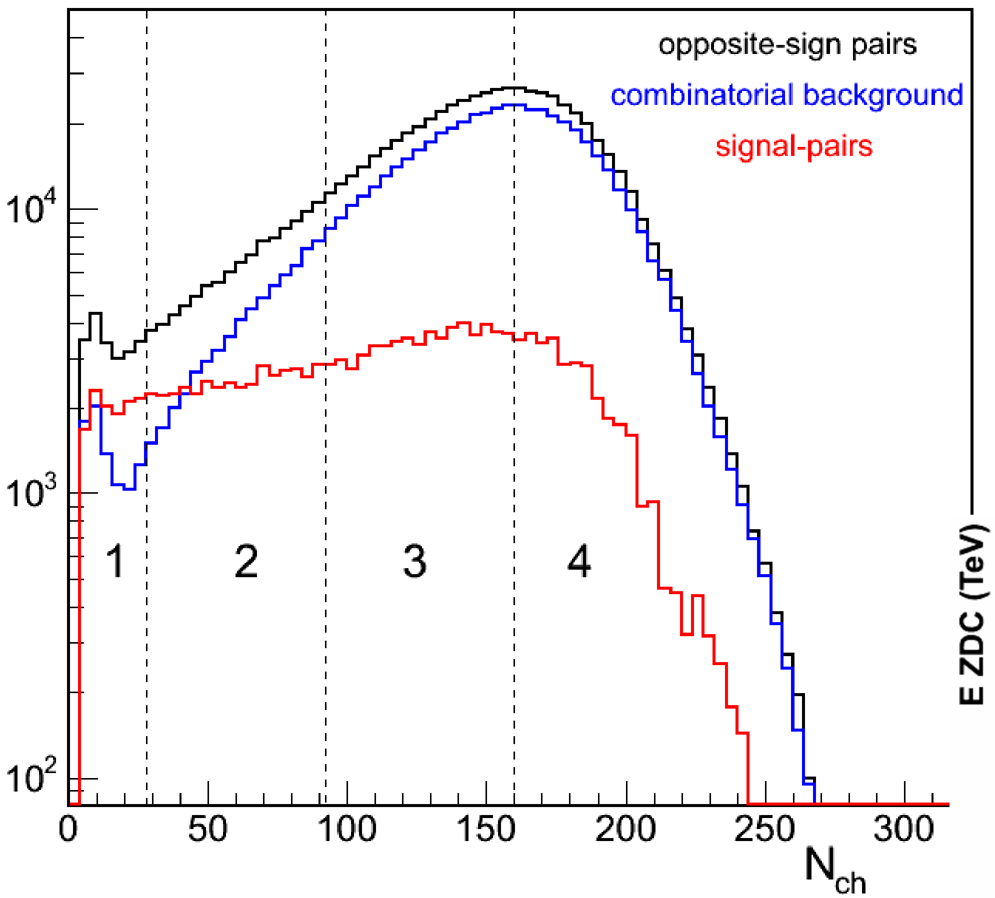
The NA60 acceptance extends, in contrast to NA38/NA50, down to small M and p_T





- Net spectrum after muon track matching and subtraction of the combinatorial background
- The ω and φ vector mesons are beautifully resolved over the whole p_T range

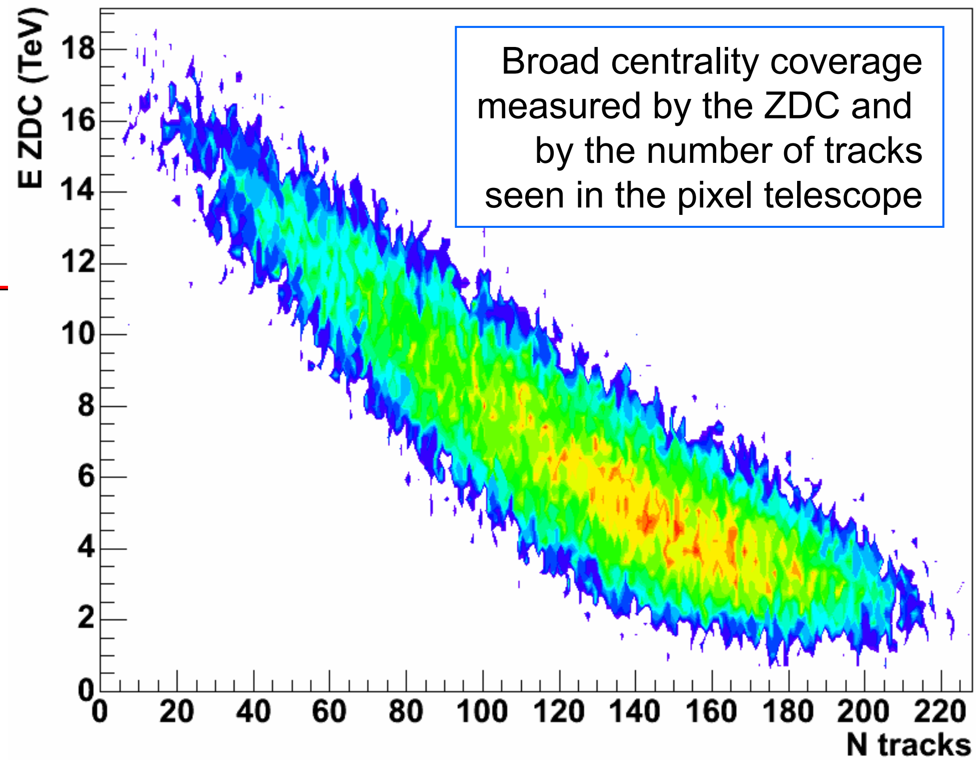
Information on the collision centrality



The associated track multiplicity is measured for each event. It is shown here for opposite-sign pairs, mixed-event background and signal pairs (after background subtraction)

The 4 centrality windows used in this analysis

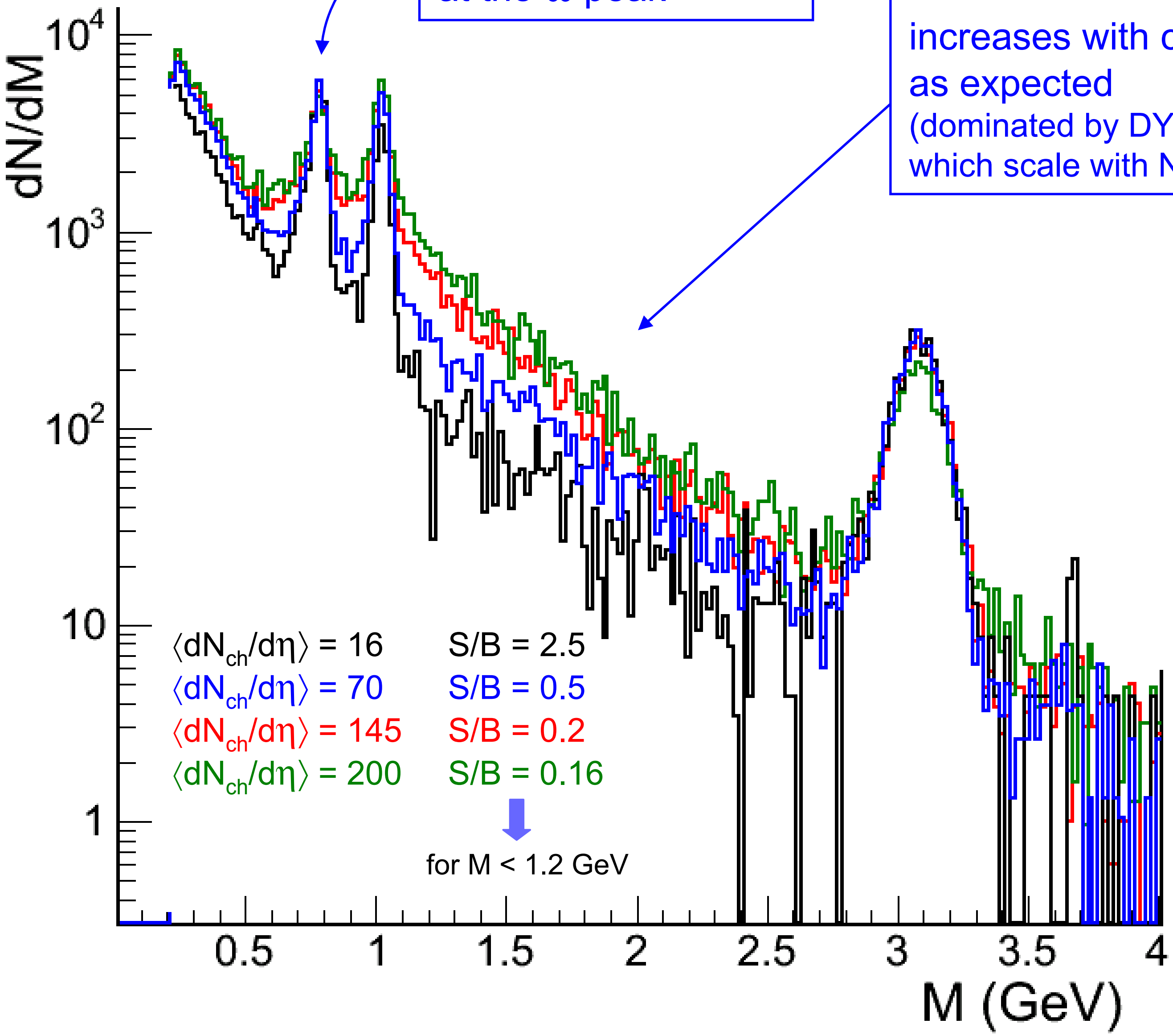
bin	N_{ch} range	$\langle dN_{ch}/d\eta \rangle$	N_{part}
1	4–28	16	~20
2	28–92	70	91
3	92–160	145	161
4	>160	200	197



Signal mass spectra versus centrality

The four spectra are relatively normalized at the ω peak

The intermediate mass dimuon yield increases with centrality faster than the ω, as expected
(dominated by DY and charm decays, which scale with N_{coll}, not with N_{part})

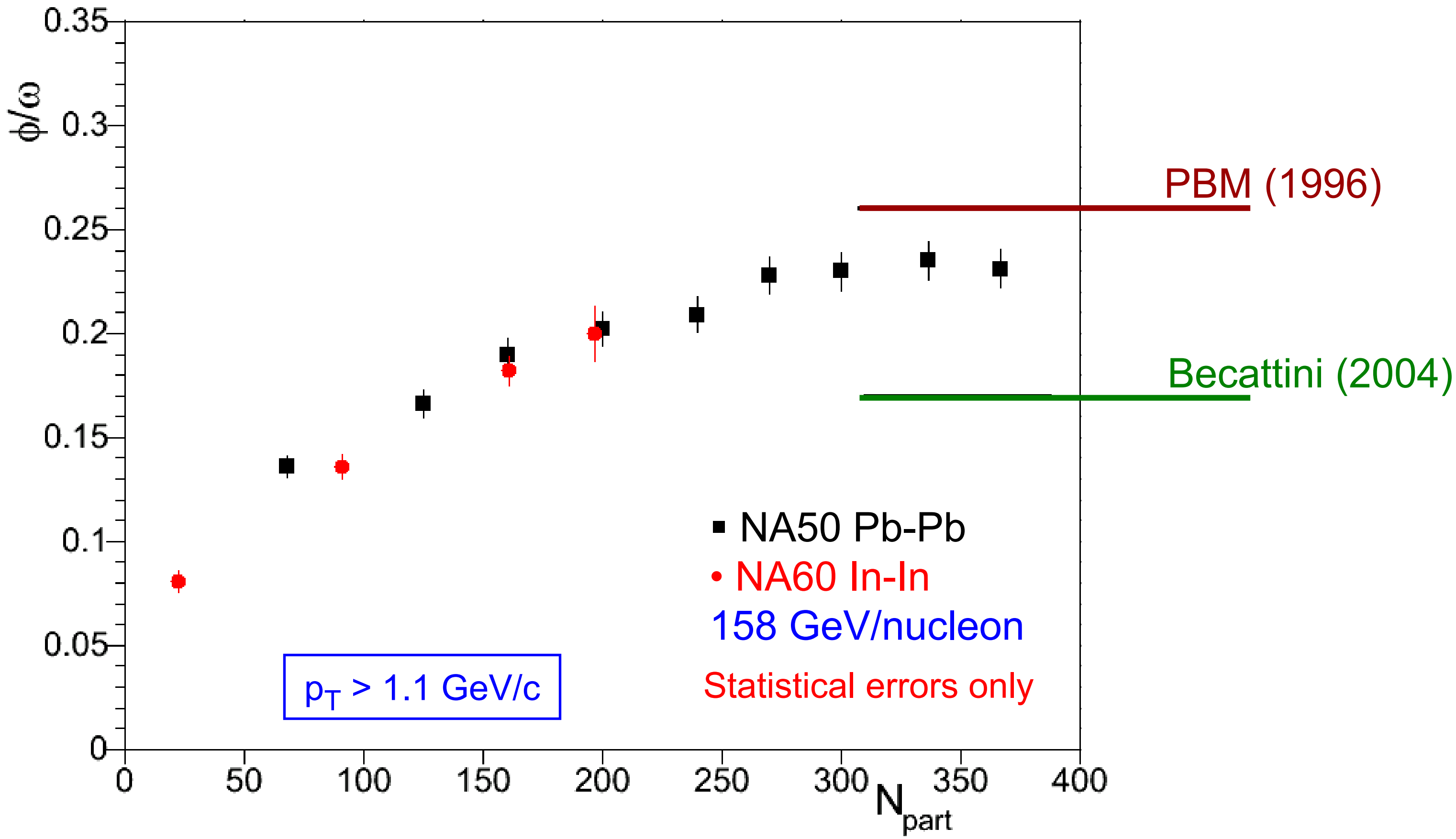


Extraction of the ϕ/ω cross section ratio

Analysis steps:

- Select dimuons in a well defined rapidity window $3.3 < y < 4.2$
- Simulate the light hadron decays using the event generator GENESIS, with particle ratios as given by the statistical model. Complement them with Drell-Yan and open charm decays generated with Pythia, to account for the continuum under and beyond the ϕ
- Propagate the generated events through the NA60 set-up and reconstruct them as the measured data
- Add the level of fake matches, in an approximate way, as estimated by MC simulation
- Assume identical production cross-sections for the ρ and ω mesons
- Fit the MC output to the data, allowing variations of the η/ω and ϕ/ω ratios and of the continuum yield.
- Repeat this procedure for each of the 4 multiplicity bins

ϕ/ω cross section ratio versus centrality

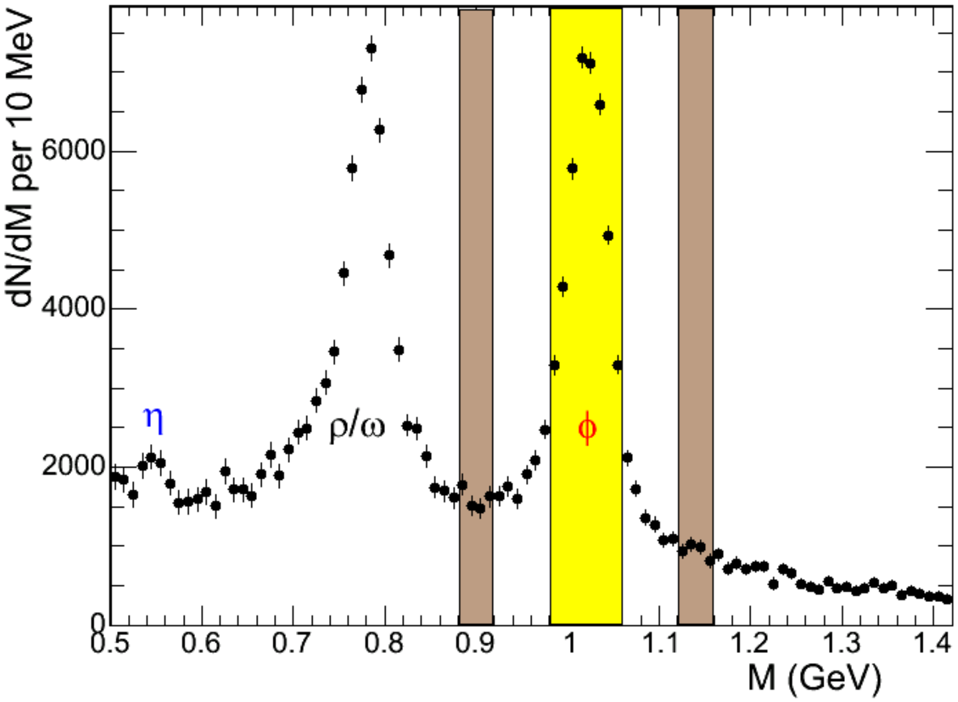


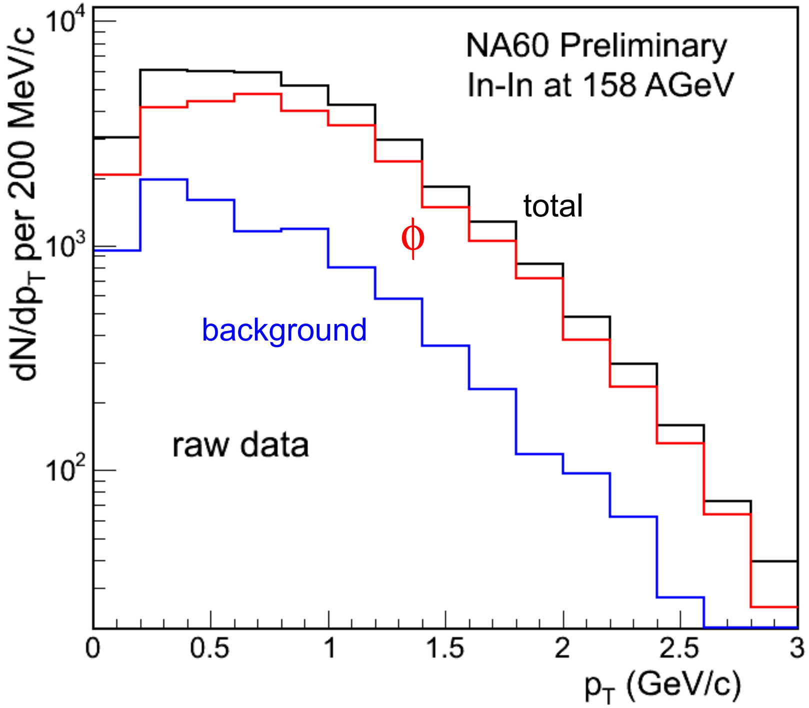
Very good agreement between the In-In and Pb-Pb colliding systems

$\rightarrow$ N_{part} seems to be the appropriate scaling variable for ω and ϕ production

- The NA50 $\phi/(\rho+\omega)_{\mu\mu}$ published values were corrected for BR, assuming $\rho/\omega = 1$, and extrapolated from $m_T > 1.5$ GeV to $p_T > 1.1$ GeV using T = 228 MeV
- The NA60 systematic uncertainties are expected to be < 10%

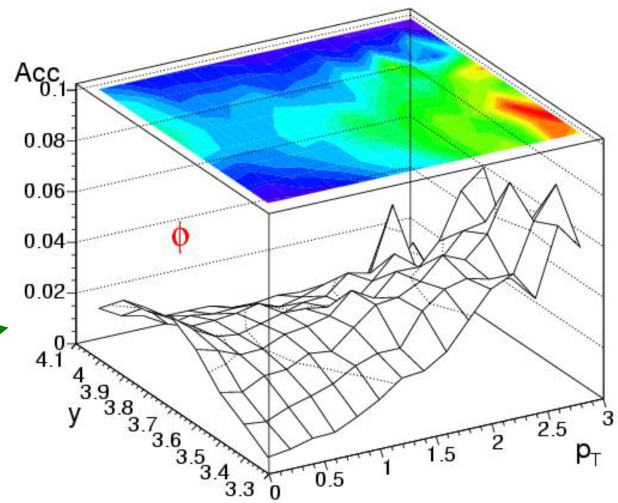
ϕ transverse momentum spectrum



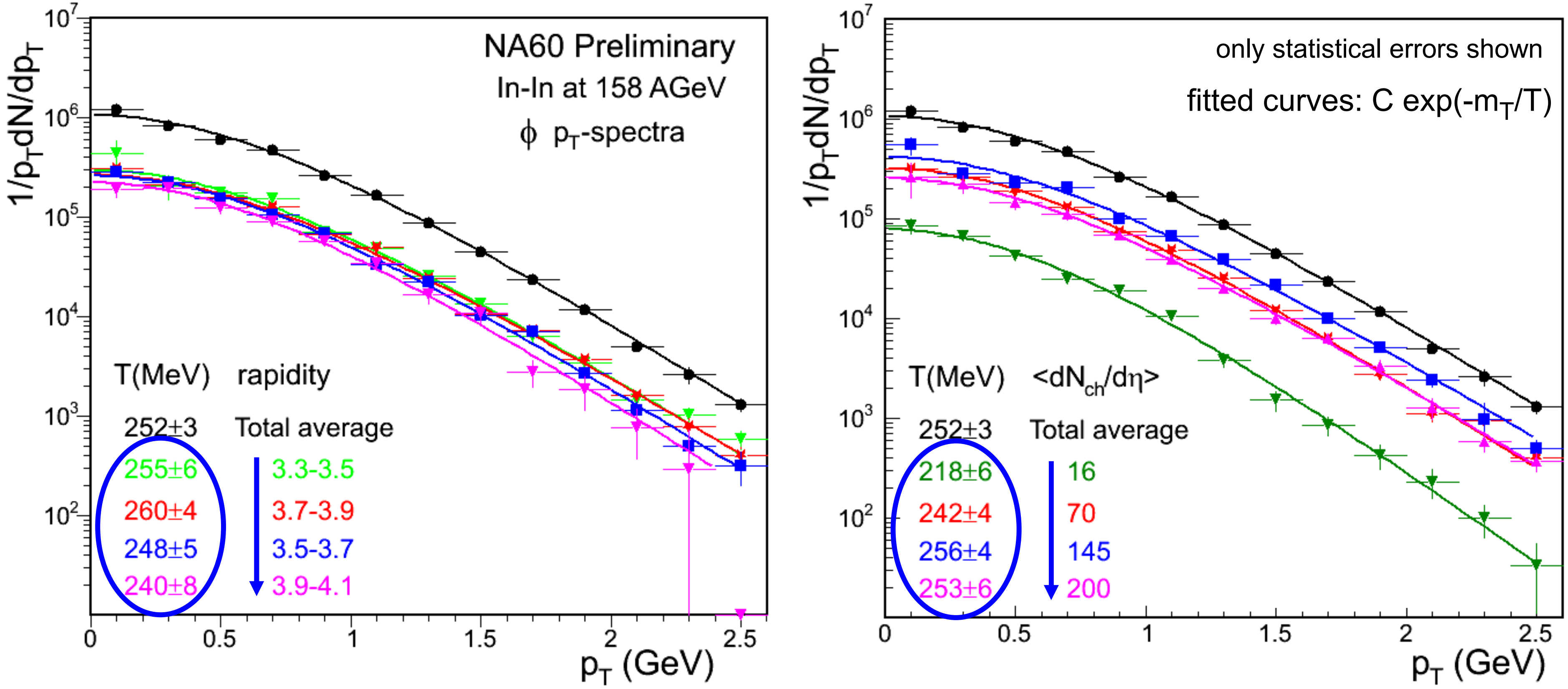


We select the events on the ϕ peak and use two side mass windows to estimate the p_T distribution of the continuum under the peak

Then we correct for the acceptance, calculated (by Monte Carlo) as a 2-dim matrix: p_T and y

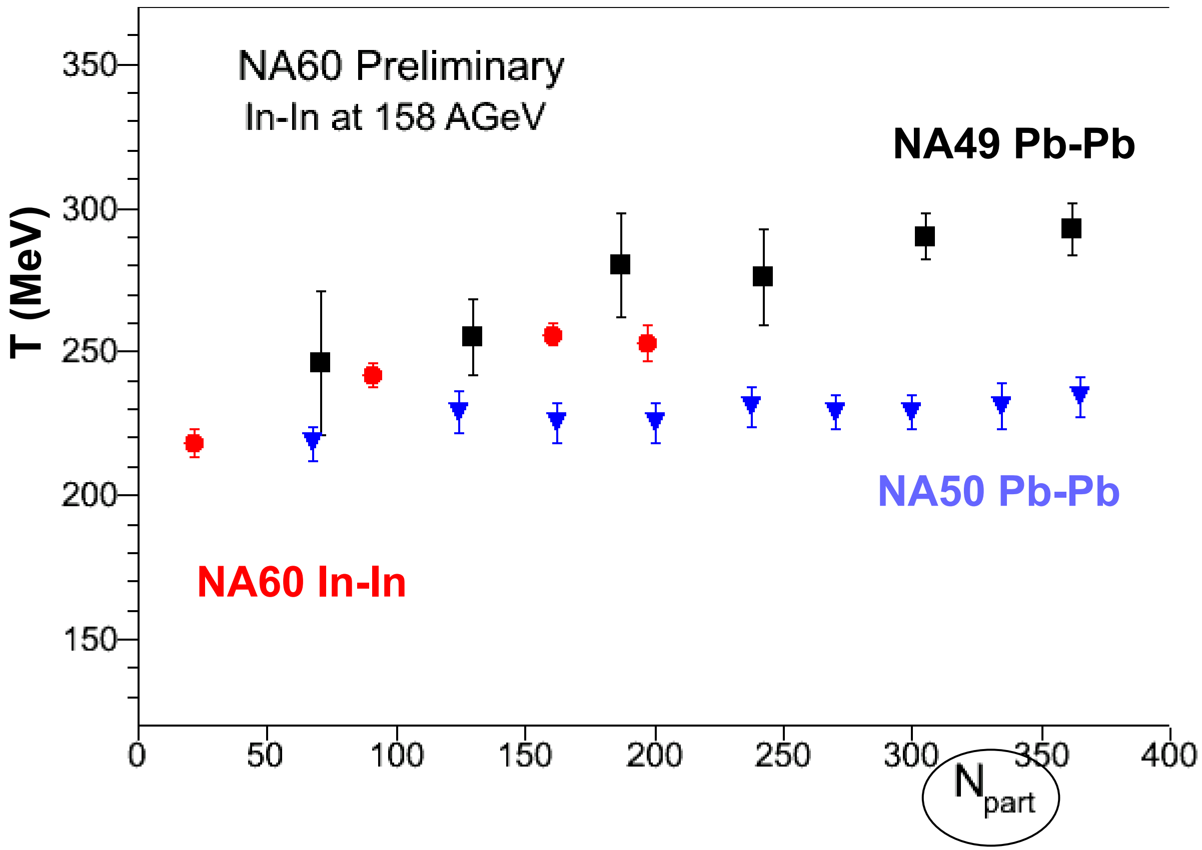


ϕ p_T spectrum versus y and centrality



- There is no significant variation of the extracted inverse slope parameter, T, with rapidity
- There is a clear increase from peripheral to central collisions
- With full statistics, extension up to $p_T > 3$ GeV/c should be feasible

T(ϕ) : NA60 versus NA50 and NA49



<u>Average T(ϕ) In-In values</u>

1) all p_T
   252 ± 3 MeV

2) p_T < 1.5 GeV (NA49 range)
   256 ± 6 MeV

3) m_T > 1.65 GeV (NA50 range)
   245 ± 5 MeV

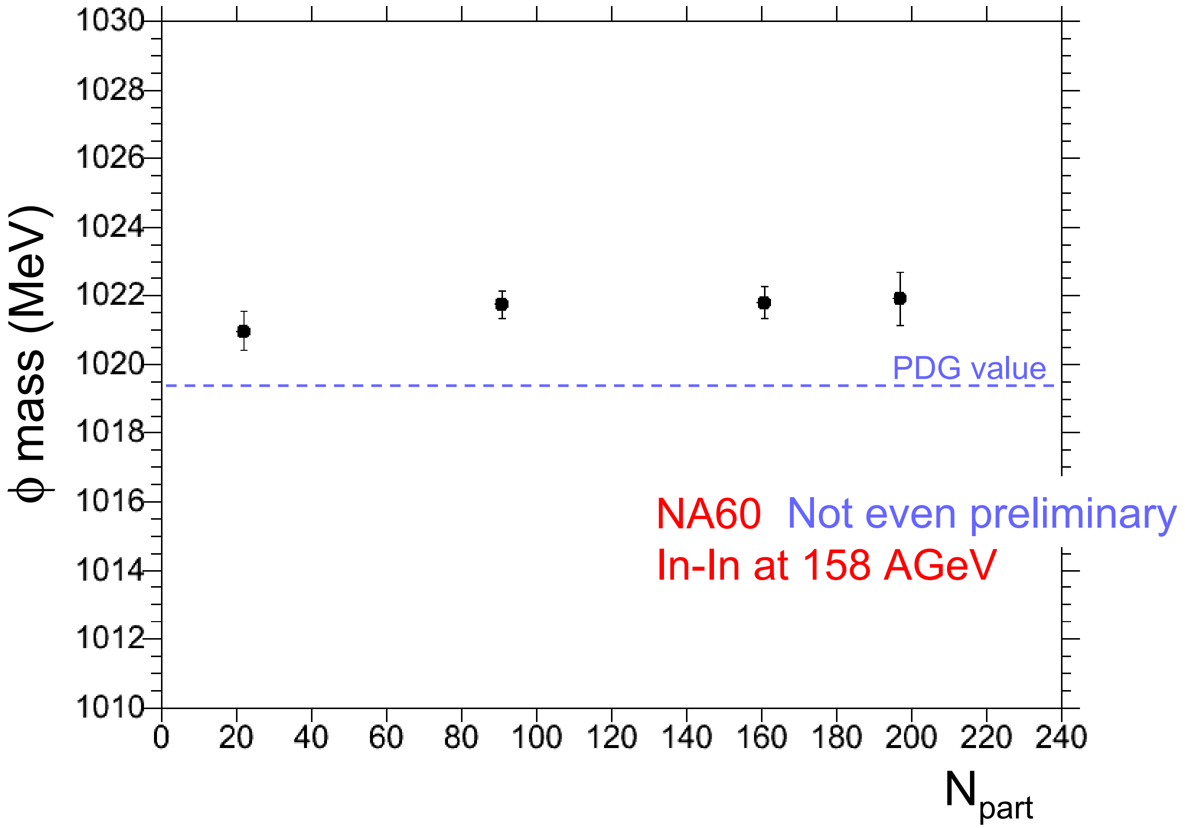
→ Always ~ 250 MeV

Systematic errors still under investigation
Expected to be less than 10 MeV

The ϕ mass versus centrality

The NA60 mass resolution at the ϕ mass is 23 MeV, in all centrality bins

→ It is tempting to look for changes of the ϕ mass versus centrality



- Data analysis at the very beginning; much work remains to be done.
- A 3 MeV shift in the absolute determination of the ϕ mass is well within the present uncertainties of the analysis. But these uncertainties should not depend on centrality…
- It seems that there are no strong M_{ϕ} changes between peripheral and central In-In collisions

Summary and future perspectives

- A total of ~1 million signal low mass dimuons, from In-In collisions, after muon track matching.
  About 35% of this statistics has been analysed by now.
  - 23 MeV dimuon mass resolution at the ϕ mass
  - good signal to background ratio

- First results on:
  - the ϕ/ω cross section ratio
  - the inverse slope parameter T of the ϕ
  - the ϕ mass

  } … as a function of centrality

<u>What's next:</u>

- Analysis of the full data sample
- Fake matches subtraction

continuum physics
in the low mass and intermediate mass region