Recent Results from CERES

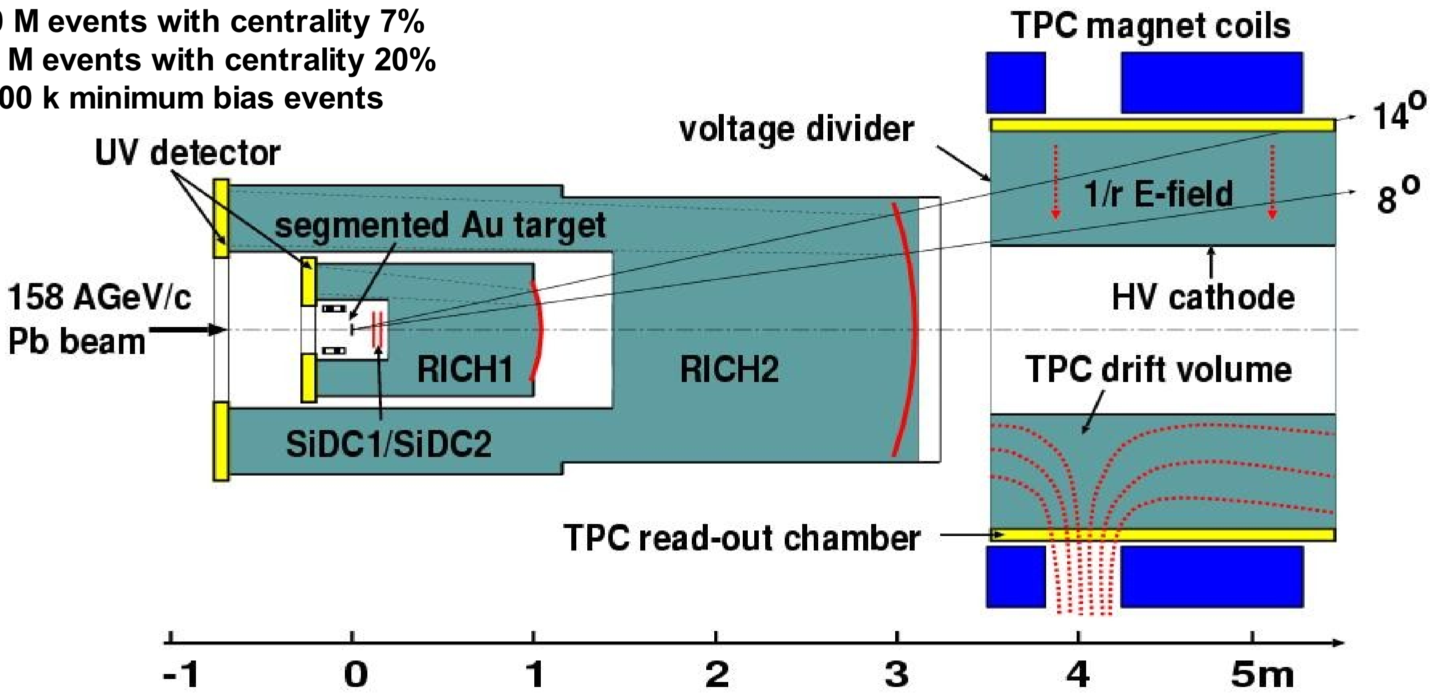
D. Miśkowiec for the CERES Collaboration

Quark Matter 2005, Budapest

- introduction
- e^+e^- continuum and in-medium effects
- leptonic and hadronic decays of ϕ
- elliptic flow of Λ
- pion-proton correlations
- fluctuations of mean pt
- high-pt angular correlations
- summary

setup with TPC: 1999 and 2000

run 2000: 30 M events with centrality 7%
2 M events with centrality 20%
500 k minimum bias events



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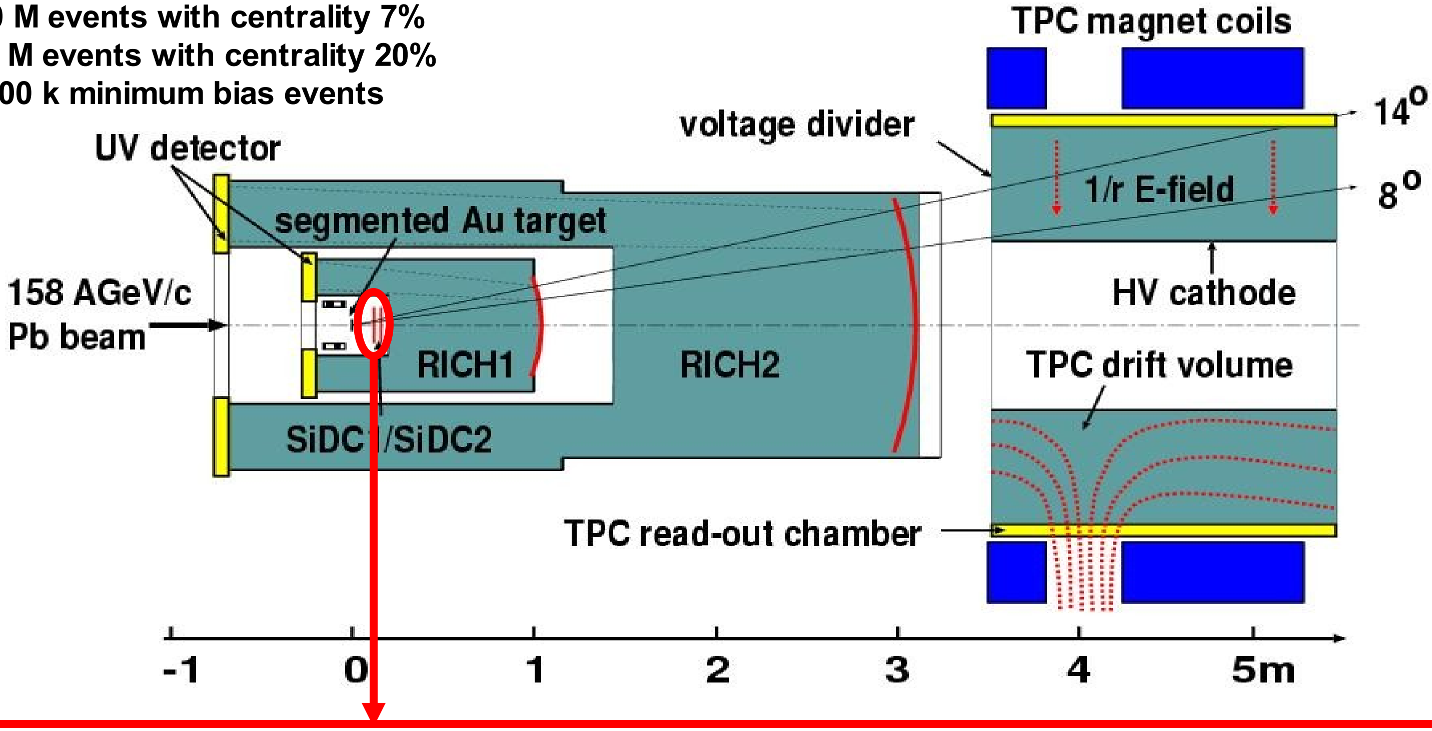
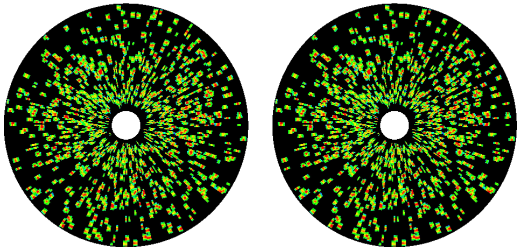
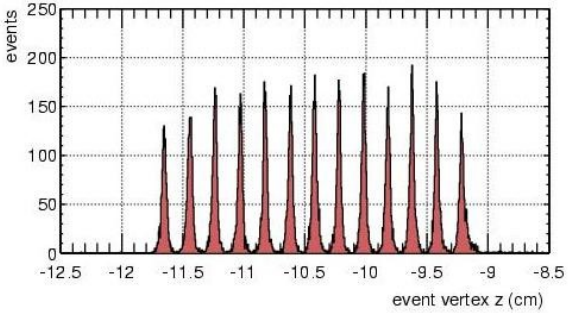


SD: event vertex, track vertex and angle





event Δz = 0.2 mm
track $\Delta\theta$ = 0.2 mrad
$\Delta\varphi$ = 2 mrad

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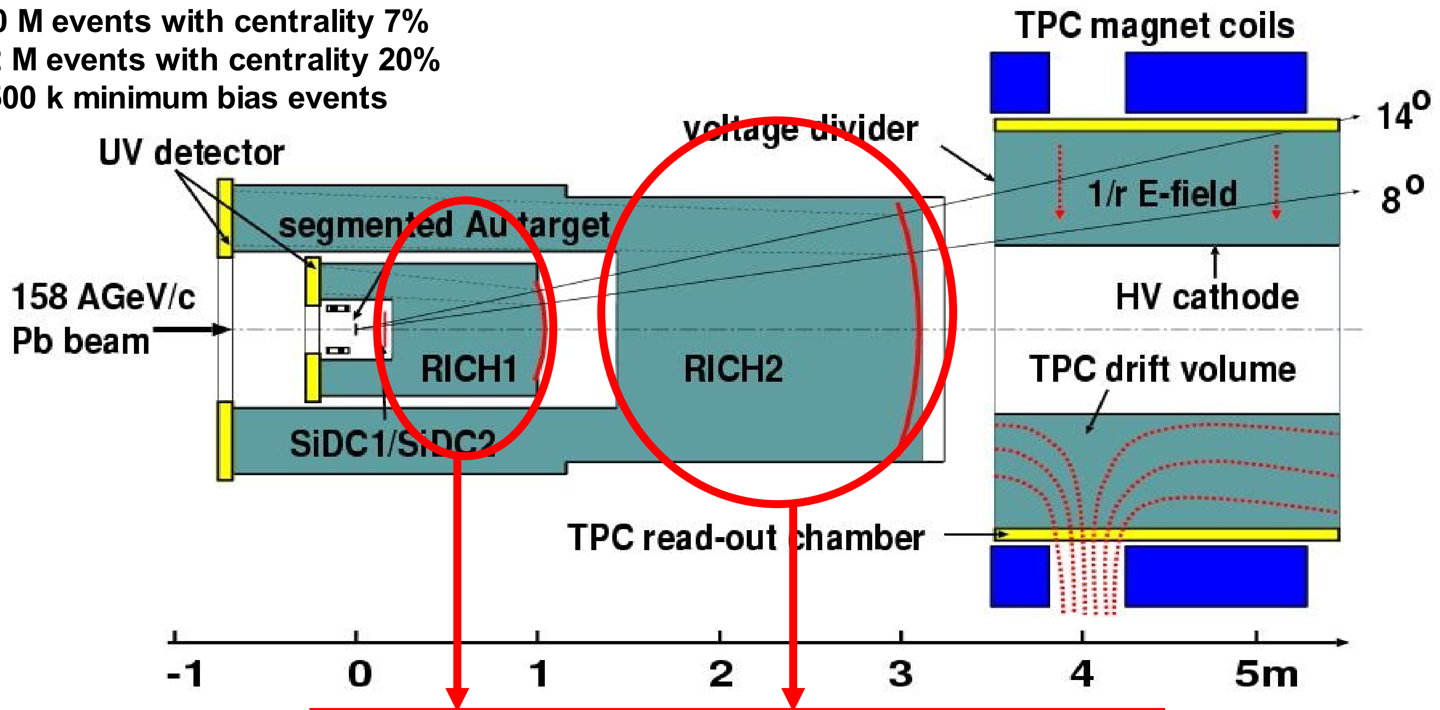
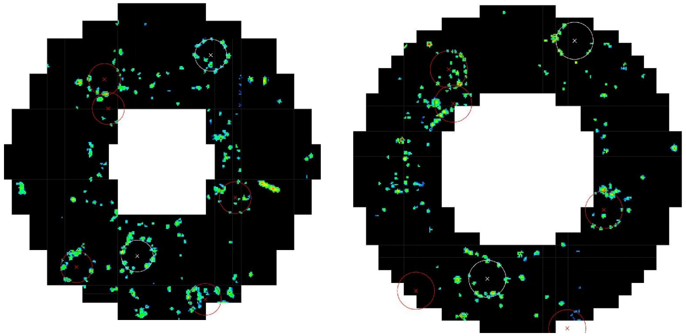


RICH's: electron identification



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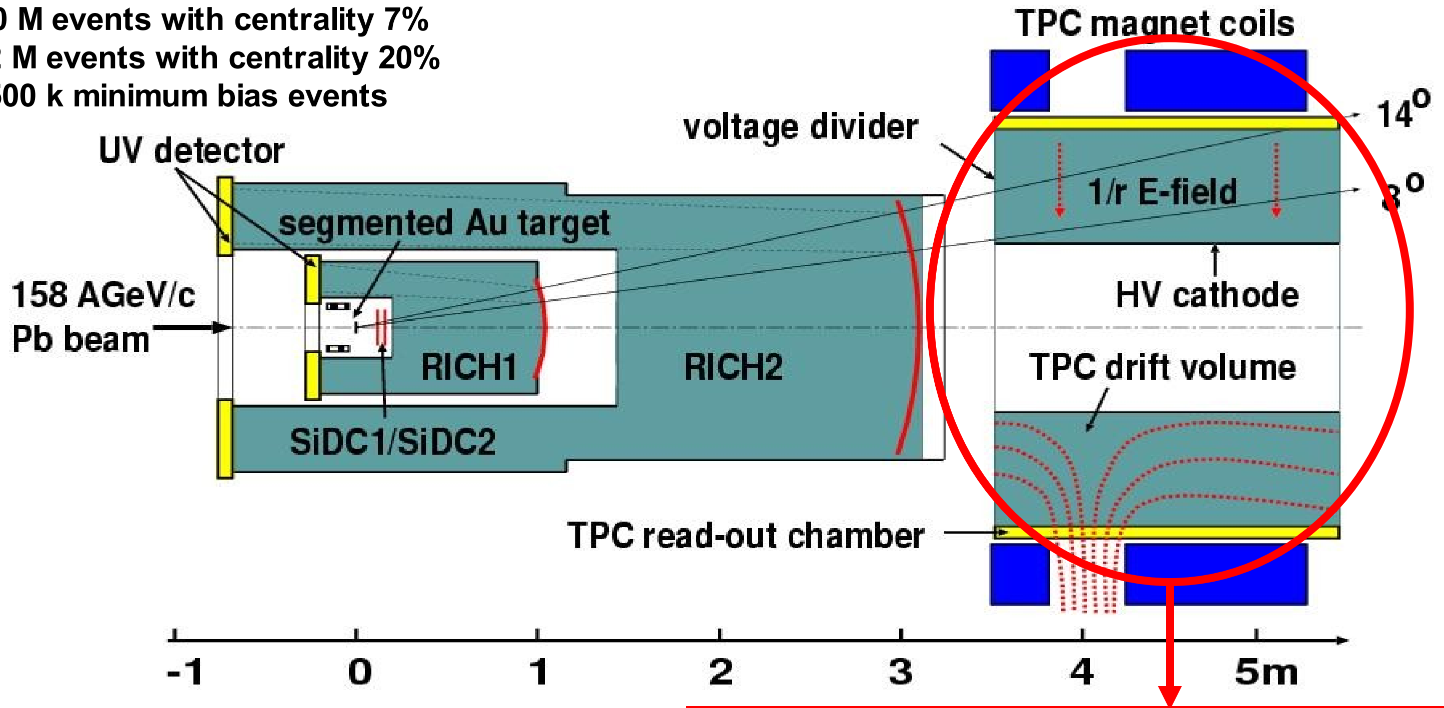
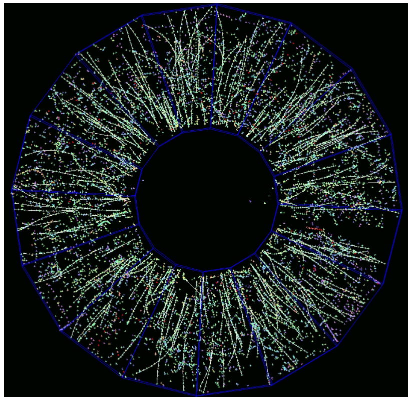


radial drift TPC: momentum and energy loss



$\delta p = 2\% \oplus 1\% * p/\mathrm{GeV}$

$\delta m = 3.8\ \%$ for ϕ

$\delta dEdx = 10\%$

centrality determination

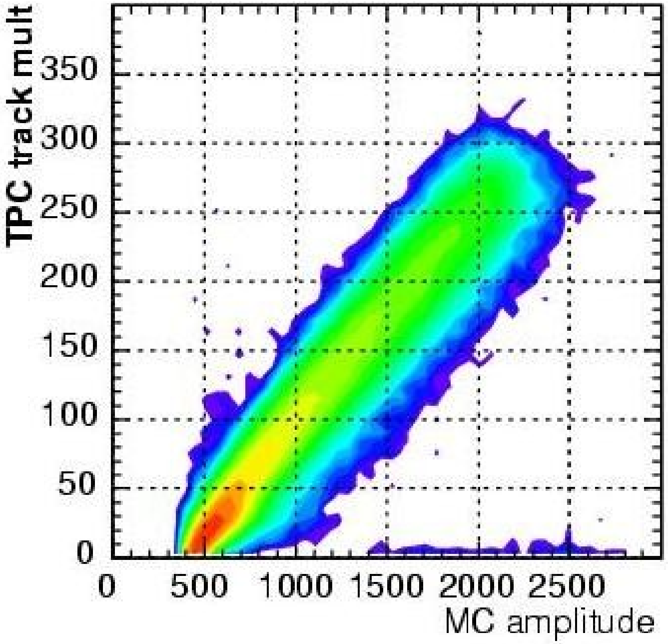
Pb+Au at 158 GeV per nucleon

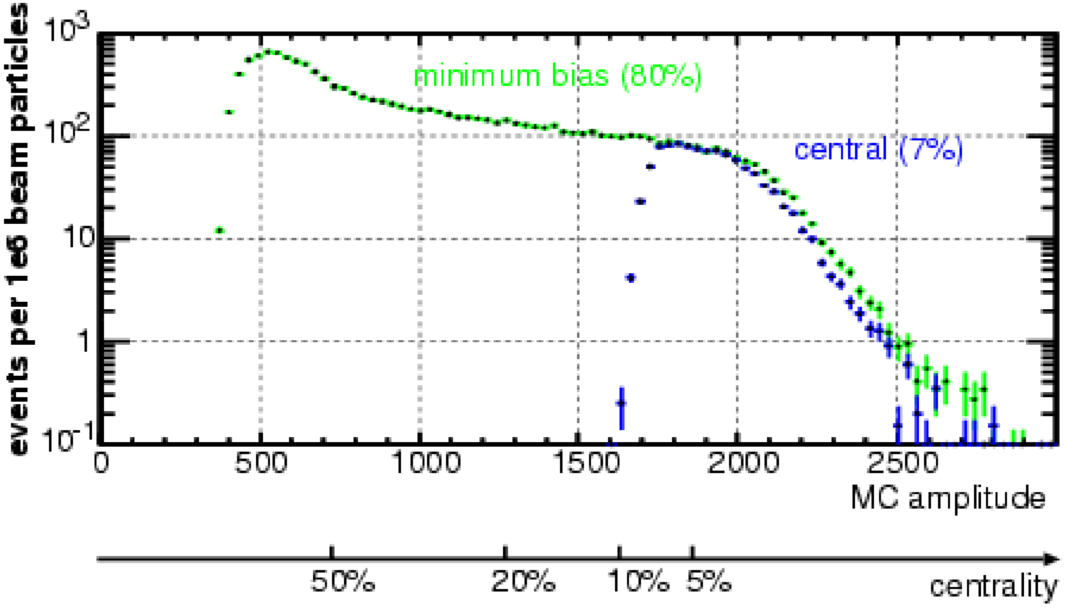
centrality deduced from the multiplicity of charged particles around mid-rapidity

MC scintillator amplitude $2.95 < \eta < 4.05$

TPC track multiplicity $2.10 < \eta < 2.80$

mid-rapidity $y = 2.91$

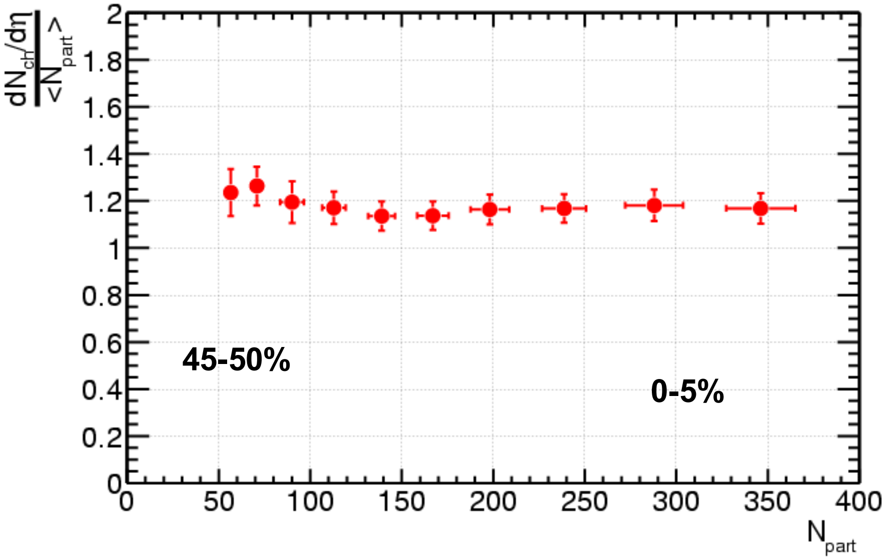




charged particle multiplicity

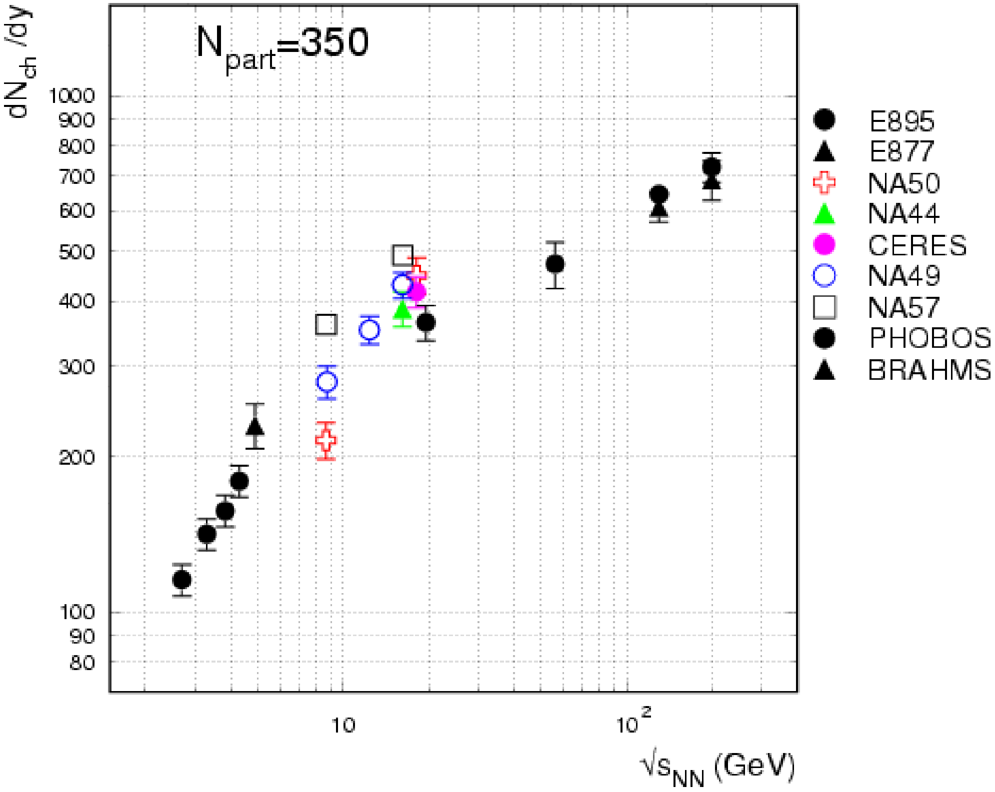
Pb+Au at 158 GeV per nucleon

charged particle multiplicity determined from hits in the two silicon detectors



flat N_{ch} per participant

dNch/dη in central collisions of Au or Pb compilation by A. Andronic



good agreement in dNch/dη between CERES, NA49, NA50, and NA44

e^+e^- analysis

Pb+Au at 158 GeV per nucleon, run 2000
about 20 M events after quality cuts
centrality 7%

tracking
↓
electron identification
↓
π^0-Dalitz and γ-conversion rejection
↓
pairing
↓
subtraction of background
(like-sign or mixed events)
↓
efficiency correction
↓
mass spectrum

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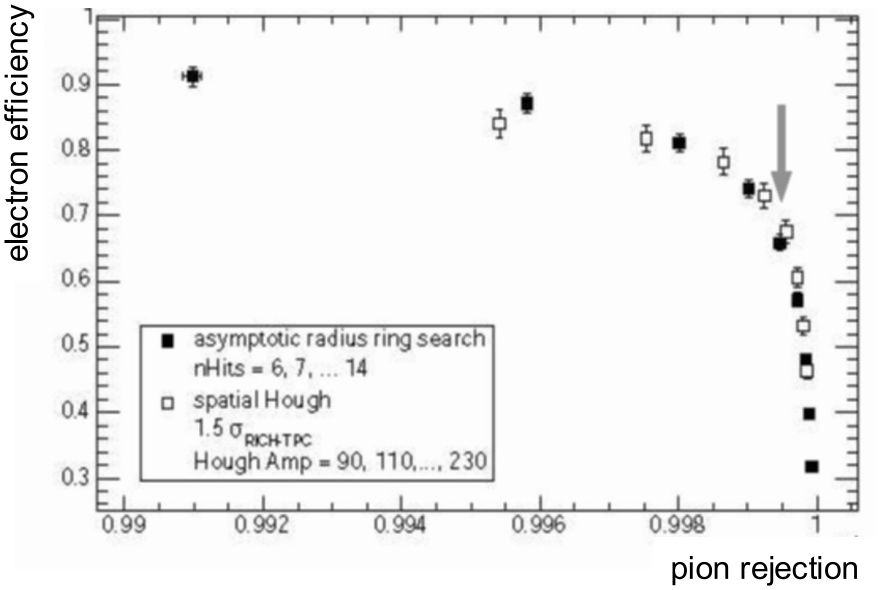
RICH performance determined from the experiment



RICH performance
determined from exp data

electron efficiency 70%
pion suppression factor $2 \cdot 10^3$
(combined RICH & TPC: $4 \cdot 10^4$)

e^+e^- analysis

Pb+Au at 158 GeV per nucleon, run 2000
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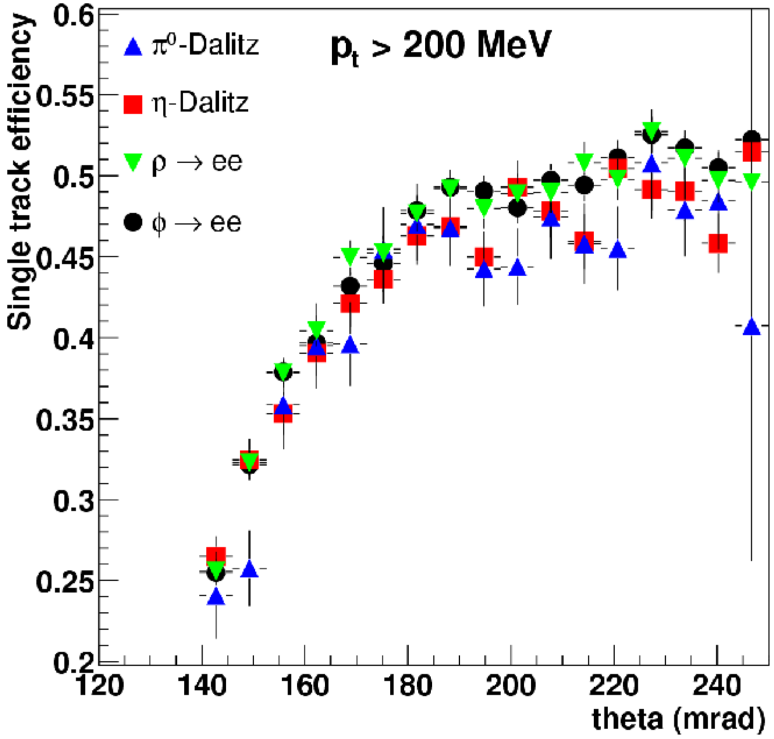
mass spectrum

Monte Carlo: tracks embedded in experimental events

overall electron efficiency well understood in terms of the single track efficiency

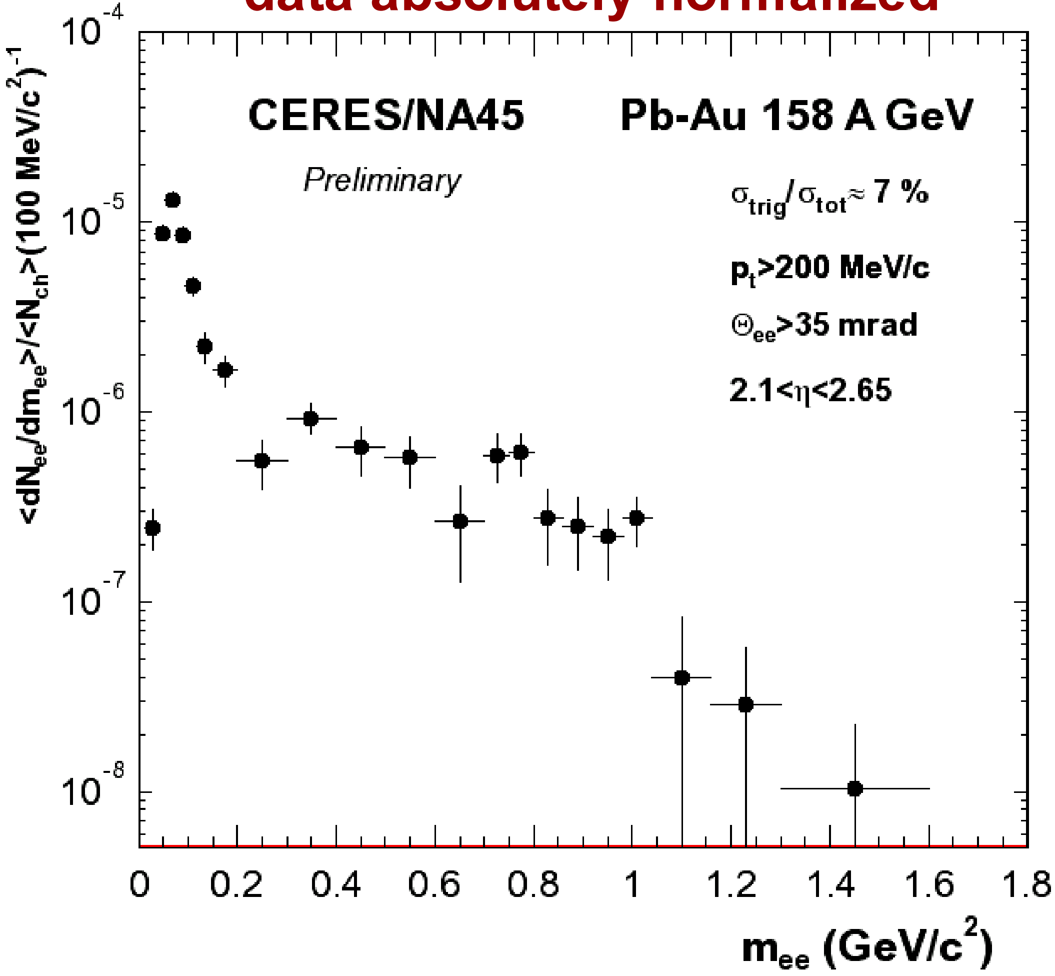


e^+e^- mass spectrum

Pb+Au at 158 GeV per nucleon

Sergey Yurevich

data absolutely normalized



2571±224 e^+e^- pairs with m_{ee} > 0.2 GeV

S/B = 1/21

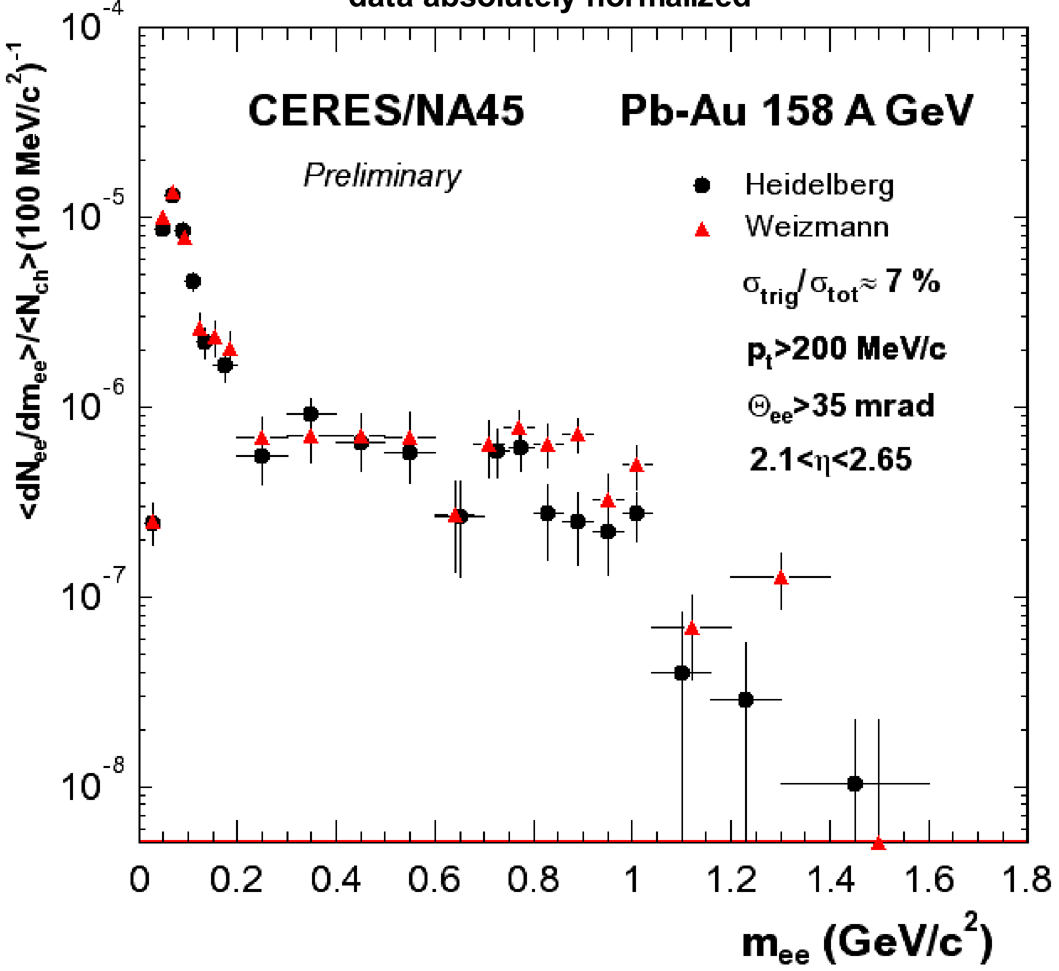
$\langle dN_{ch}/d\eta \rangle$= 335

e^+e^- mass spectrum

Pb+Au at 158 GeV per nucleon

Sergey Yurevich, Heidelberg University
Alexander Cherlin, Weizmann Institute
Oliver Busch, GSI Darmstadt

data absolutely normalized



two physics analyses give identical results

third analysis:

track all charged particles, for each track determine pid

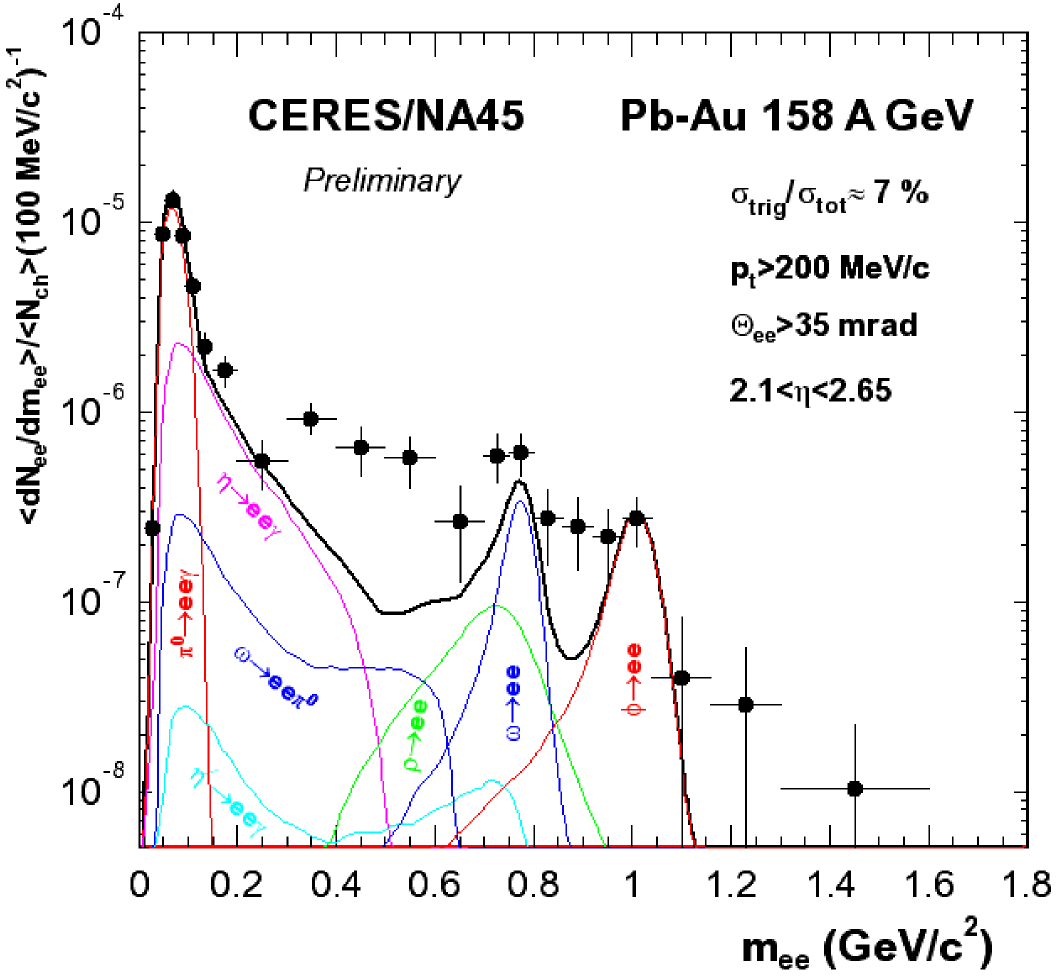
→ identical shape, absolute efficiency not yet finished

e^+e^- mass spectrum: enhancement

Pb+Au at 158 GeV per nucleon

Sergey Yurevich

comparison to the hadron decay cocktail



enhancement over hadron decay cocktail

for m_{ee} > 0.2 GeV:

2.43±0.21 (stat)

for 0.2 GeV<m_{ee}< 0.6 GeV:

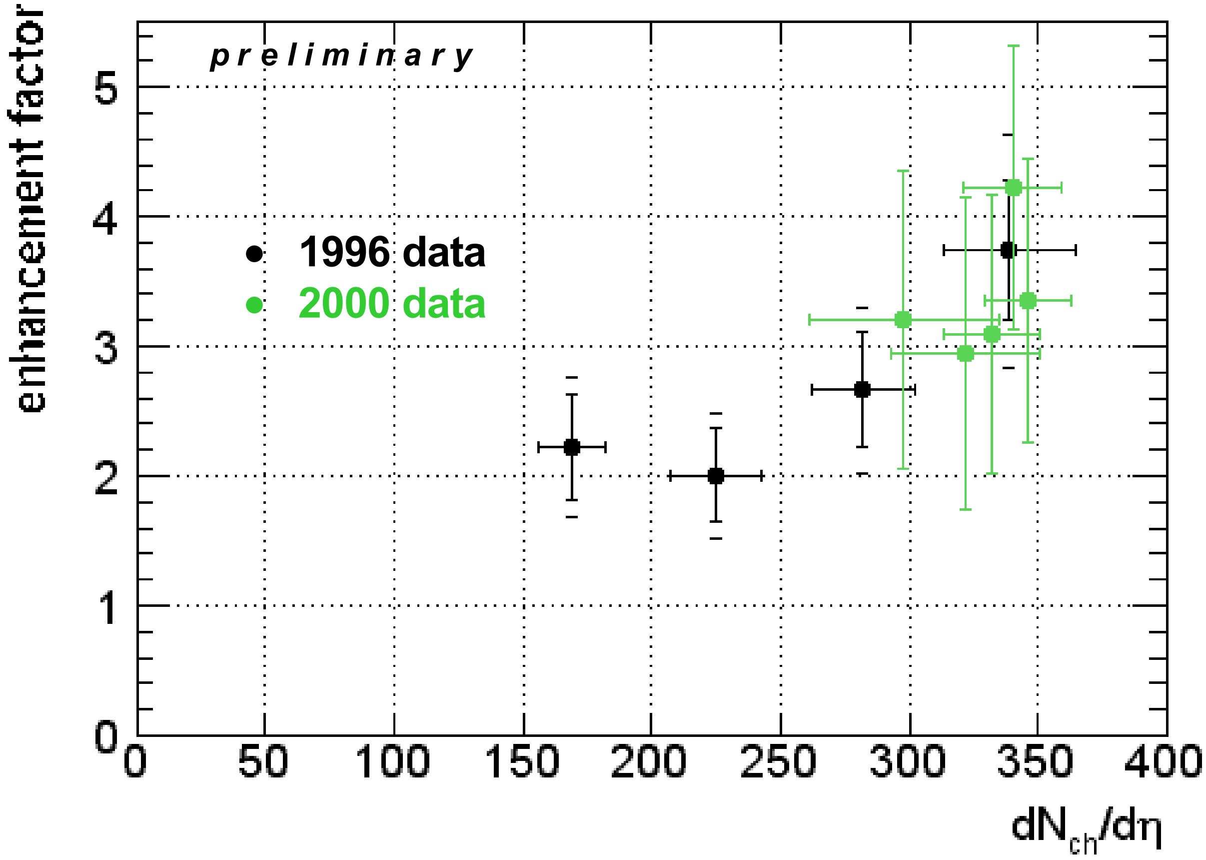
2.8±0.5 (stat)

overall systematic uncertainty of normalization: 21%

e^+e^- enhancement: centrality dependence

Pb+Au at 158 GeV per nucleon

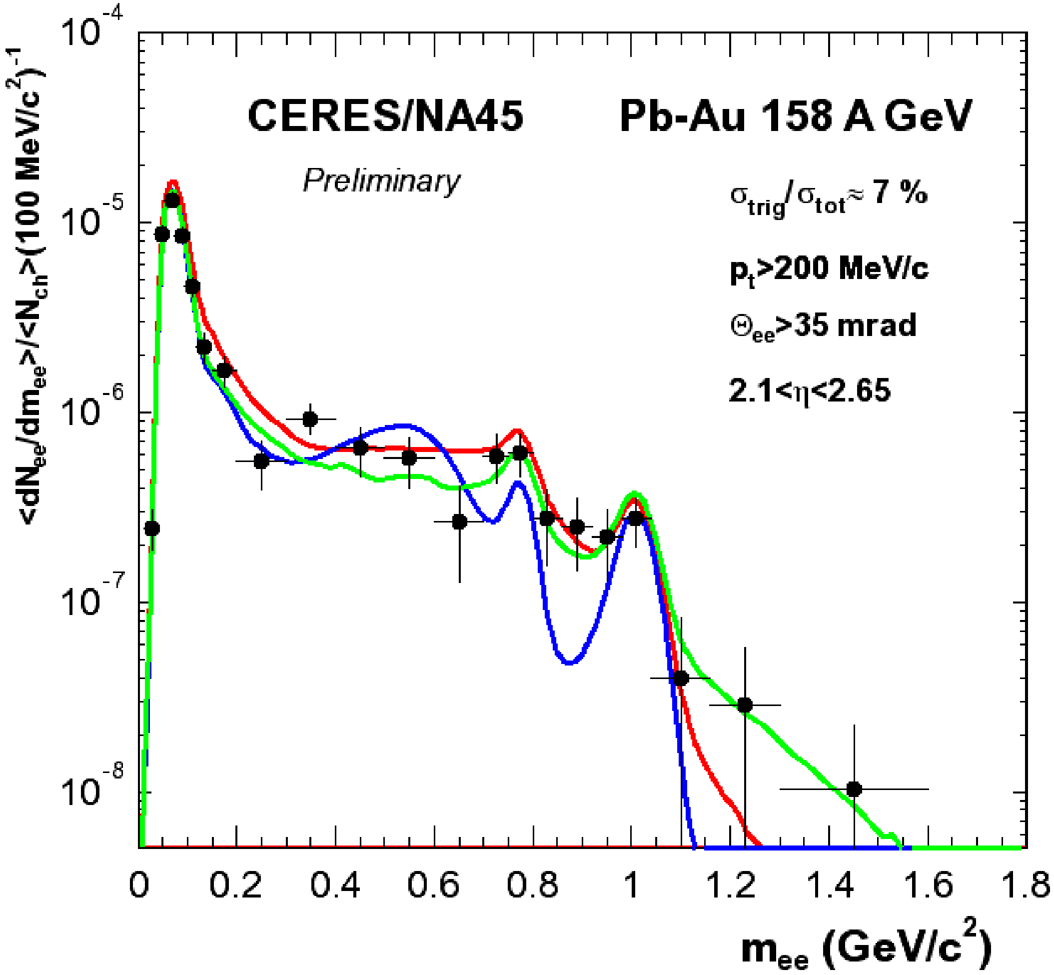
Sergey Yurevich



e+e- mass spectrum: comparison to the models

Pb+Au at 158 GeV per nucleon

Sergey Yurevich



calculation by R.Rapp using Rapp/Wambach medium modification of rho spectral function

calculation by R.Rapp using Brown-Rho scaling

B. Kämpfer, thermal emission

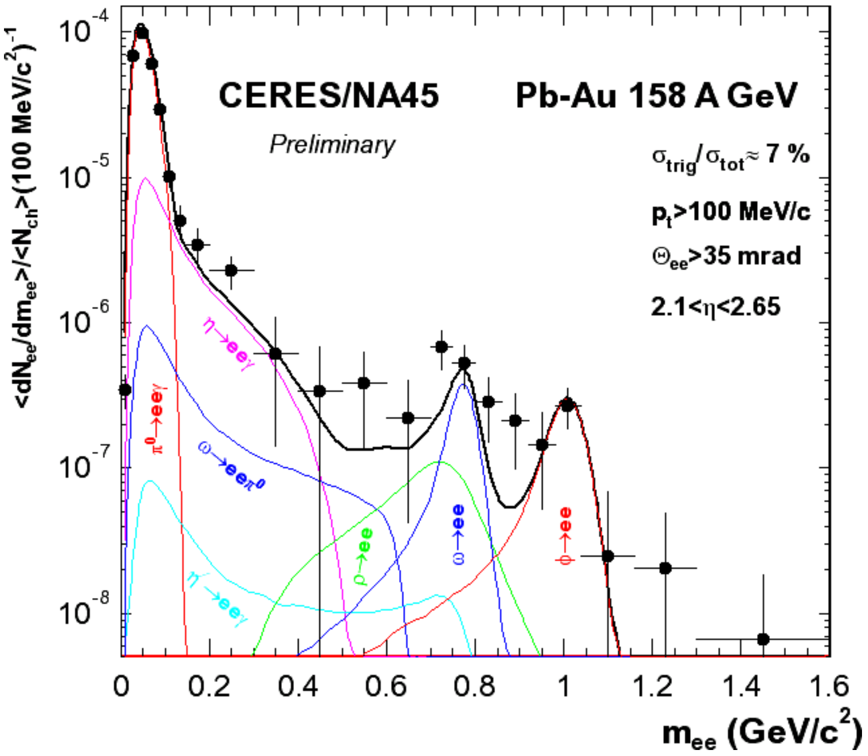
...added to the cocktail.

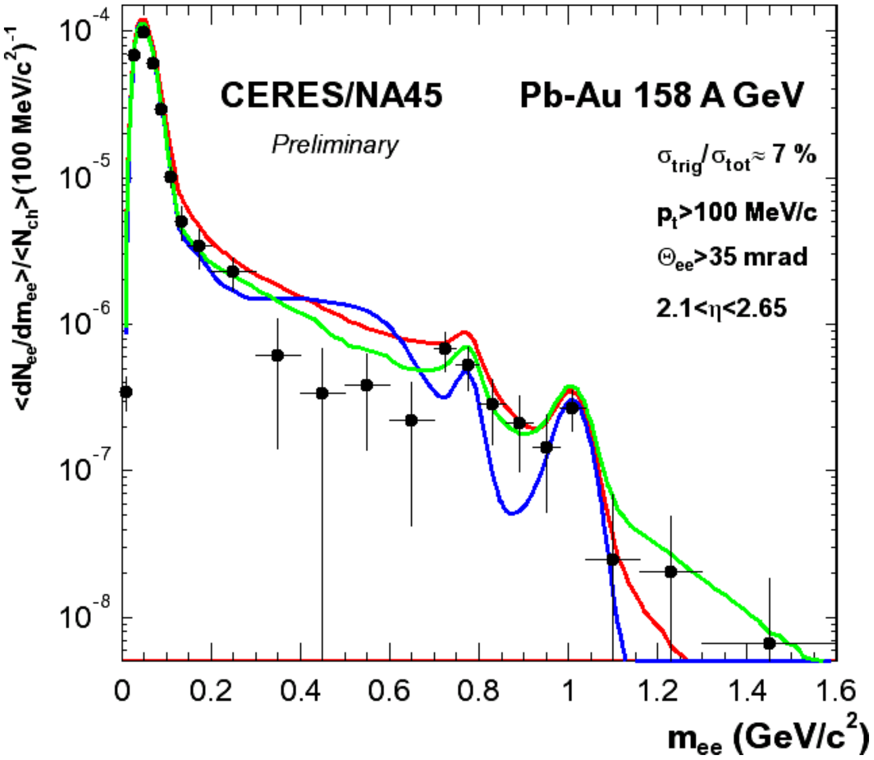
in the 0.8 < m < 0.98 GeV region:
Brown-Rho curve: $\chi^2/n = 2.4$
the other two curves: $\chi^2/n \sim 0.3$

e+e- mass spectrum: lowering the pt-cut

Pb+Au at 158 GeV per nucleon

Sergey Yurevich





S/B = 1/87
enhancement for 0.2<m<0.6: 1.52 ± 0.36

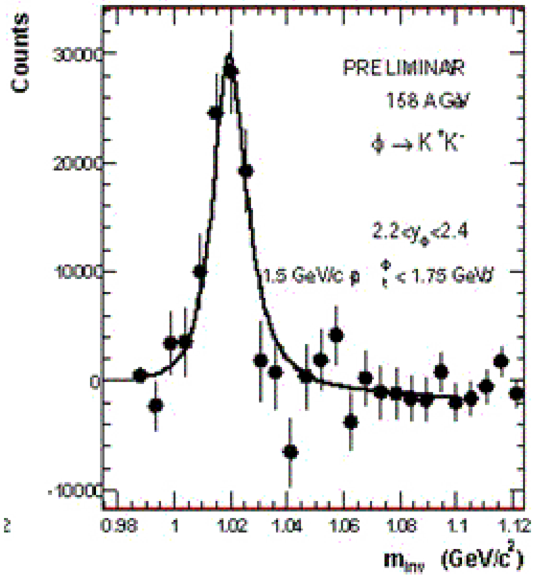
poor signal-to-background ratio due to the π^0-Dalitz electrons

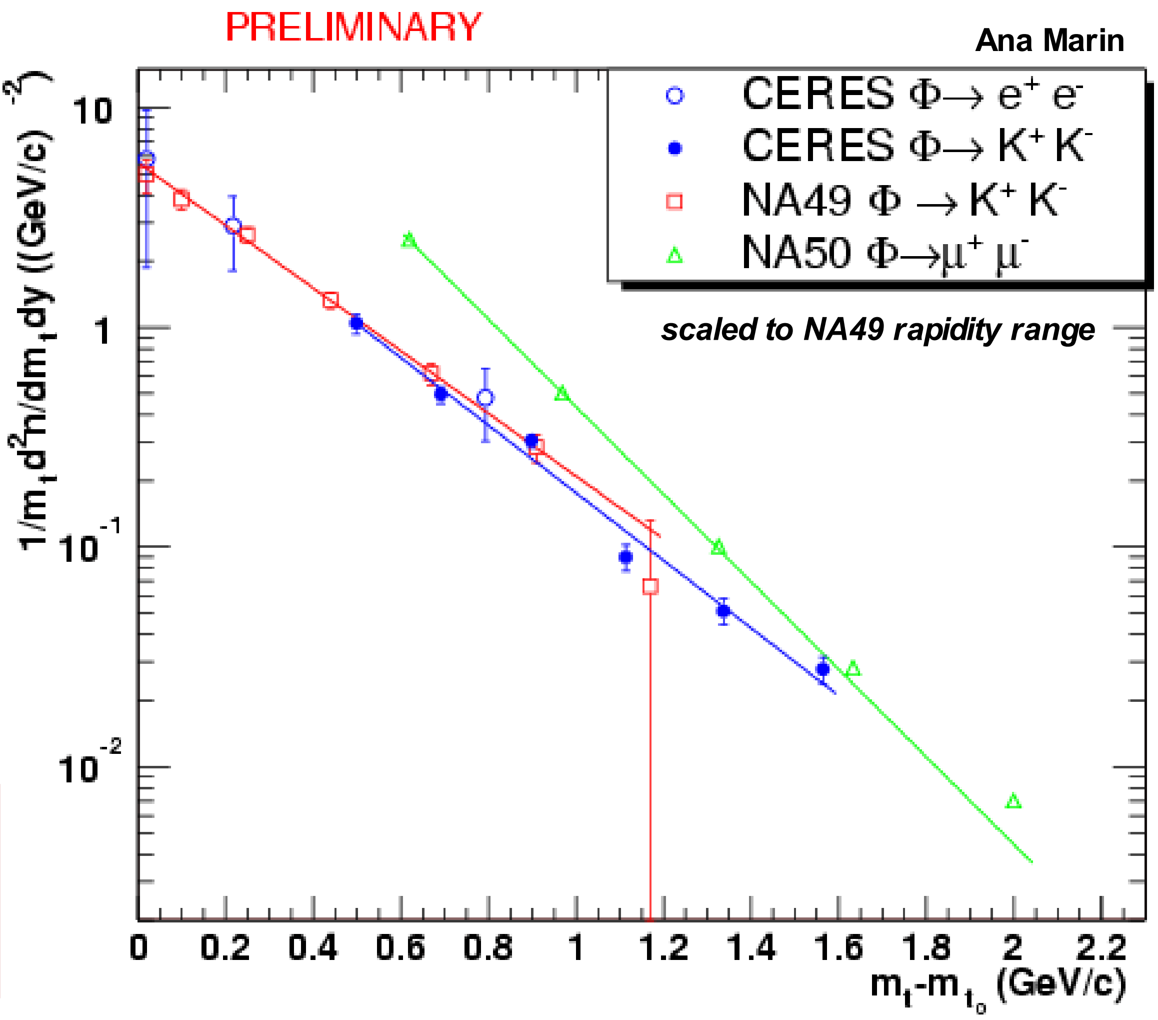
pt spectrum of the ϕ

ϕ → e^+e^- extracted from the e^+e^- mass spectrum;

ϕ puzzle: D. Röhrich, J.Phys.G 27(2001)355

ϕ → K^+K^-





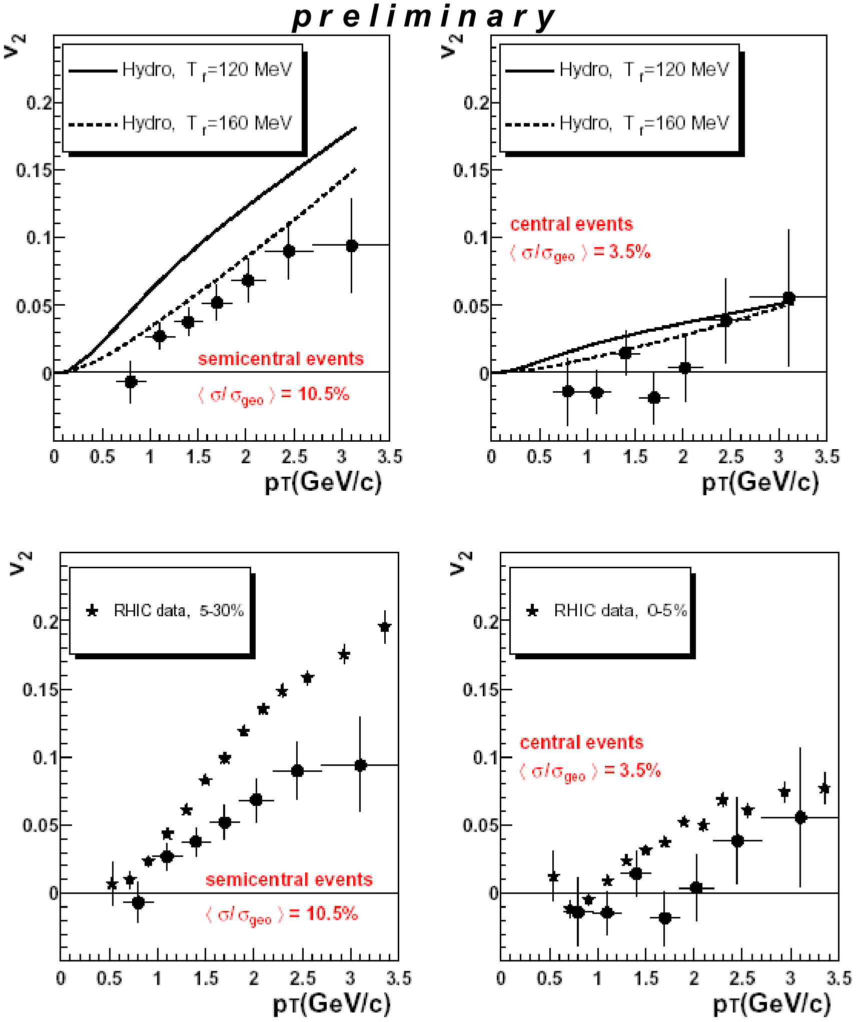
Ana Marin

CERES ϕ spectra observed in the leptonic and the hadronic decay channels agree

Λ flow

Pb+Au at 158 GeV per nucleon

Jovan Milosevic, visit his talk on Friday afternoon



comparison with hydro (P. Huovinen):

calculation with T=160 MeV describes the Λ and π flow

comparison with STAR PRL 92(2004)052302:

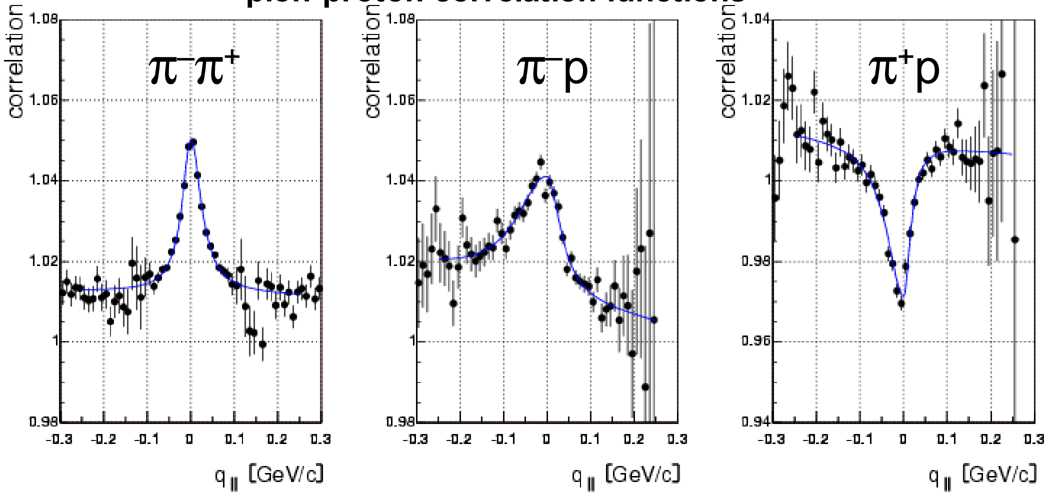
similar pt dependence about 60% in magnitude

pion-proton correlations

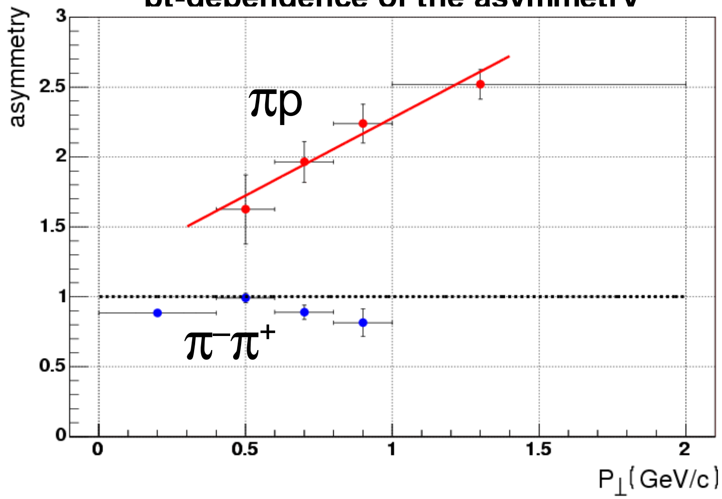
central Pb+Au at 158 AGeV

Dariusz Antonczyk, see his poster

pion-proton correlation functions



pt-dependence of the asymmetry



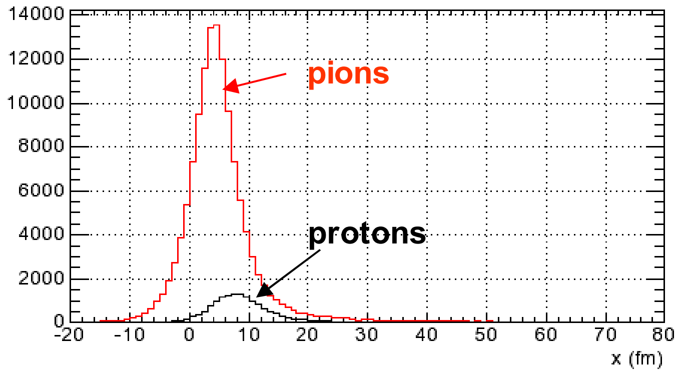
asymmetry of correlation function is related to the asymmetry of the relative source distribution (Lednicky, Phys.Lett.B373(96)30)

the proton source is located at a larger transverse radius than the pion source

most probable origin: transverse flow

sensitive to the details of reaction dynamics

pion and proton sources in UrQMD



pt fluctuations

measures of fluctuations

$\sigma_{pt\ dyn}^2$	**difference between the variances of pt and mean pt**
Σ_{pt}^2	**same divided by mean pt**
$\langle \Delta pt_i, \Delta pt_j \rangle$	**pt covariance**
Φ_{pt}	**difference between the standard deviations of pt and mean pt**

relations

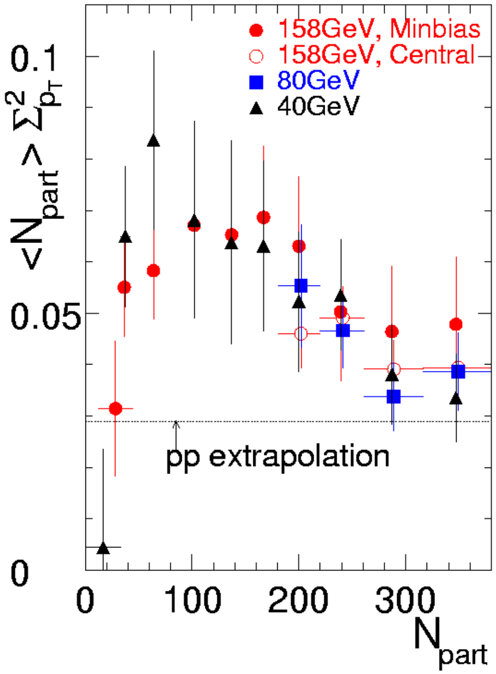
$$\sigma_{pt\ dyn}^2 = \sigma_{\langle pt \rangle}^2 - \sigma_{pt}^2/\langle M \rangle$$

$$\Sigma_{pt} = \sigma_{pt\ dyn} / \langle pt \rangle$$

$$\langle \Delta pt_i, \Delta pt_j \rangle \cong \sigma_{pt\ dyn}^2$$

$$\Phi_{pt} \cong \langle M \rangle \sigma_{pt\ dyn}^2 / 2\sigma_{pt}$$

CERES data



interesting non-monotonic behavior: strongest in peripheral collision

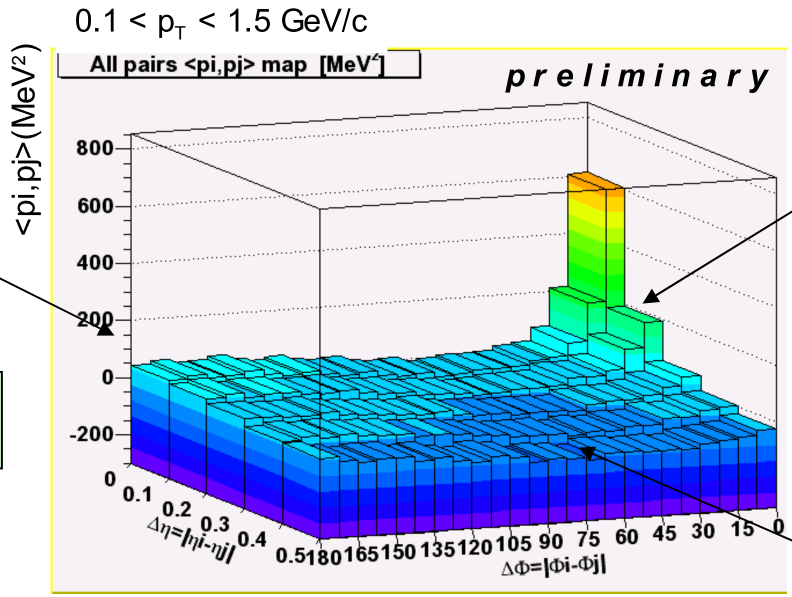
similar dependence
observed by NA49, STAR, PHENIX

→ what is the origin?

pt fluctuation

Pb+Au at 158 GeV per nucleon

Georgios Tsiledakis



away-side correlations

elliptic flow, jets?

rich structure → averaging over Δφ and Δη is not good

short range correlations

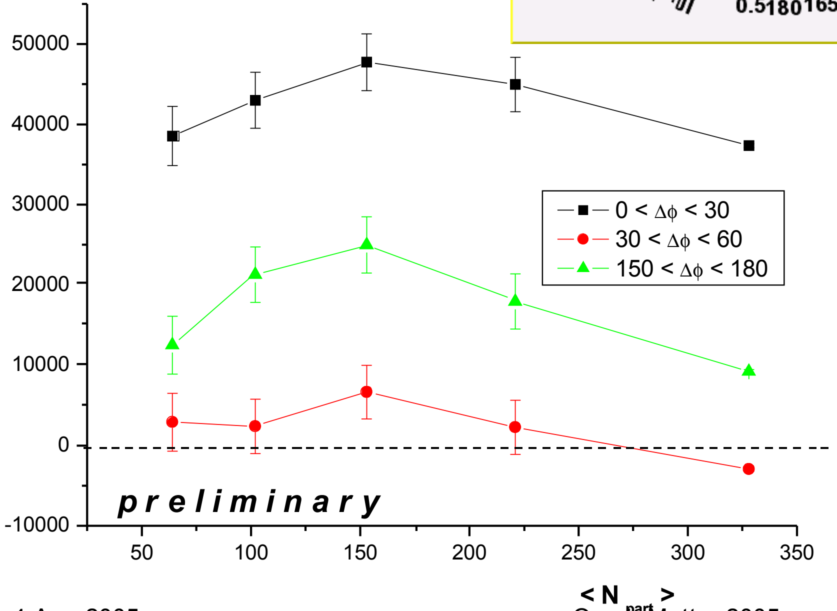
confined to Q_{INV}<70 MeV

narrower and weaker for unlike pairs → HBT and Coulomb?

decline with Δη

reproduced with event mixing

trivial effect of pt(η) dependence?

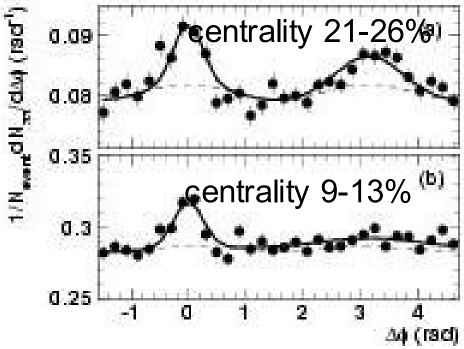


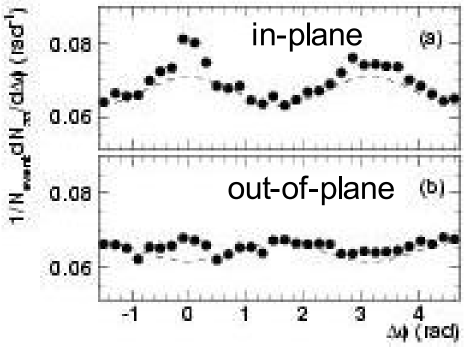
short range and away-side correlation produce the observed centrality dependence

region around Δφ = 45° is not affected by the elliptic flow, HBT, Coulomb, jets
→ look here for the critical point

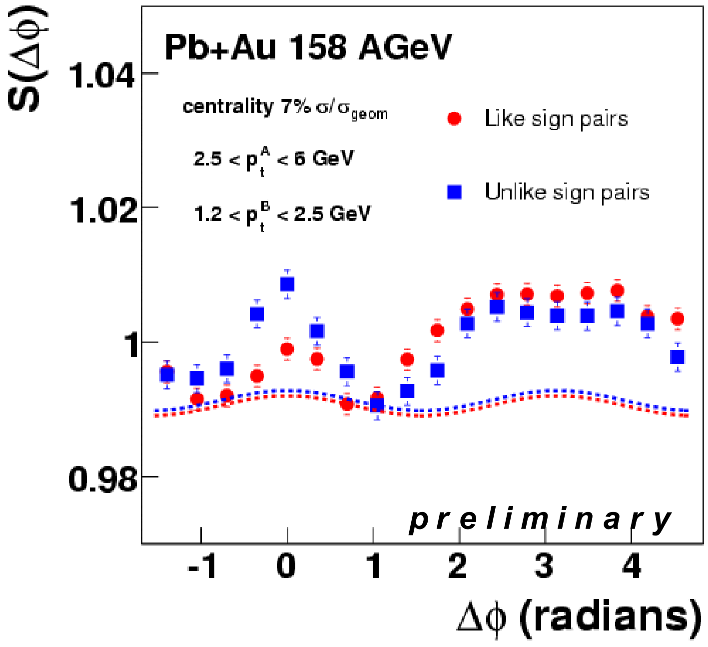
angular correlations of high-pt particles

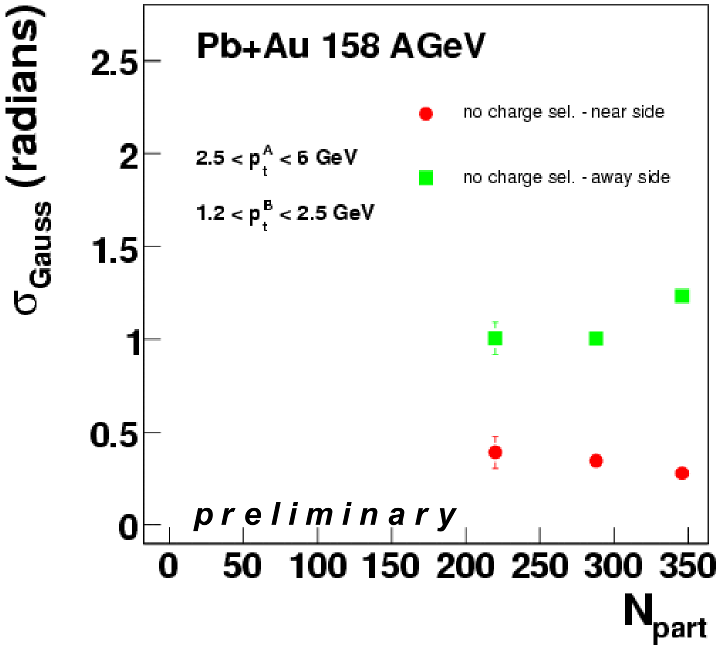
Pb+Au at 158 GeV per nucleon





J. Bielcikova, 1996 data
PRL 92 (2004) 032301





analysis of 2000 data in progress see poster by Mateusz Ploskon

summary

- e+e- low mass excess corroborated
- Brown-Rho scaling less favored by the data
- $\phi \rightarrow e^+e^-$ consistent with $\phi \rightarrow K^+K^-$, no puzzle
- Λ and π elliptic flow like in hydro with T=160 MeV
- evidence for displaced sources of pions and protons in the non-identical particle correlation functions
- pt fluctuations dominated by HBT/Coulomb, elliptic flow, and high-pt correlations
- ongoing analyses: K0, high-pt correlations, Δ, ...

CERES Collaboration

D. Adamova, G. Agakichiev, **D. Antonczyk**, A. Andronic, H. Appelshäuser, V. Belaga, J. Bielcikova, P. BraunMunzinger, **O. Busch**, A. Castillo, **A. Cherlin**, S. Damjanovic, T. Dietel, L. Dietrich, A. Drees, S. Esumi, K. Filimonov, **K. Fomenko**, Z. Fraenkel, C. Garabatos, P. Glässel, G. Hering, J. Holeczek, V. Kushpil, B. Lenkeit, **W. Ludolphs**, A. Maas, A. Marin, **J. Milosevic**, A. Milov, D. Miskowiec, R. Ortega, Yu. Panebrattsev, O. Petchenova, V. Petracek, A. Pfeiffer, M. Ploskon, **S. Radomski**, J. Rak, I. Ravinovich, P. Rehak, W. Schmitz, J. Schukraft, H. Sako, S. Shimansky, S. Sedykh, J. Stachel, M. Sumbera, H. Tilsner, I. Tserruya, **G. Tsiledakis**, T. Wienold, B. Windelband, J.P. Wessels, J.P. Wurm, W. Xie, **S. Yurevich**, V. Yurevich

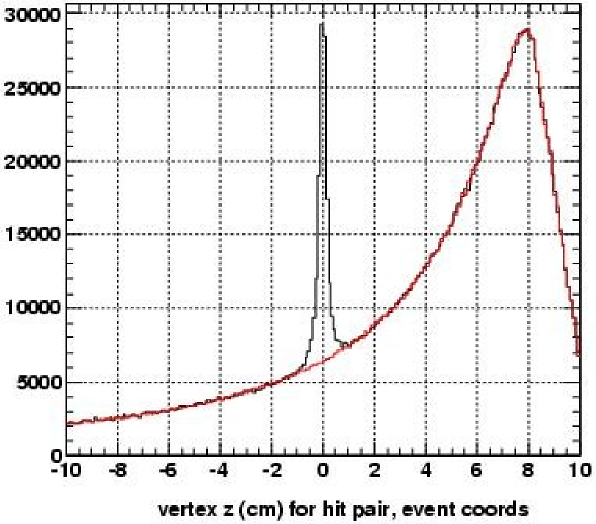
NPI ASCR, Rez, Czech Republic
GSI Darmstadt, Germany
Frankfurt University, Germany
Heidelberg University, Germany
JINR Dubna, Russia
Weizmann Institute, Rehovot, Israel
SUNY at Stony Brook, USA
CERN, Switzerland
BNL, Upton, USA
Münster University, Germany

backup slides

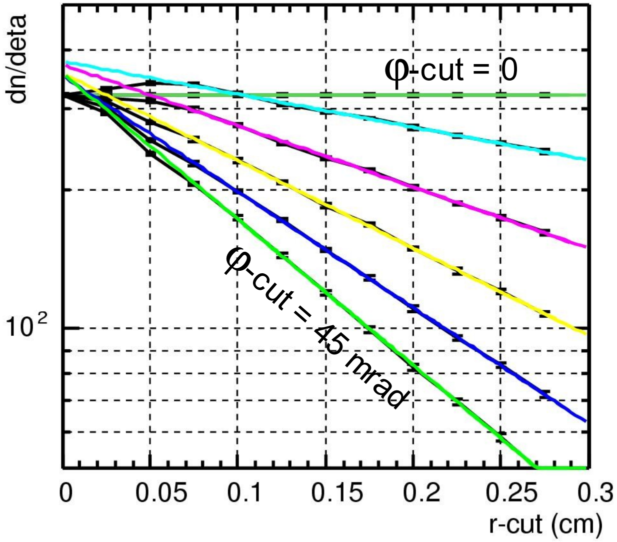
charged particle multiplicity

charged particle multiplicity determined from hits in the two silicon detectors

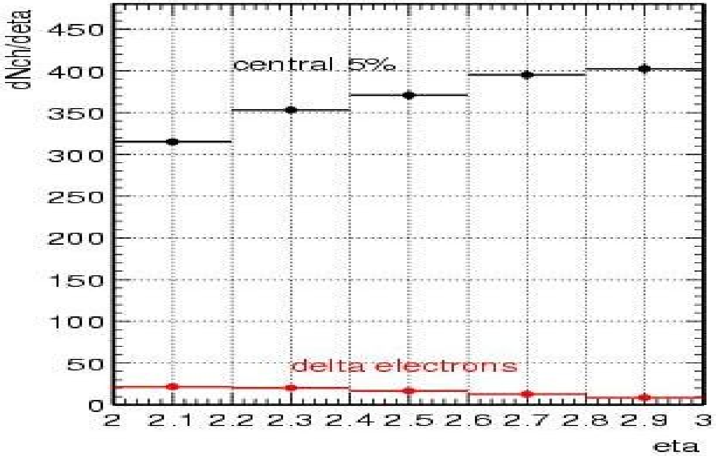
1. correlation between hits in SD1 and SD2
   random combinations determined by rotating



2. two-hit efficiency circumvented by applying
   separation cuts and extrapolating to zero



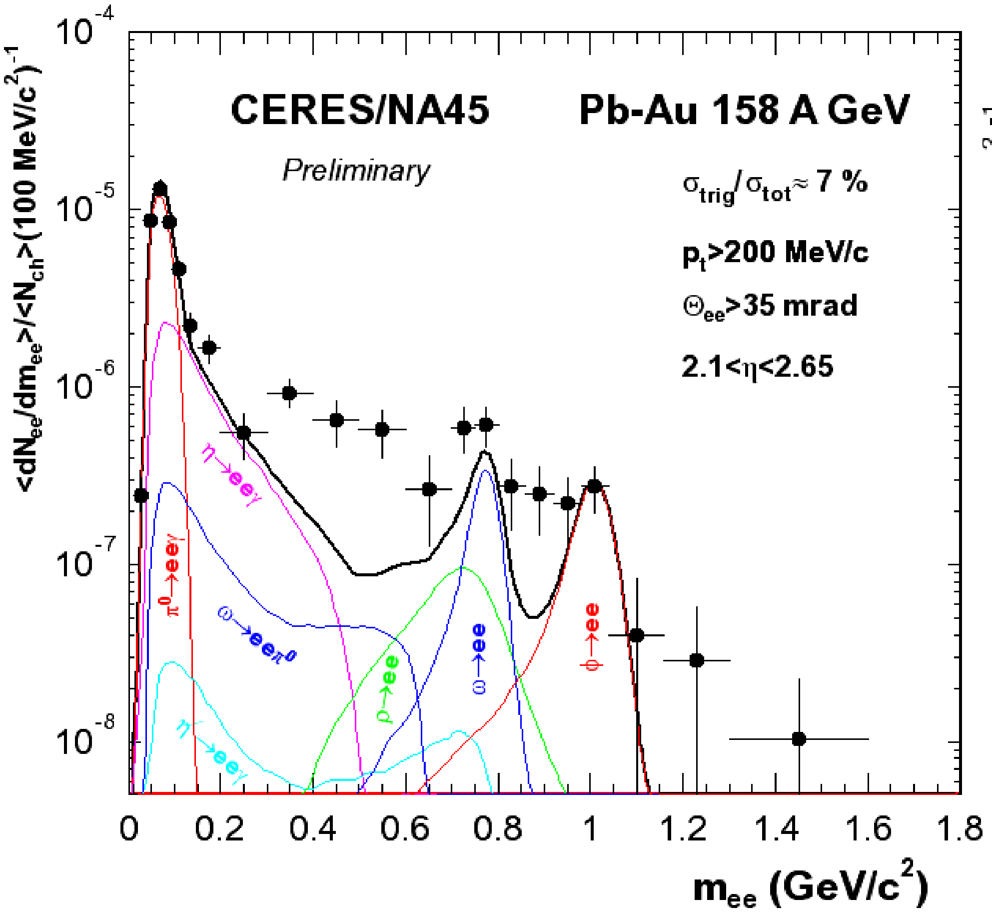
3. dn/dη for each centrality class
   delta electrons subtracted

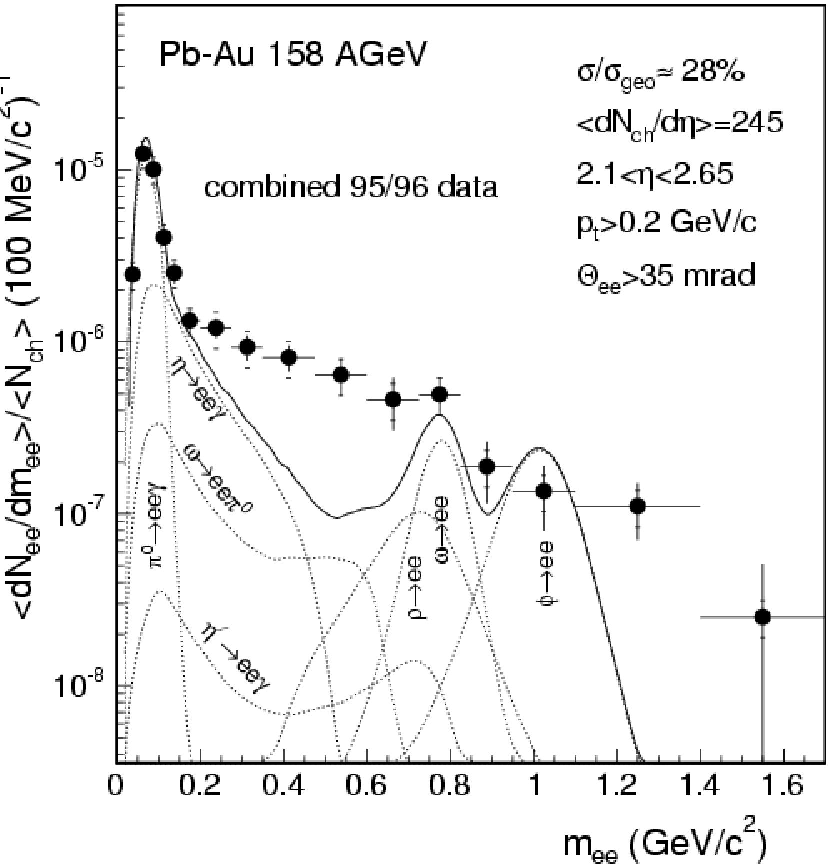


e+e- mass spectrum: comparison to the 95/96 data

Pb+Au at 158 GeV per nucleon

2000 data:
Sergey Yurevich, Heidelberg

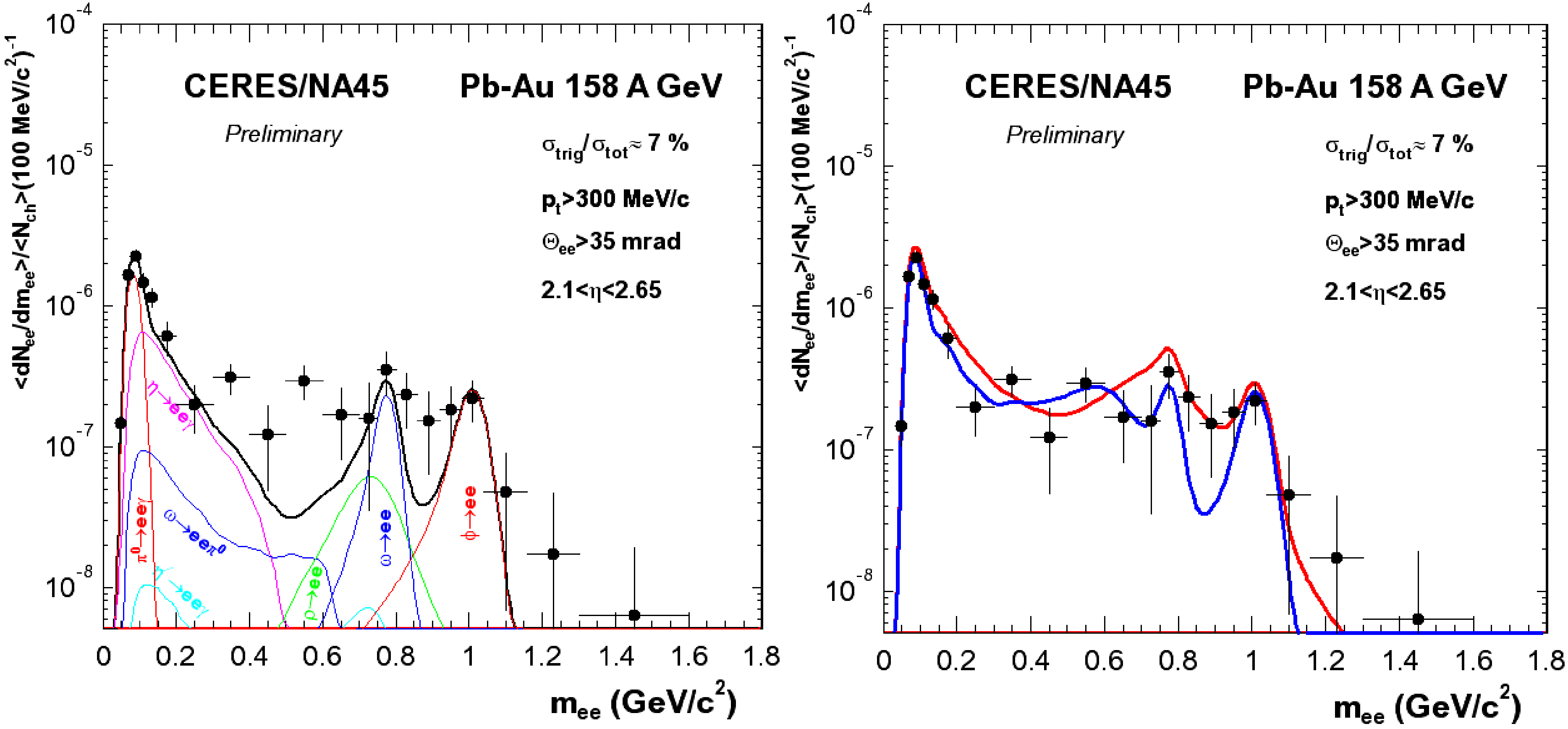




e+e- mass spectrum: increasing the pt-cut

Pb+Au at 158 GeV per nucleon

Sergey Yurevich

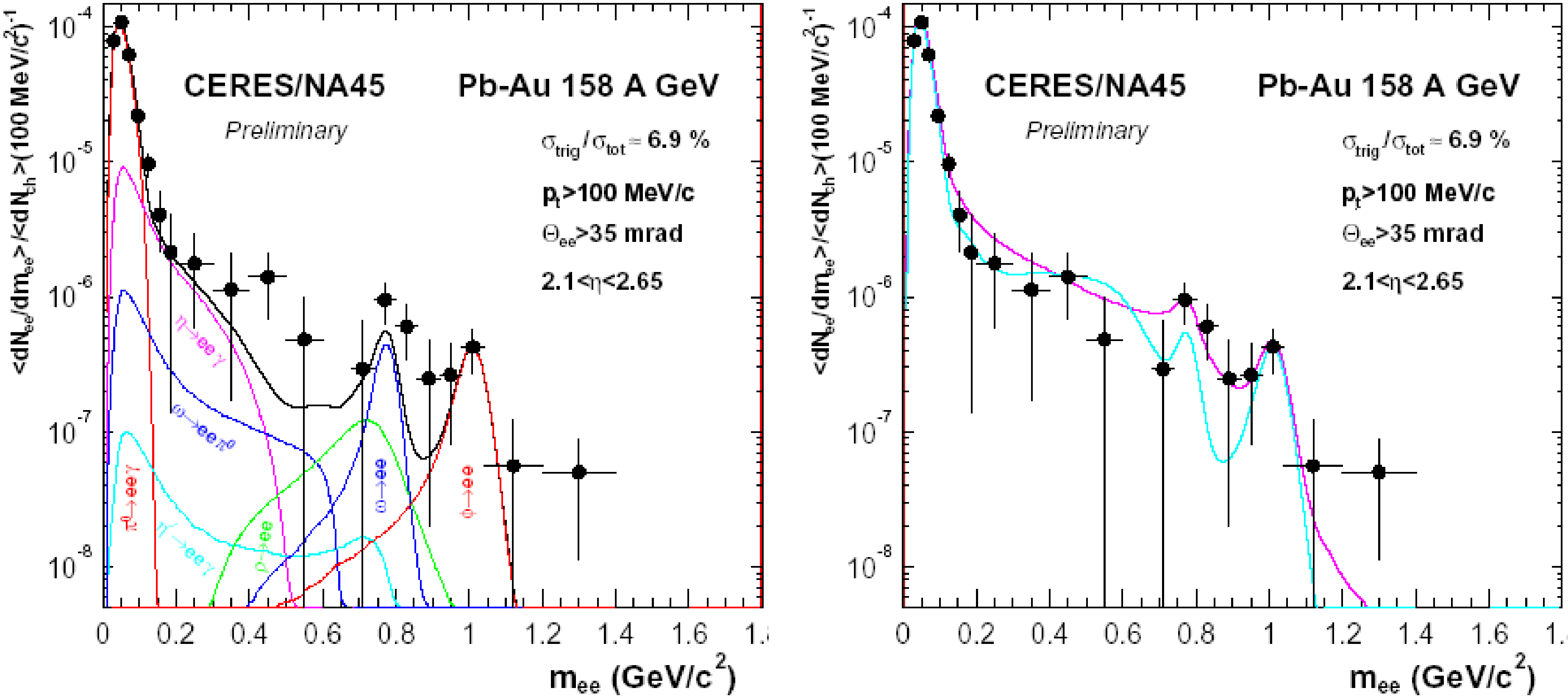


e+e- mass spectrum: lowering the pt-cut

Pb+Au at 158 GeV per nucleon

Alexander Cherlin

Number of pairs with m>200 MeV/c^2: 1432 +- 408   S/B = 1/57

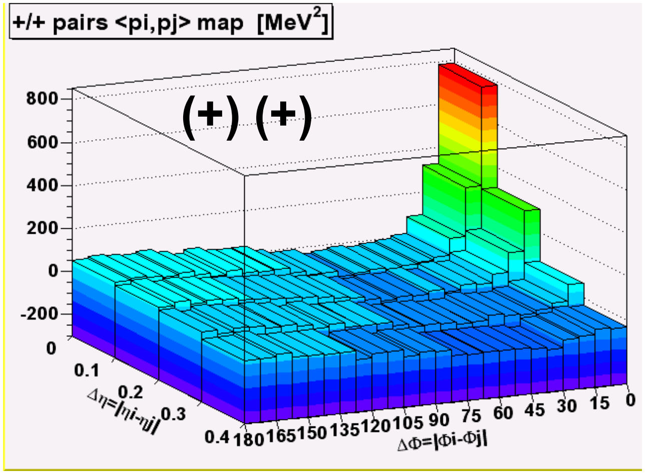


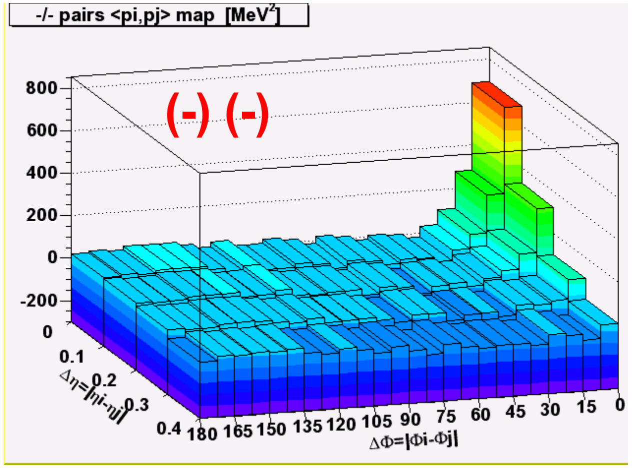
signal-to-background ratio deteriorates because of the π^0-Dalitz electrons

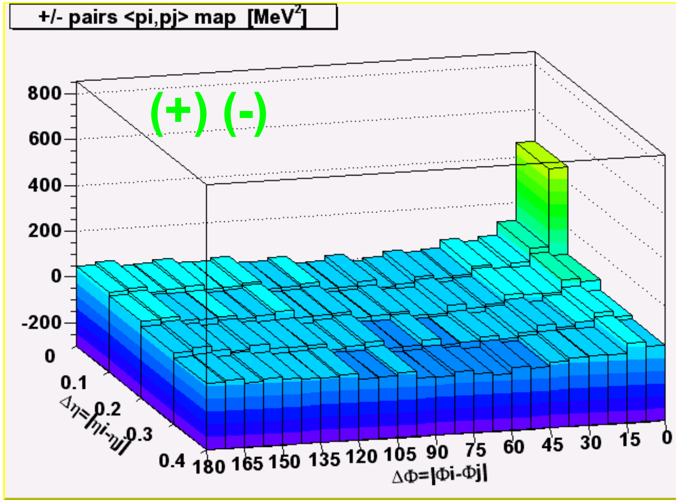
pt fluctuations, charge dependence

Pb+Au at 158 GeV per nucleon

G. Tsiledakis, GSI Darmstadt



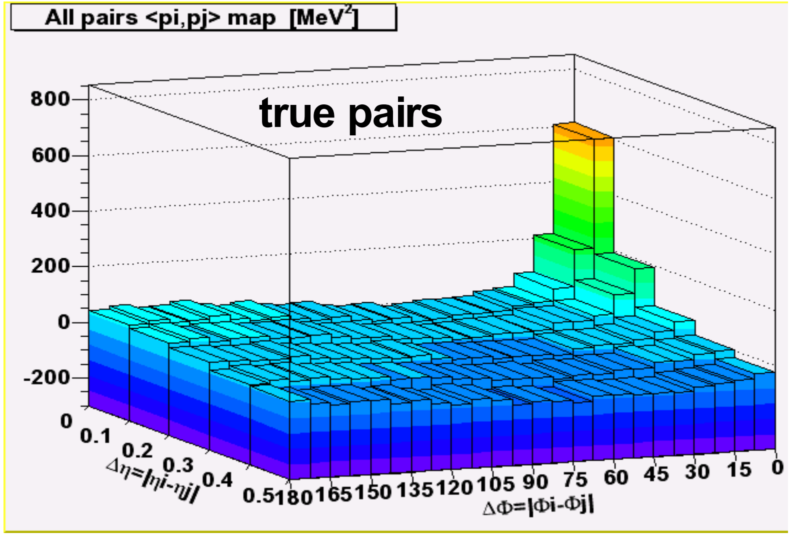




pt fluctuations, event mixing

Pb+Au at 158 GeV per nucleon

G. Tsiledakis, GSI Darmstadt



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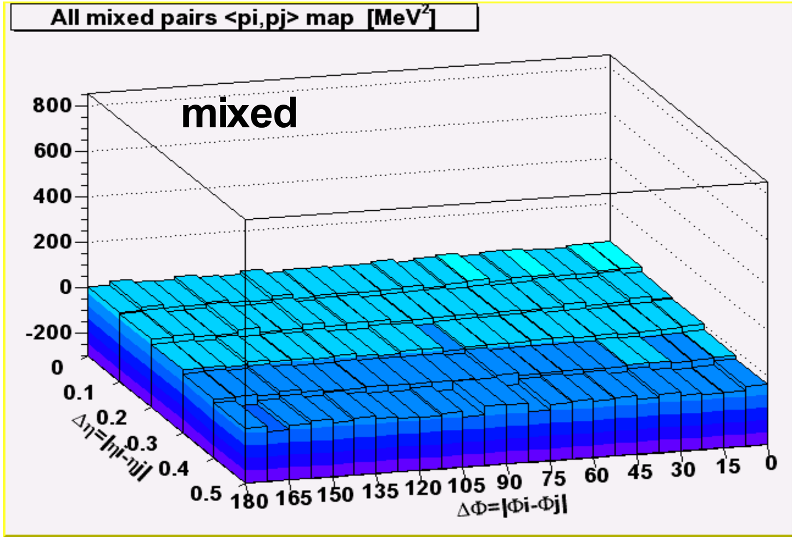

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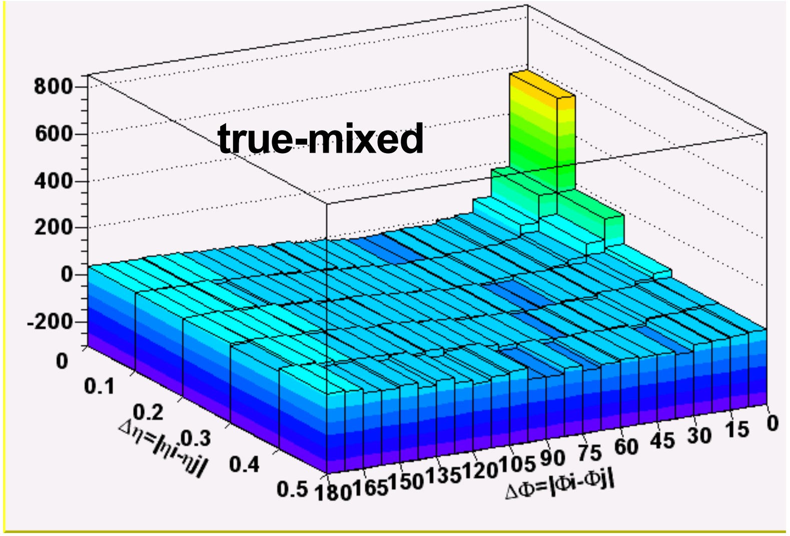
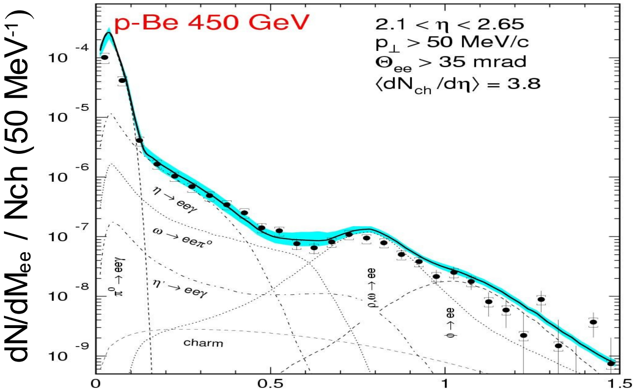
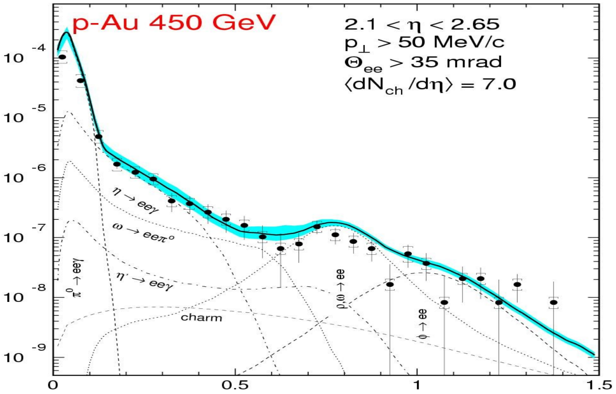


prehistory: 1992-1996

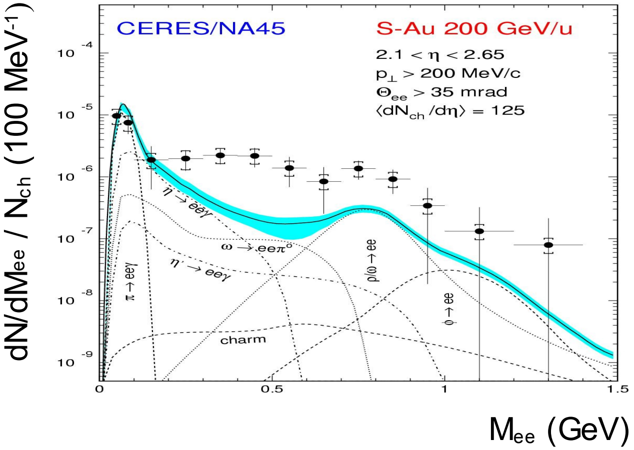
Eur. Phys. J C4 (1998) 231



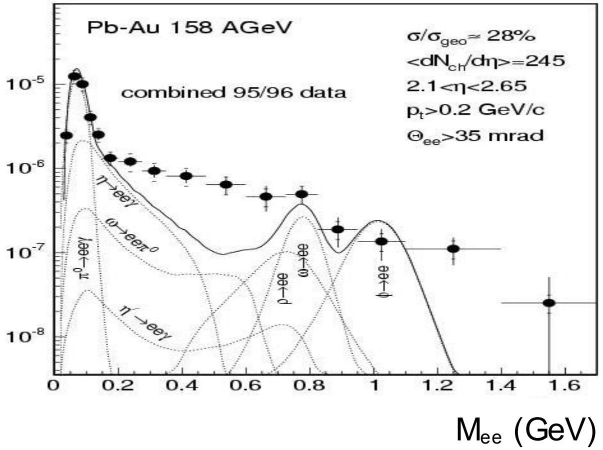
Eur. Phys. J C4 (1998) 231



Phys. Rev. Lett. 75 (1995) 1272



to appear in Eur. Phys. J. C (2005)



→ excess of e^+e^- pairs in heavy ion collisions

CERES run history

1991	installation	
1992	200 GeV S+Au	4M central 3M pairs
1993	450 GeV p+Be 450 GeV p+Au	10M pairs 3M pairs
1995	160 GeV Pb+Au	10M central
1996	160 GeV Pb+Au	50M central
1997	TPC construction	
1998	TPC installation	
1999	40 GeV Pb+Au	10M central
2000	80 GeV Pb+Au 160 GeV Pb+Au	1M central 30M central
2004	decommissioning	

Sources of e^+e^- pairs

$qq \to \gamma^* \to e^+e^-$	Drell-Yan
$qg \to q\gamma^* \to qe^+e^-$	
$qqbar \to g\gamma^* \to ge^+e^-$	
$\rho,\omega,\varphi,\psi,Y \to e^+e^-$	vector meson decay
$\pi\pi \to e^+e^-$	pion annihilation
$qqbar \to \gamma^* \to e^+e^-$	QGP thermal radiation
$\pi^o,\eta,\eta' \to e^+e^-\gamma$	Dalitz decay
$\omega \to e^+e^-\pi^o$	
$D \to e\,X$	open charm production and semileptonic decay
$\gamma X \to e^+ e^- X$	pair conversion

GENESIS

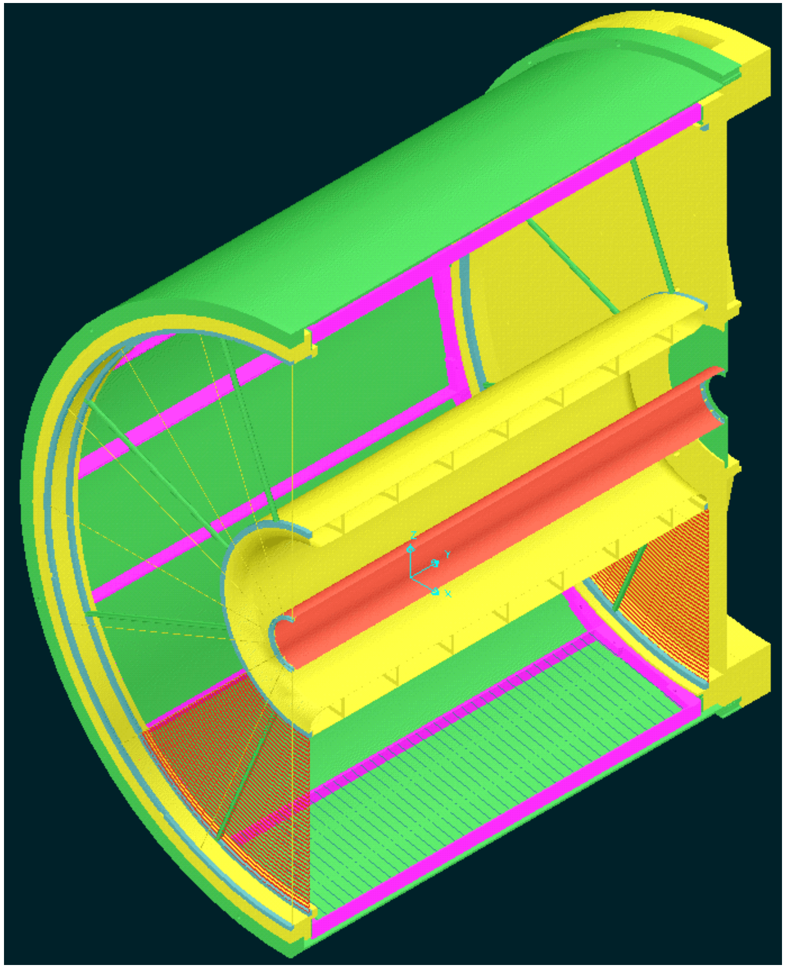
particle	relative abundance	decays
π^o	1.0	$\pi^o \rightarrow \gamma e^+e^-$
η	0.053	$\eta \rightarrow \gamma e^+e^-$
η'	0.009	$\eta' \rightarrow \gamma e^+e^-$
φ	0.0033	$\varphi \rightarrow e^+e^-$
ρ	0.065	$\rho \rightarrow e^+e^-$
ω	0.065	$\omega \rightarrow e^+e^-$ $\omega \rightarrow \gamma e^+e^-$

$$dN/dy \sim \cosh^{-2}[0.75/\sigma(y-y_o)]$$

$$dN/dp_t \sim Ae^{-Bm_t} + C(1-0.0682\, m_t)^{7.9}/(1+m_t^2)^4$$

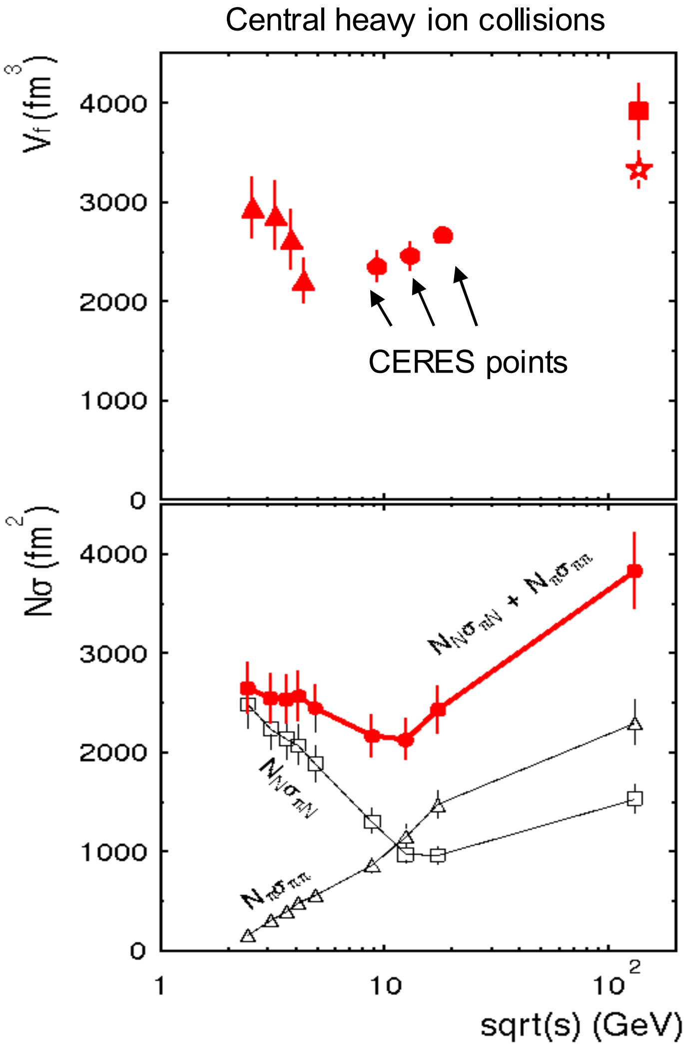
CERES TPC

- cylinder Φ 2.6 m x 2 m
- gas Ne:CO_2 (80:20)
- radial E-field E_R~1/r with E=200-600 V/cm
- radial drift with v=0.7-2.4 cm/μs



New freeze-out criterium from two-pion HBT

H. Appelshäuser, H. Tilsner
Phys. Rev. Lett. 90 (2003) 022301



Central heavy ion collisions

CERES points

Freeze-out volume $V_f = (2\pi)^{3/2} R_{long} R_{side}^2$ has a minimum at a beam energy of 10-40 GeV per nucleon

Particle multiplicity times mean hadron-hadron cross-section $N\sigma$ has a similar beam energy dependence

$V_f / N\sigma = \lambda_f$ = 1 fm, indep. of beam energy

Freeze-out
-- not at a fixed spatial density
-- not at a fixed phase-space density
-- not when mean free path ≈ R
but
when mean free path ≈ 1 fm