High Acceptance DiElectron Spectrometer

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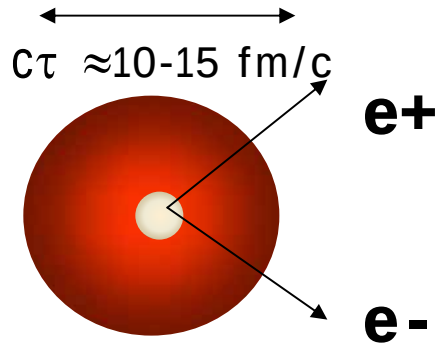
Main Items

- Motivation
- Status of HADES spectrometer
- Physics program and data analysis
- HADES upgrade
- JINR proposal for σ_0 meson study
- Summary

More Information:
http://www-hades.gsi.de

Electron pairs as penetrating probes of interior of compressed matter



$$m_{e+e-} = \sqrt{p_{e+}p_{e-}}\,\sin\frac{\vartheta_{e+e-}}{2}$$

HADES

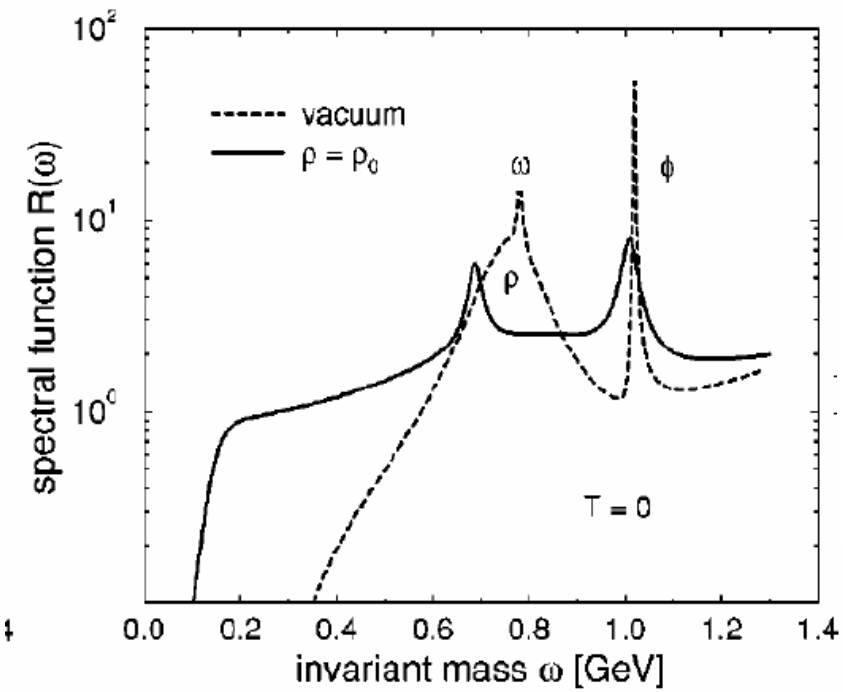
✓ (p, π, A) + A collisions at SIS – GSI, $0 \le \rho \le 3\,\rho_0$, $0 \le T \le 80$ MeV

✓ Dielectron two-body decays of light Vector Mesons ρ, ω, ϕ

✓ High resolution spectroscopy of e^+e^- - pairs, no final state interaction !

Meson	Mass (MeV/c^2)	Γ (MeV/c^2)	cτ (fm)	Main decay	e^+e^- BR
ρ	768	152	1.3	$\pi^+\pi^-$	4.4×10^{-5}
ω	782	8.43	23.4	$\pi^+\pi^-\pi^0$	7.2×10^{-5}
ϕ	1019	4.43	44.4	K^+K^-	3.1×10^{-4}

Model predictions for vector mesons embedded in normal nuclear matter



DLS (Berkley)
CERES (CERN)

T.Renk et al.
Phys.Rev. C66(2002) 014902

- "Melting" of the ρ meson
- Mass shift and broadening of the ω meson
- Little effect on the φ meson (some broadening)

HADES: Experimental Challenges

- Small production rates
  - 1 dilepton ρ decay / 10^6 central collisions
- Large background
  - hadronic (particle misidentification)
  - electromagnetic (photon conversion, mainly from π^0)
  - combinatorial (false combination of electrons and positrons)
- Detector Requirements
    - Excellent particle id (hadron-blind detectors)
    - High resolution (ρ/ω separation)
    - Low mass/low Z – design for reduced background
    - Highly selective trigger
    - High performance data acquisition

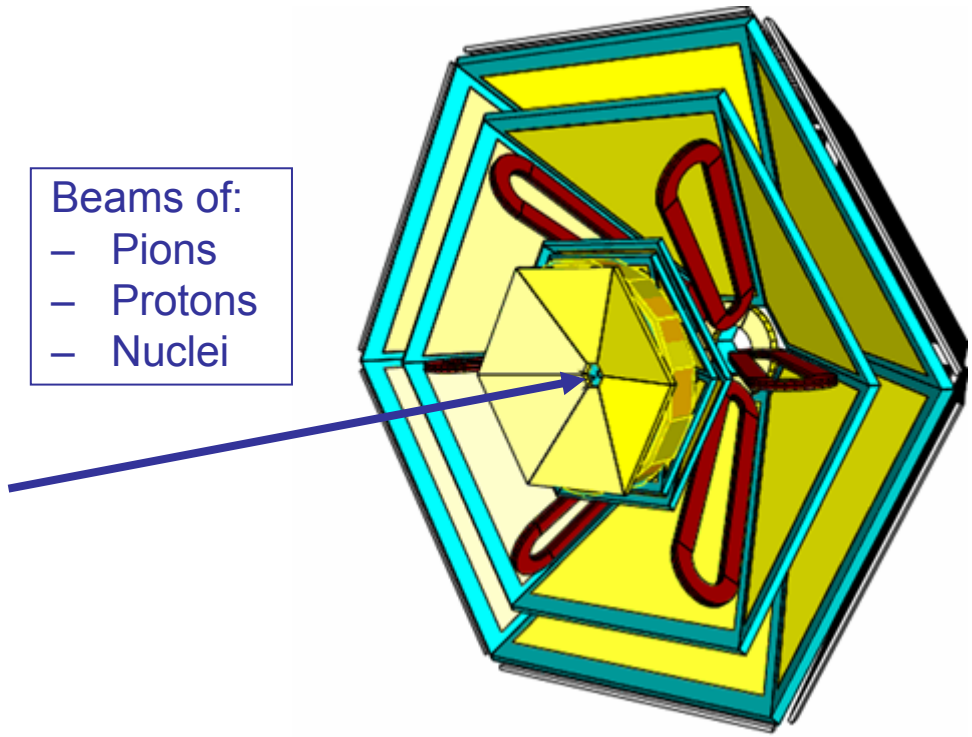
High Acceptance DiElectron Spectrometer

J.Stroth (GSI), Trento 2005

Low-mass vector mesons (ρ, ω, ϕ)

- Detected via electron pair reconstruction (penetrating probes).
- Spectrometer with high invariant mass resolution and high rate capability.
- Utilises dedicated second level trigger processors to select rare events before mass storing.
- Installed at the SIS18, GSI Darmstadt

Beams of:
- Pions
- Protons
- Nuclei



Project launched in late 1994
6 years R&D and construction.

First production run in 2002

Collaboration
More than 100 physicists from
Cyprus, Czech Rep., France, Germany, Italy, Poland, Portugal, Russia, Slovakia, Spain

HADES is optimized for the detection of low-mass vector mesons

Collaboration Institutions

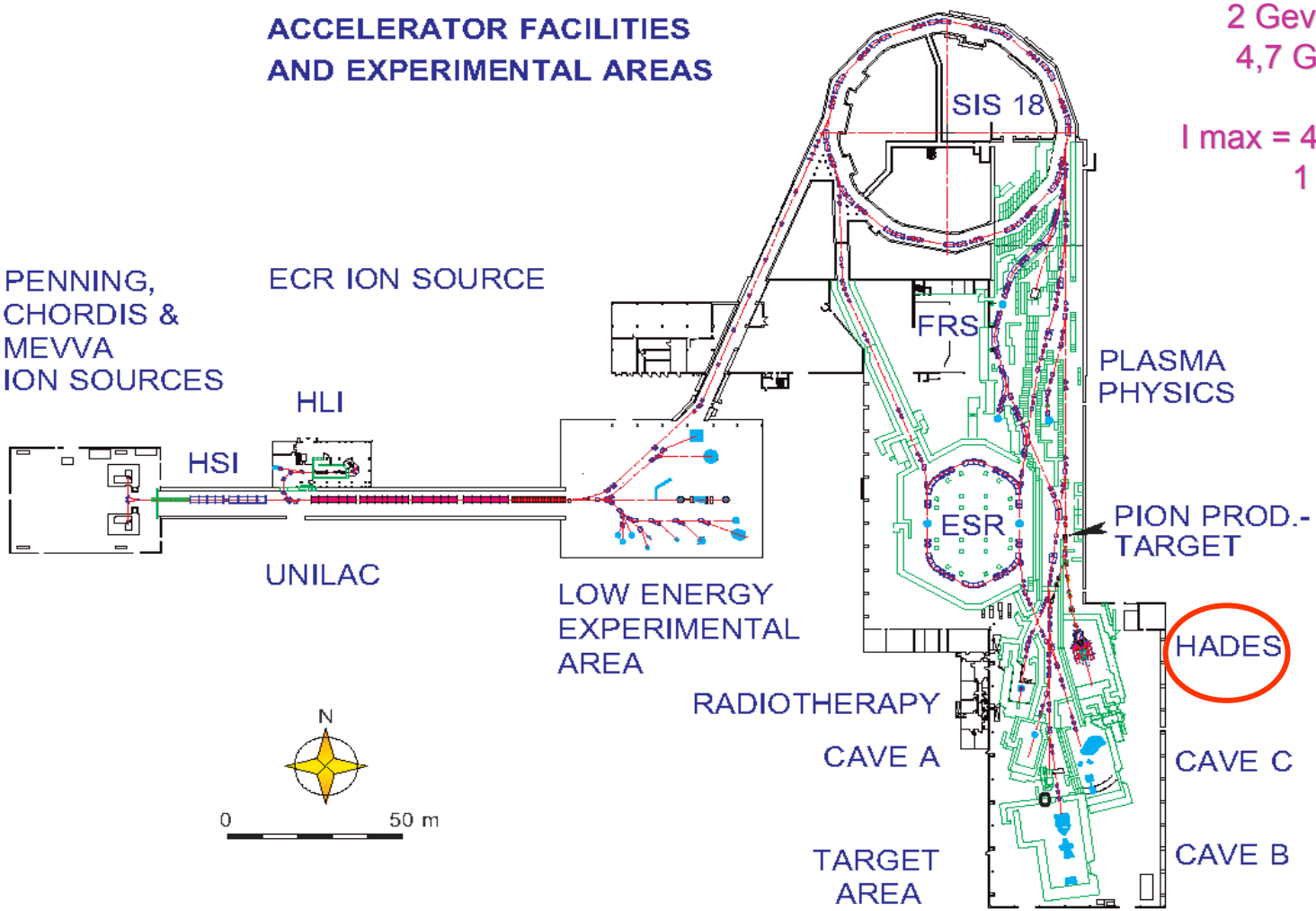
1) Institute of Physics, Slovak Academy of Sciences, 84228 Bratislava, Slovakia
2) Istituto Nazionale di Fisica Nucleare - Laboratori Nazionali del Sud, 95125 Catania, Italy
3) Dipartimento di Fisica e Astronomia, Università di Catania, 95125, Catania, Italy
4) Smoluchowski Institute of Physics, Jagiellonian University of Cracow, 30059 Cracow, Poland
5) Gesellschaft für Schwerionenforschung mbH, 64291 Darmstadt, Germany
6) Joint Institute of Nuclear Research, 141980 Dubna, Russia
7) Institut für Kernphysik, Johann Wolfgang Goethe-Universität, 60486 Frankfurt, Germany
8) II.Physikalisches Institut, Justus Liebig Universität Giessen, 35392 Giessen, Germany
9) Istituto Nazionale di Fisica Nucleare, Sezione di Milano, 20133 Milano, Italy
10) Dipartimento di Fisica, Università di Milano, 20133 Milano, Italy
11) Institute for Nuclear Research, Russian Academy of Science, Moscow, 117259 Moscow, Russia
12) Institute of Theoretical and Experimental Physics, 117218 Moscow, Russia
13) Moscow Engineering Physics Institute (State University), 115409 Moscow, Russia
14) Physik Department E12, Technische Universität München, 85748 Garching, Germany
15) Department of Physics, University of Cyprus, 1678 Nicosia, Cyprus
16) Institut de Physique Nucléaire d'Orsay, CNRS/IN2P3, 91406 Orsay Cedex, France
17) Nuclear Physics Institute, Czech Academy of Sciences, 5068 Rez, Czech Republic
18) Institut für Kern- und Hadronenphysik, FZR, PF 510119, 01314 Dresden, Germany
19) Departamento de Física de Partículas. University of Santiago de Comp.. 15782 Santiago de Compostela, Spain
20) Instituto de Física Corpuscular, Universidad de Valencia-CSIC,46971-Valencia, Spain

Heavy-Ion Sinchrotron SIS18

Bending Power:
12 Tm – ramp rate 10T/s
18 Tm – ramp rate 4T/s

2 Gev/u for light ions
4,7 Gev for p

I max = 4×10^{10} for U (73+)
1 Gev/u



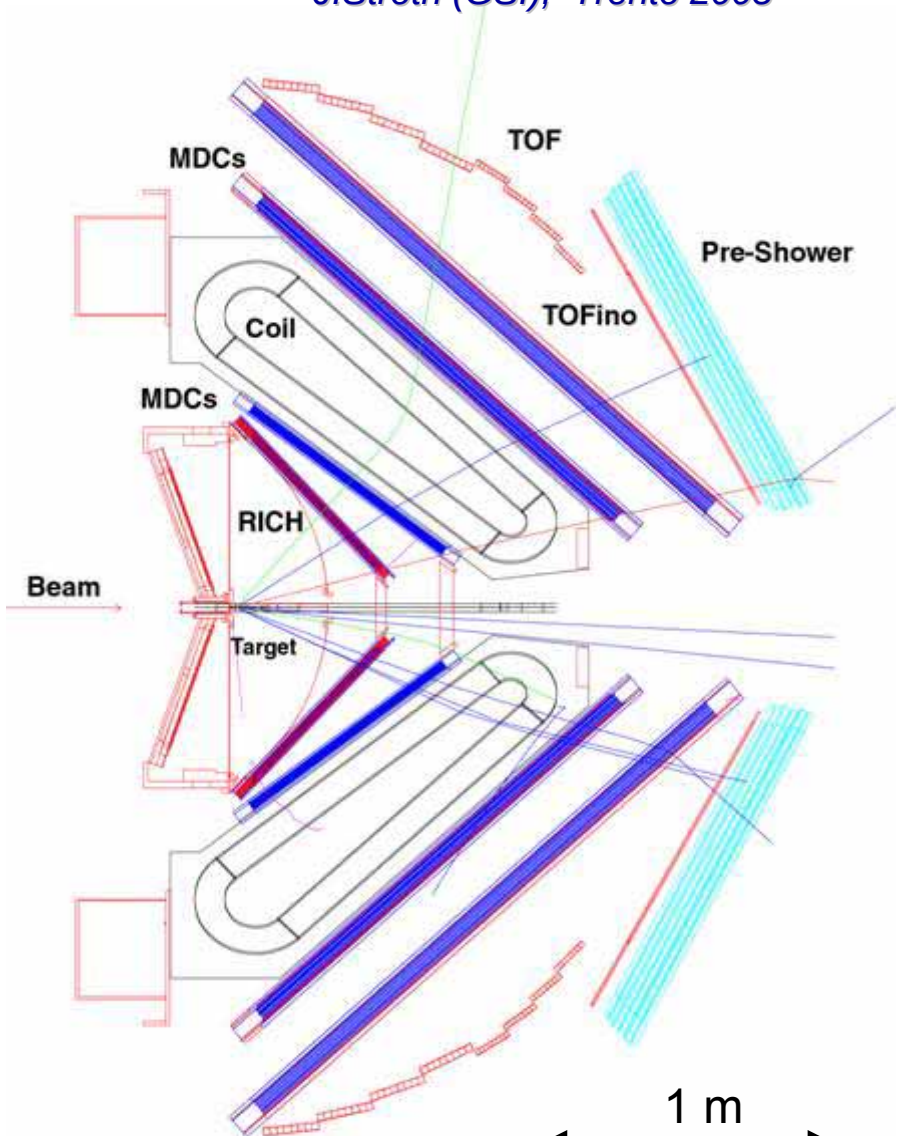
Spectrometer concept

J.Stroth (GSI), Trento 2005

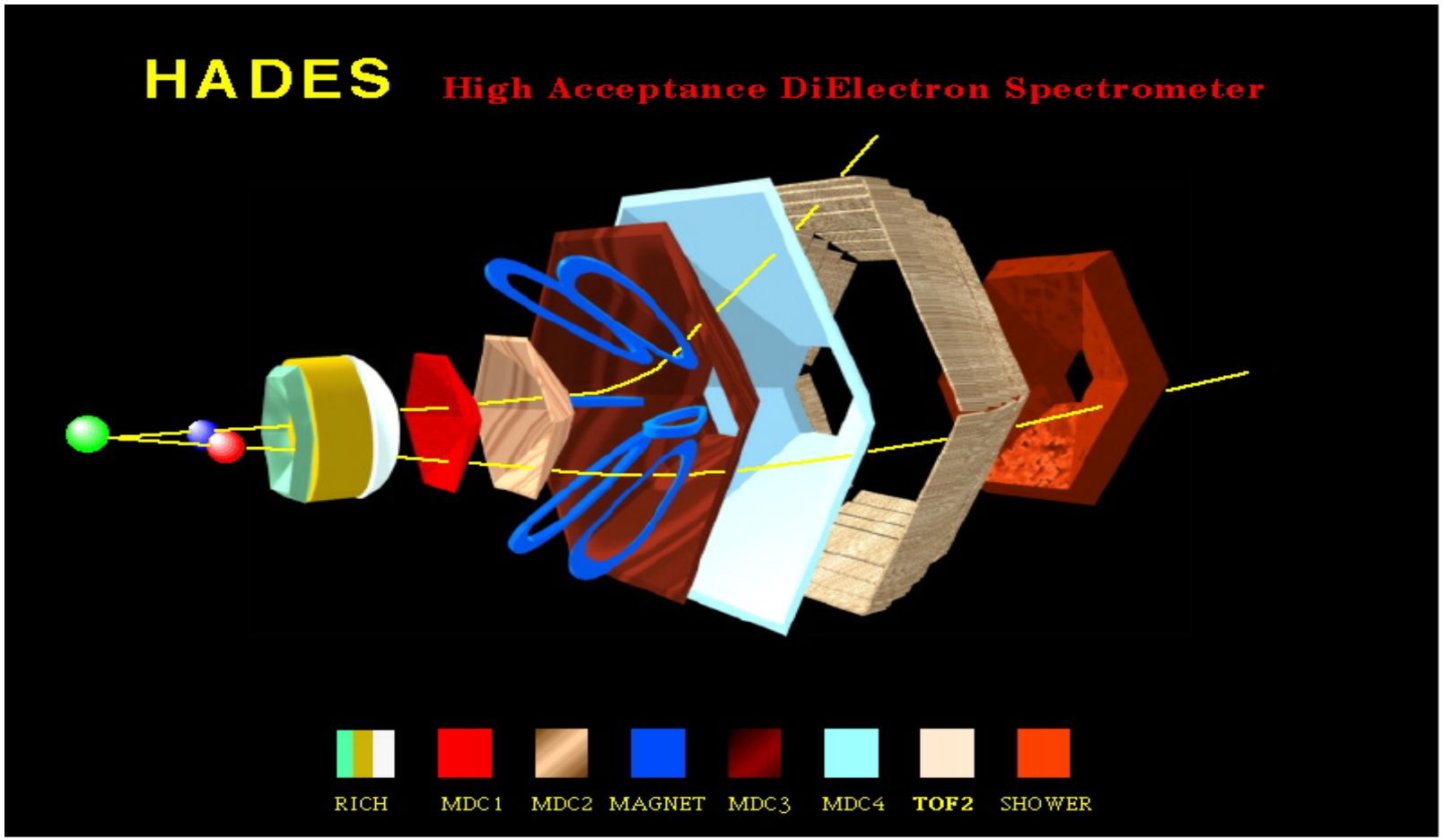
- **Geometry**
  - Full azimuth , polar angles 18° - 85°
  - Pair acceptance ~ 0.35
  - About 80.000 detector channels

- **Fast particle identification**
  - RICH
    CsI solid photo cathode, N_o~ 80, C_4F_{10} radiator
  - TOF (Scintillator rods)
  - TOFino (Scintillator paddles)
    temporary solution, RPC in future
  - Pre-Shower
    18 pad chambers & lead converters

- **Momentum measurement**
  - ILSE, super conducting toroid
    $B\rho$ = 0.7 Tm
  - MDC Multi-wire drift chamber,
    $\sigma_y \approx 100\ \mu m$
  - $\Delta M_{e+e}/M \approx 1.5\%$ at ρ/ω



High Acceptance Di-Electron Spectrometer

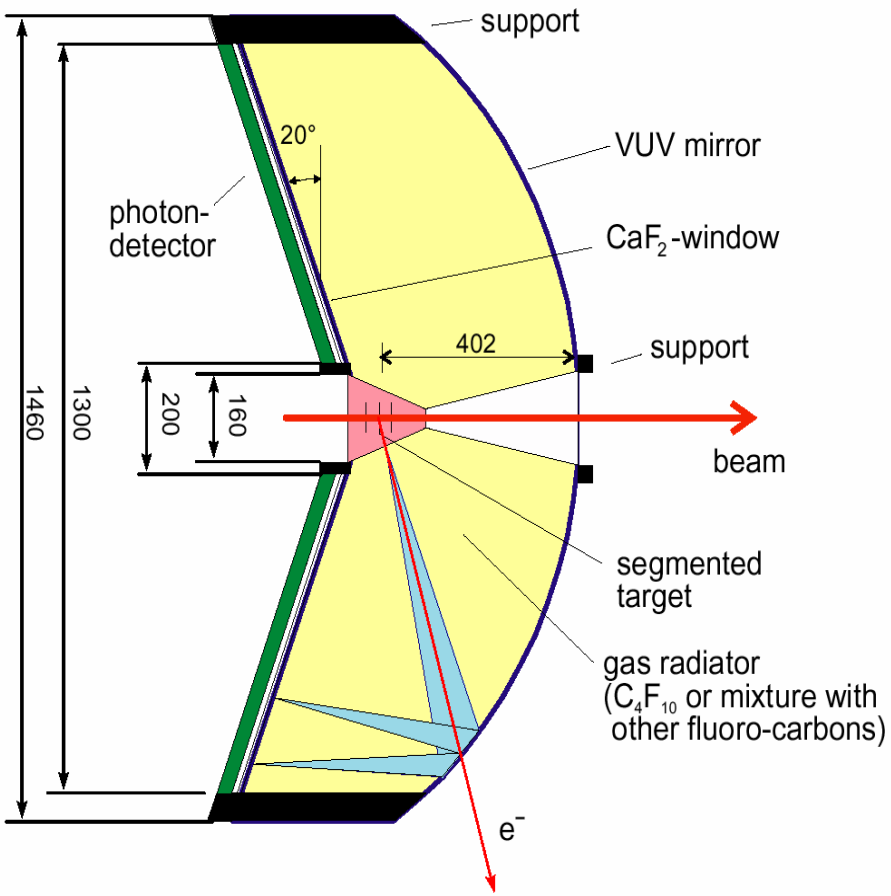


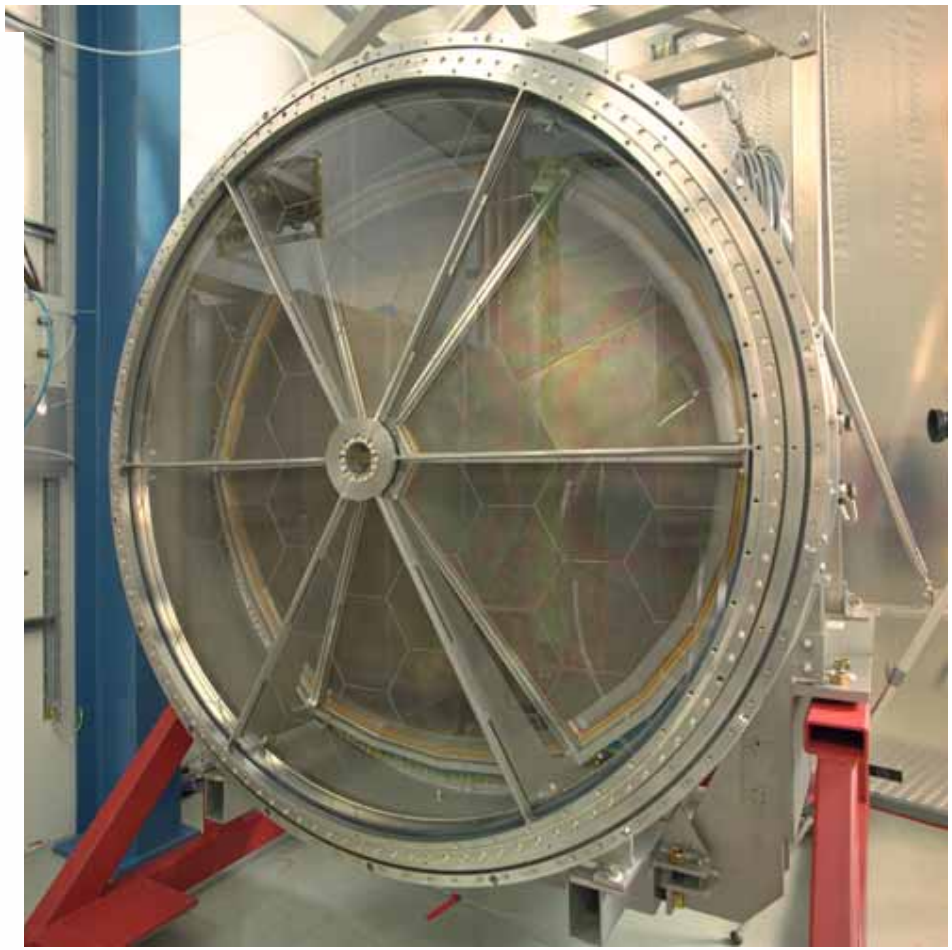
3D sketch of the HADES spectrometer, split along the longitudinal direction for clarity. In operating conditions all the shown elements fit into each other making the whole structure much more compact.

Superconducting Toroidal Magnet

A superconducting toroidal magnet with 6 coils in separate vacuum chambers. The magnet provides the momentum kick necessary to obtain charged particle momenta with a resolution ~ 1%

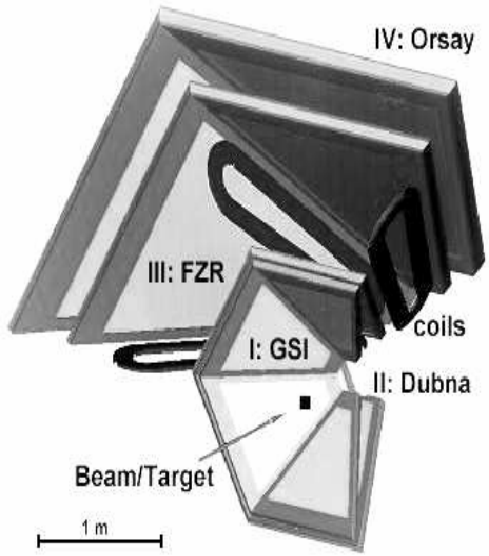
Ring Imaging Cherenkov Detector





Drift Chambers

DRIFT CHAMBERS (plane 2)



DRIFT CHAMBER (for plane 3)

4 planes of Drift Chambers

I, II - inner planes; III, IV - outer planes

- 6 modules in each plane.
- Each module contains 6 chambers (with different angles of wire orientation).

Total 24 modules (33 m²)

- Helium based counting gas
- Aluminum cathode/field wires
- 27000 cells

Fast 2nd level trigger

I First Level Trigger
TOF/TOFINO multiplicity

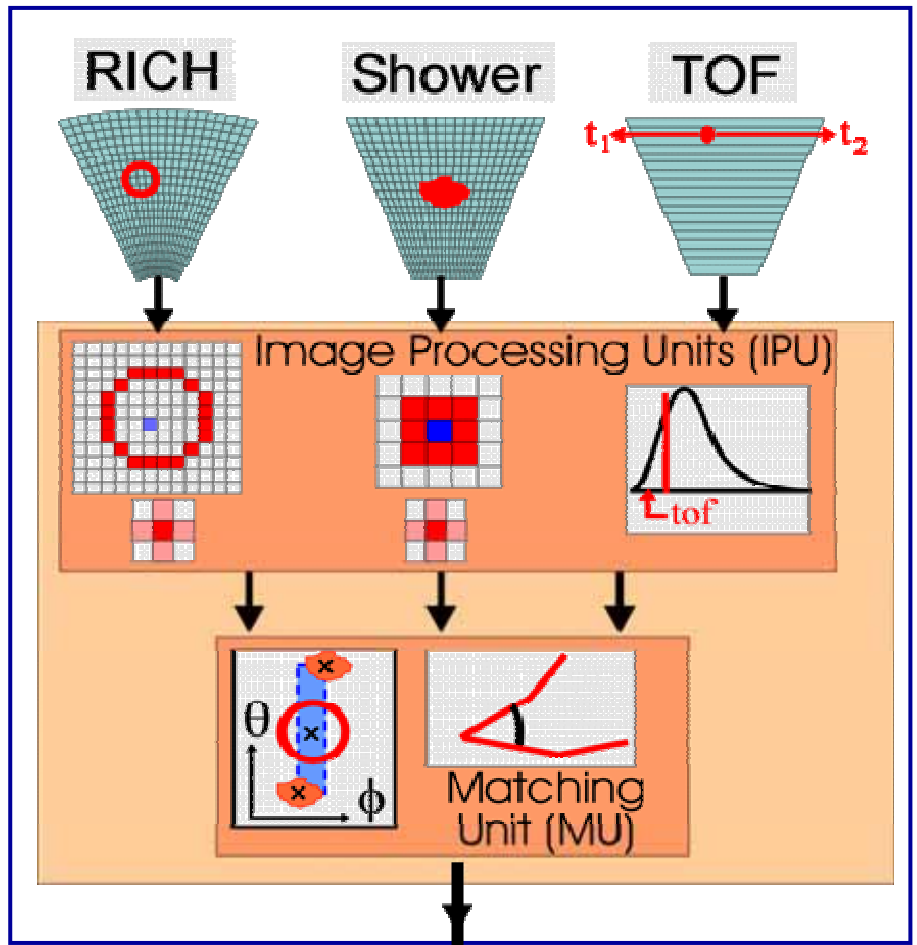
II Second Level Trigger
Electron candidates in IPUs:

Shower hits
Cherenkov rings
Time-of-flight cut
Matching hits (Δθ,Δφ)

on-line selection of electron candidates

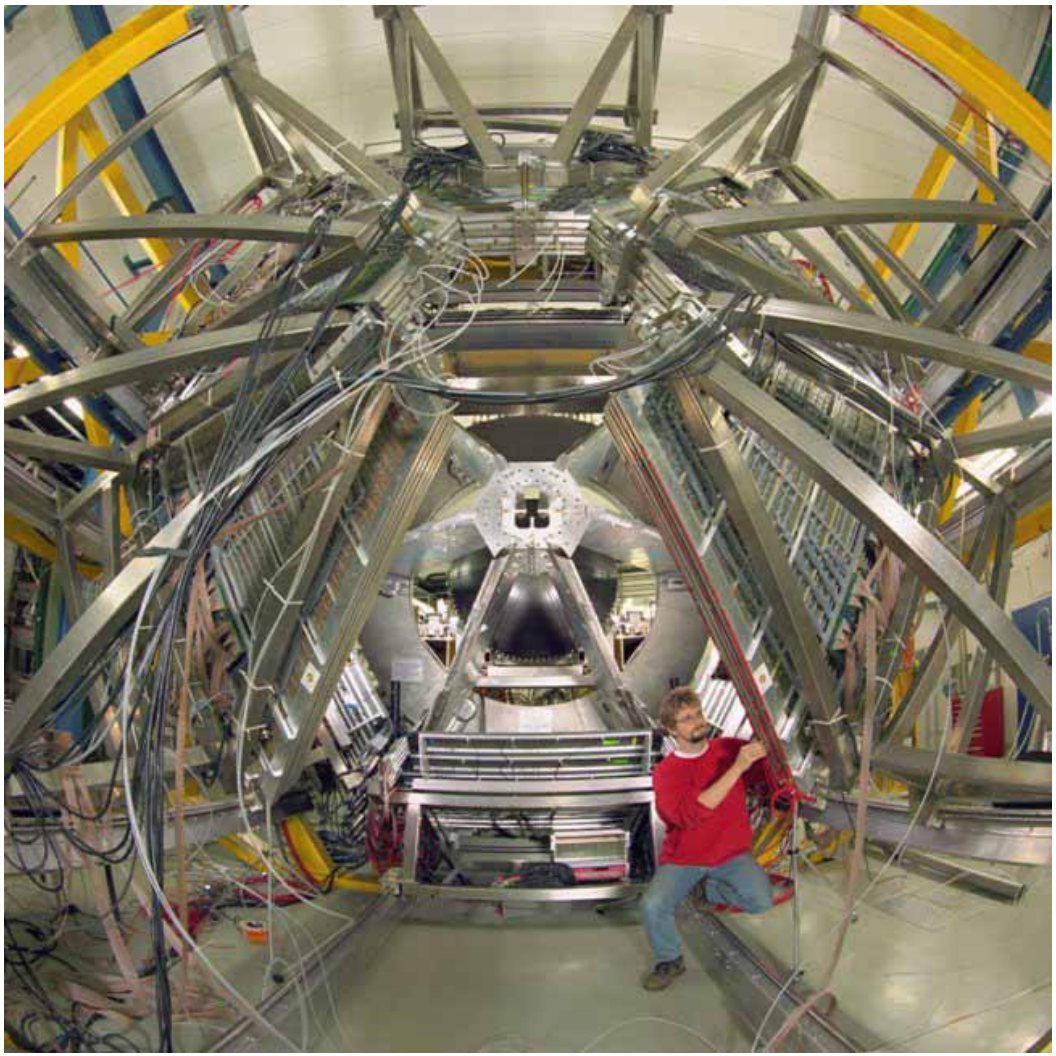
Suppression 10 - 100

LVL2 triggered events are transported to mass storage



up to 20 kHz LVL1
Fast multiplicity trigger

JINR contribution for HADES



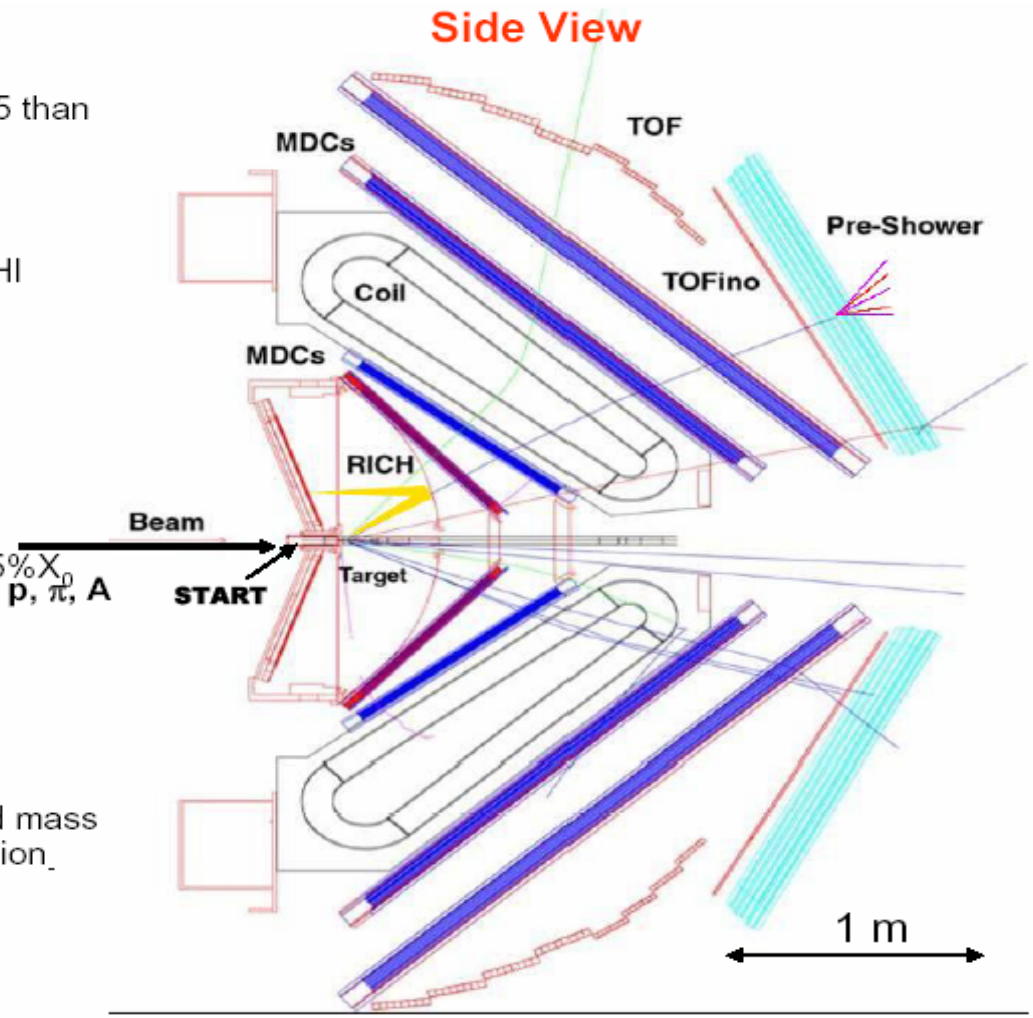
- Full-size Prototype of multilayer Drift Chamber has been developed and tested
- Front End Electronics for Drift Chambers has been developed and tested.
- Six low mass multilayer Drift Chambers (plane 2) were constructed, tested and integrated into the HADES spectrometer.
- Track reconstruction software has been developed and successfully applied for data analysis

  (‘ Dubna Tracking Software ’).
- Participation in physical program and data analysis.

Detector Status

From P. Salabura report on PAC / GSI, September 2004

- **Beams:**
  - ✓ p (LH_2) , C -production runs
  - ✓ π^- with I=0.8*10^6/spill and 4*10^{10} N_2/spil (<5 than needed for physics run of S262)
- **Beam detectors :**
  - ✓ Diamond detectors (START& VETO) for HI
  - ✓ Scintillating fibers for p,d,π beams
  - ✓ Forward Hodoscope (0-8^0)
- **RICH**
  - ✓ Full azimuth coverage,
  - ✓ Detector figure of merit N_0=79
  - ✓ Carbon mirrors (2 need to be installed)-0.5%X_0
  - ✓ Image Processing
- **Tracking system**
  - ✓ 3 MDC layers complete, 4 MDCIV
  - ✓ remaining 2 ready in 2004/2005.
  - ✓ Internal resolution ≈ 100 μm ⇒ anticipated mass mass resolution: $\Delta M_{e+e}/M \approx 1.5\%$ at ρ/ω region
- **META**
  - ✓ TOF/TOFINO, Pre-Shower –full coverage
  - ✓ Image Processing
  - ✓ Low granularity TOFINO->RPC upgrade



Experimental runs & Data analysis

J.Stroth (GSI), Trento 2005

- **November 2001**: commissioning run target = 5%
  - C+C 2 AGeV LVL1 triggered events ($M_{ch.}$>3) : **45 Mevents**
  - C+C 1 AGeV LVL1 trigger : **7.3 Mevents**
  - full coverage with inner MDC chambers ($\Delta p/p \approx 10\%$ at 0.7 GeV/c)

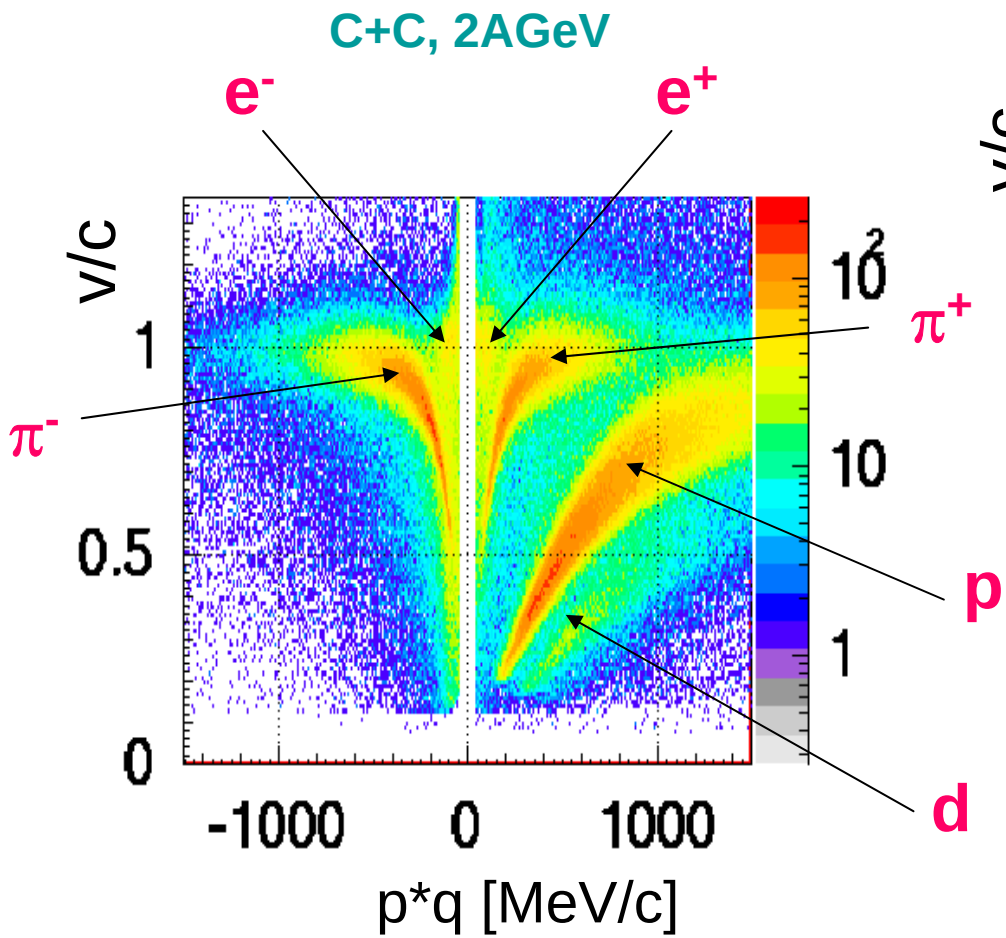
- **November 2002**: C+C 2 AGeV, commissioning and physics runs
  - target= 2 x 2.5%, 56% LVL1 trigger + 44% LVL2 trigger **220 Mevents**
  - 6 outer drift chambers (MDC) in 4 sectors

- **October 2003**: p+p commissioning run (1 GeV, 2 GeV)
  - full coverage with outer MDC III (4 MDC IV) ($\Delta p/p \approx 1.5$ % at 0.7 GeV/c)

- **February 2004**: p+p 2 GeV production run
  - target 5 cm l-H_2 **400 Mevents**

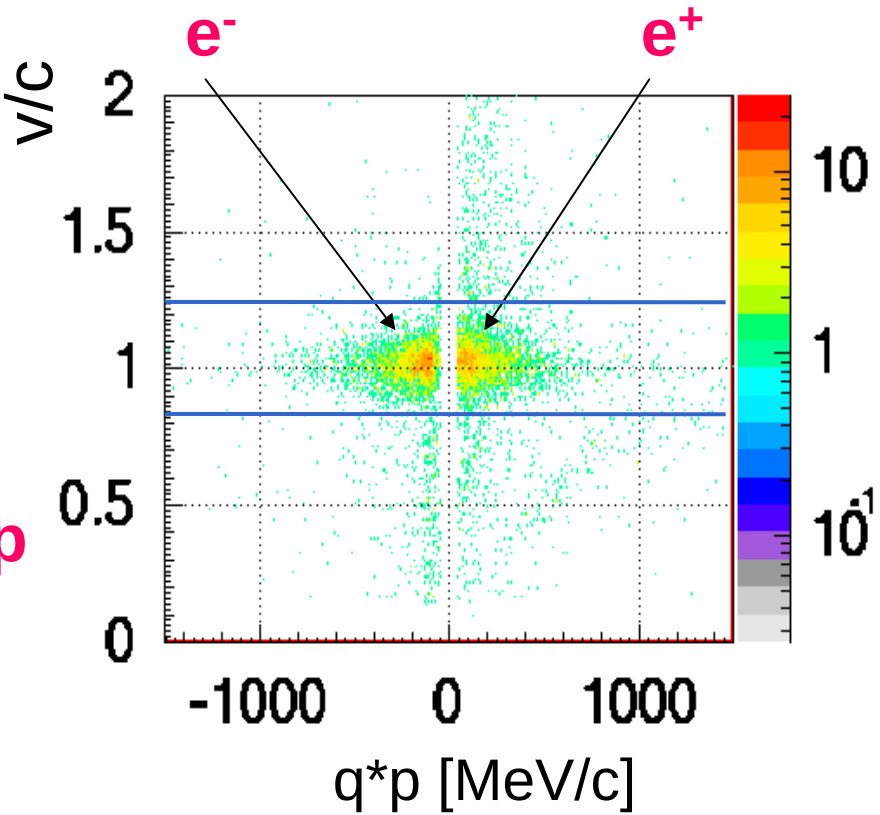
- **August 2004**: C+C 1 AGeV production run
  - 3x1.5 % target, 56% LVL1 trigger + 44% LVL2 trigger **650 Mevents**

Electron Identification



Tracking+TOF

✓ p/π separation for p <1000 MeV/c

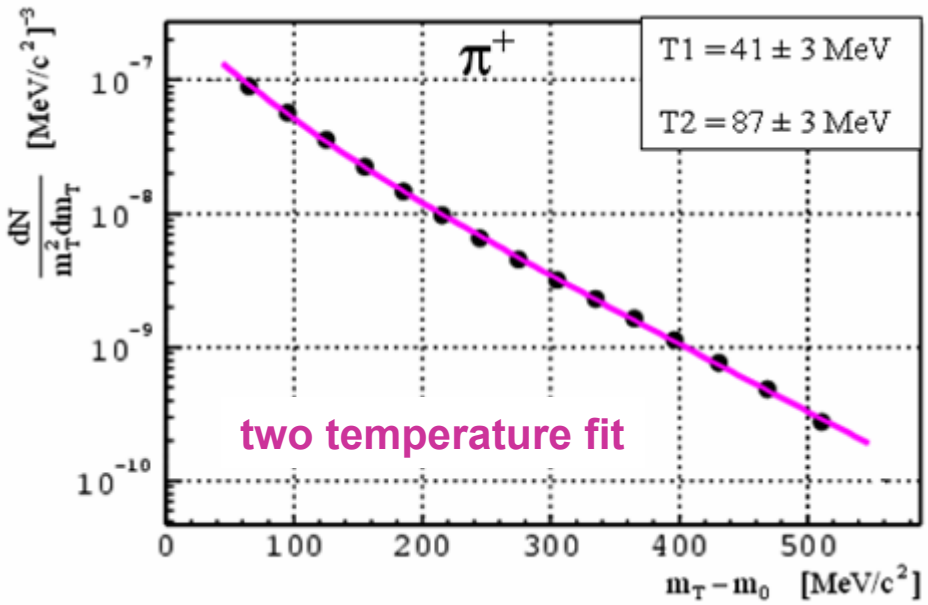


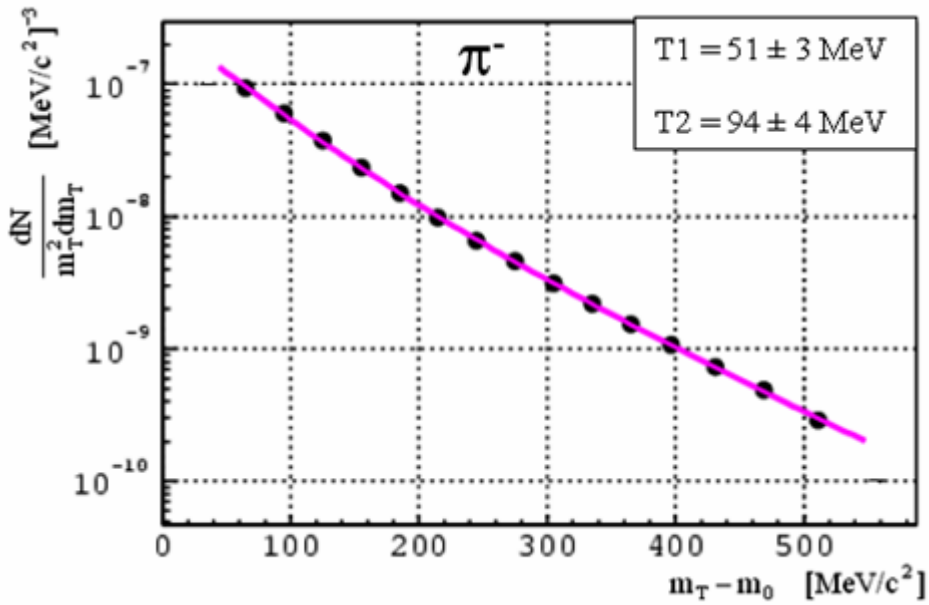
RICH +Tracking +TOF/PreShower

✓ hadron contamination <2%

Pion spectra in $^{12}C+^{12}C$ 2 AGeV (Preliminary)

J.Stroth (GSI), Trento 2005

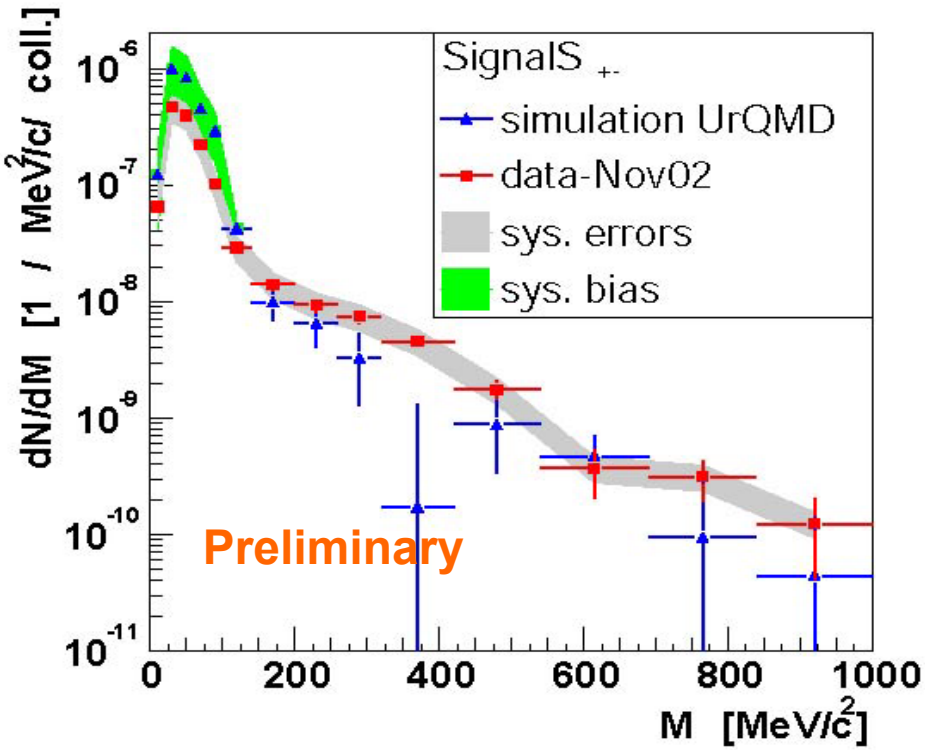


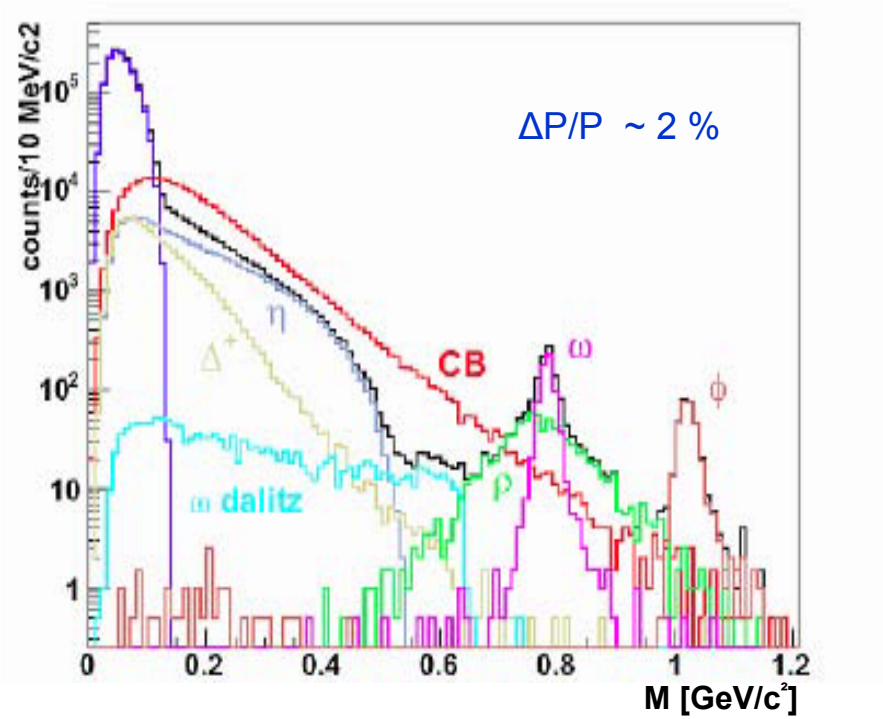


	Multiplicity	"Temperature"
HADES	$N_{\langle\pi^+\pi^-\rangle}/A_{\text{part}} = 0.148 \pm 0.018$	$T_{\pi^+} = 41 \pm 3;\ 87 \pm 3$ $T_{\pi^-} = 51 \pm 3;\ 91 \pm 4$
TAPS	$N_{\pi^0}/A_{\text{part}} = 0.138 \pm 0.014$	
KaoS	$N_{\pi^+}/A_{\text{part}} = 0.126 \pm 0.010$	$T_{\pi^+} = 40 \pm 3;\ 86 \pm 3$

data in good agreement with TAPS/KaoS results!

DiElectron spectrum: C+C @ 2.2AGeV





Experimental data: C+C @ 2.2AGeV Nov'2002
Spectrum of effective mass of e+ e- pairs (red color).
There is a good agreement with simulation.
Without outer Drift Chambers (ΔP/P is ~ 8%)

Simulation: Ca+Ca@ 2.2 AGev
ΔP/P is improved up to ~ 2 % with outer Drift Chambers were installed in HADES Spectrometer.

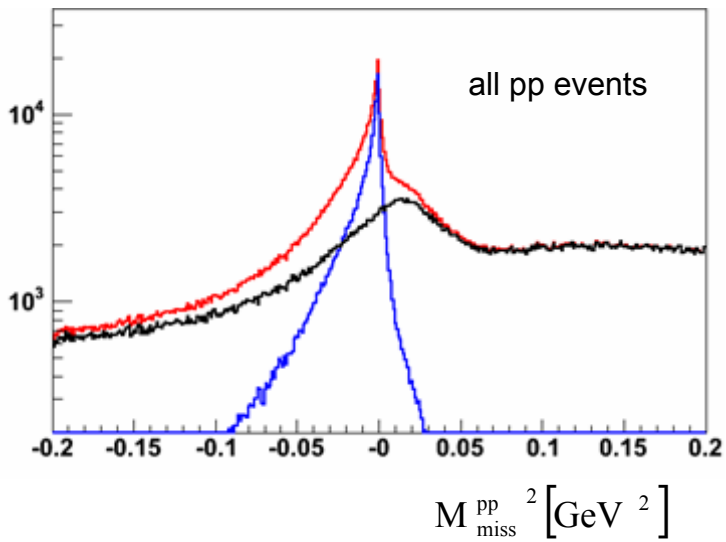
π^0 meson reconstruction @ pp 2.2 GeV

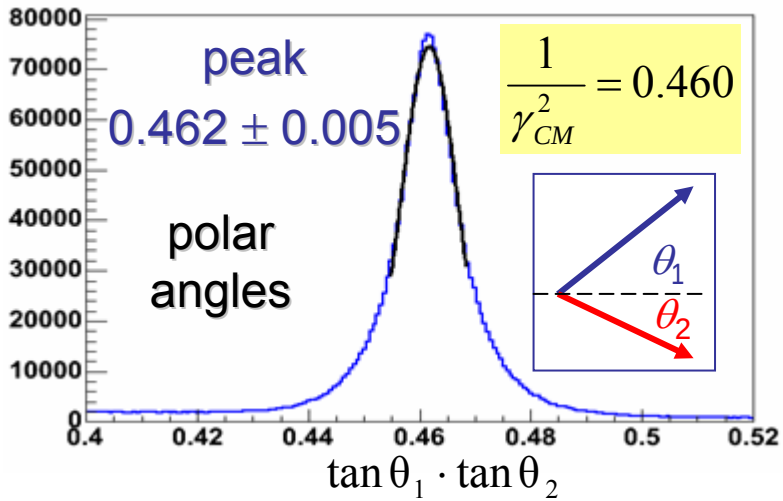
Hadron final states - 2 charged particles

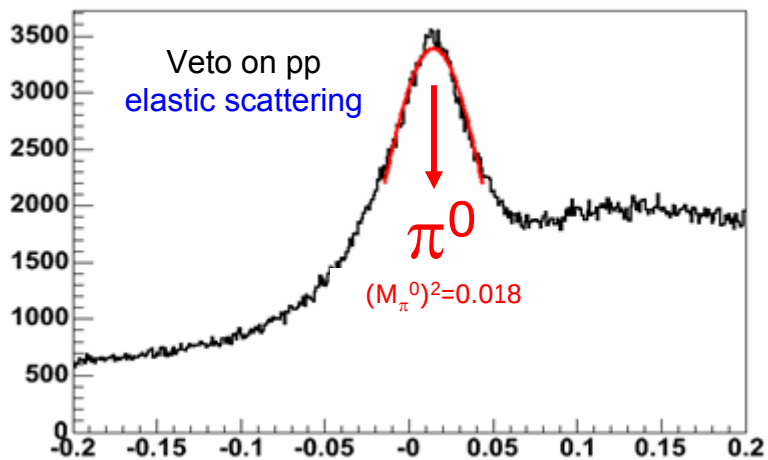
Stefano Spataro, INFN Catania

Inelastic channel

$p + p \rightarrow p + p + X\ (\pi^0)$



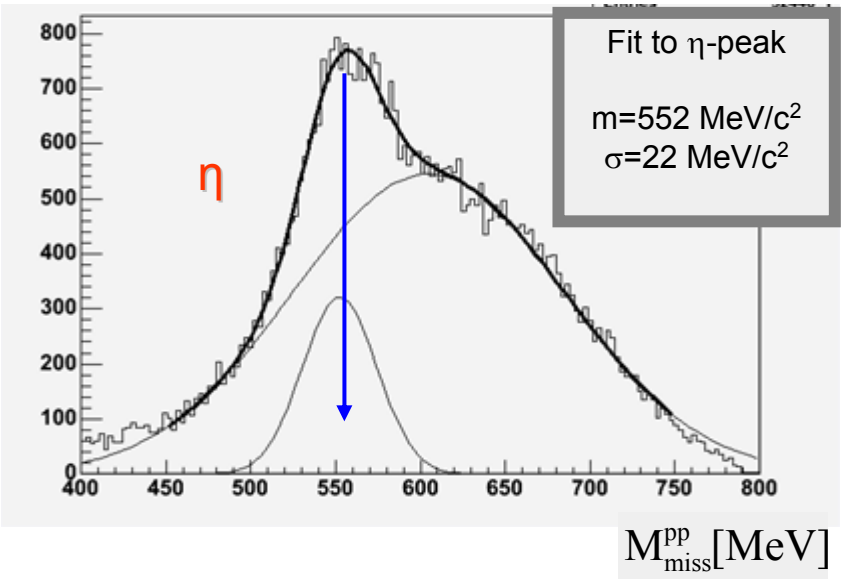


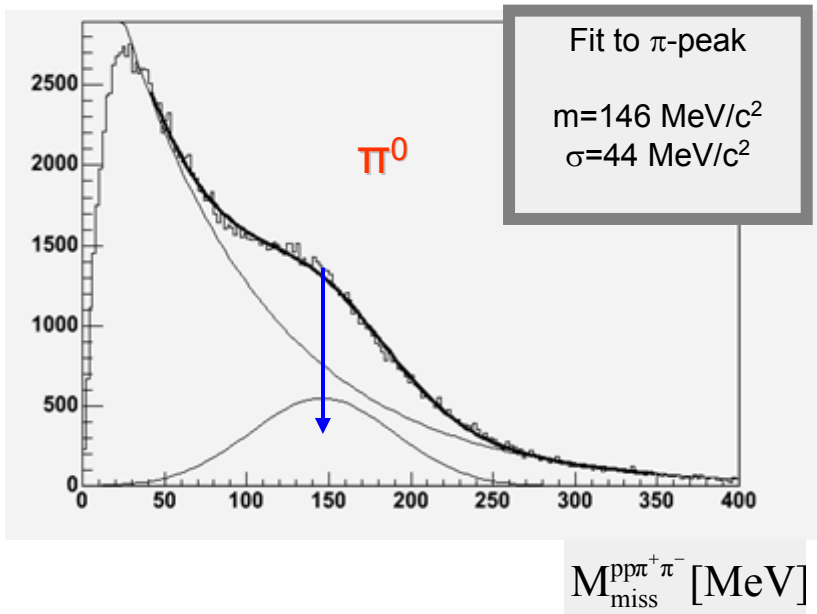


η meson reconstruction @ pp 2.2 GeV

Missing mass method

Stefano Spataro, INFN Catania



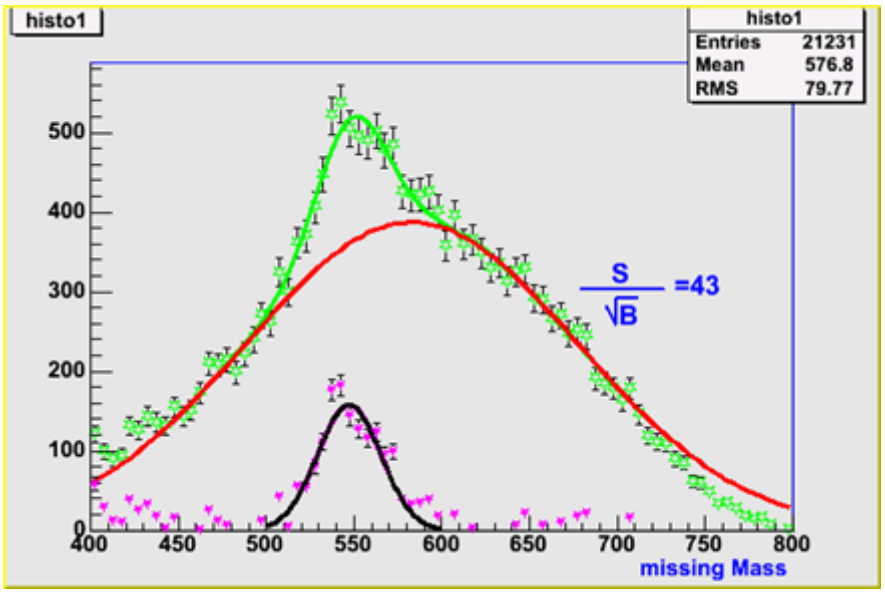


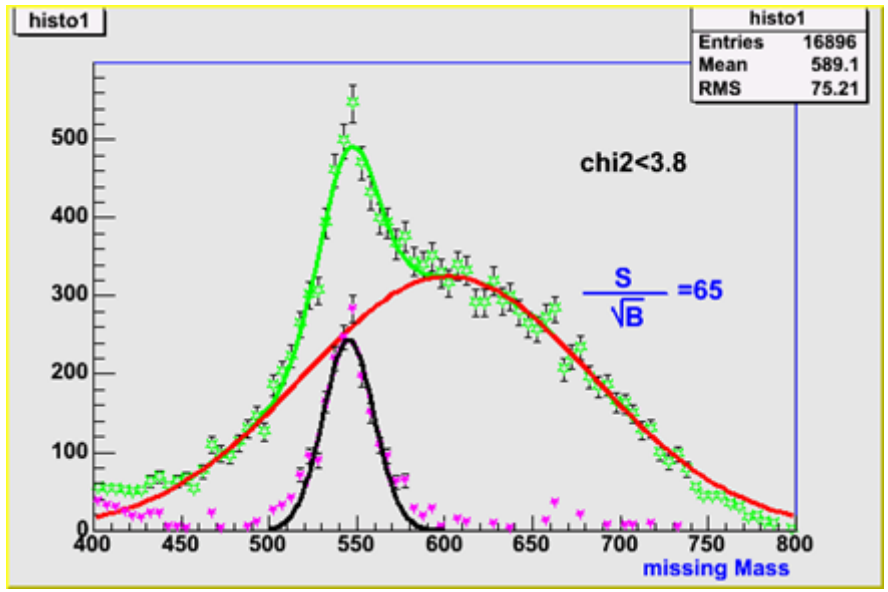
- 4 identified tracks in the acceptance ($pp\pi^+\pi^-$)
- identify $pp \rightarrow pp\eta \rightarrow pp\pi^+\pi^-\pi^0$

M^{pp}_{miss} ⟸ Missing mass distribution ⟹ $M^{pp\pi^+\pi^-}_{miss}$

Kinematical fit for η meson reconstruction

Anar Rustamov, GSI





Vary |p|,θ,φ of each track to minimize $\left| m^{pp}_{miss.} - m_{\eta} \right|$

- High S/B ratio
- pp missing mass resolution ≈ 2.4%

Nearest Physics Program

1. DiElectrons from pp/pd
2. On threshold η production in dp
3. ω production in pp collisions
4. Dielectrons from Ca+Ca

JINR Proposal : the study of low-mass scalar σ^omeson in the reaction $pp \rightarrow pp\sigma^o$ with the decay of mesons through the modes $\sigma^o \rightarrow 2e^+ 2e^-$ and $\sigma^o \rightarrow e^+ e^- \gamma$

Yu.A.Troyan et al.
Particle and Nuclei, Letters,
2002 No.5 (114)

Electromagnetic decay of σ^0 meson

Low-mass σ^0–meson:

- chiral symmetry in L
- attractive part in NN - potential

Theoretical predictions:

$(q\bar{q}) \rightarrow$ **M** = 500 ÷ 1000 MeV/c,
Γ = 200 ÷ 500 MeV/c

$(gg) \rightarrow$ **M** = 280 ÷ 700 MeV/c,
Γ = 2 ÷ 60 MeV/c

Hot and dense matter:

M.K.Volkov et al. (BLTP, JINR):

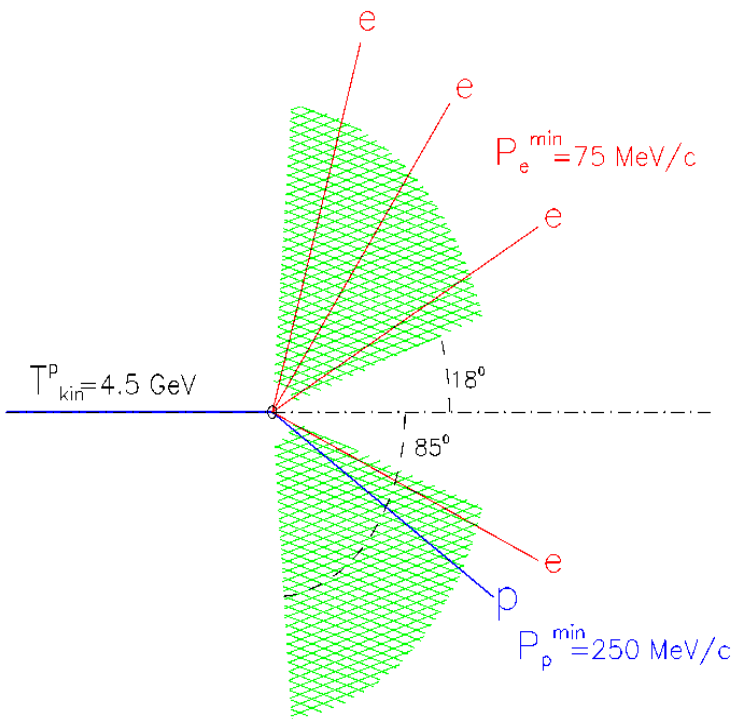
At critical (T,μ) ⇒
- $\Gamma_\sigma \rightarrow$ smaller
- $M_\sigma \rightarrow$ down to m_π
- BR $(\sigma \rightarrow \gamma\gamma)$ $\uparrow 10^3$

⇓

Change of mass and width of σ meson is a signature of properties of nuclear medium

Scalar σ^0 meson at HADES
(JINR proposal)

σ^0 production in $pp \rightarrow 2e+2e- X$



Simulation

pp – interaction at T_p=4.5GeV

$\sigma(pp \rightarrow pp\sigma_0)=\sigma(np \rightarrow np\sigma_0)$

Background:

$pp \rightarrow NN+K\pi^0+X$ – from compilation and OPER-model

$BR(\sigma_0 \rightarrow 2e^+2e^-) = BR(\pi^0 \rightarrow 2e^+2e^-)=3 \cdot 10^{-5}$

$BR(\pi^0 \rightarrow e^+2e^-\gamma)=1.2 \cdot 10^{-2}$

Smearing:

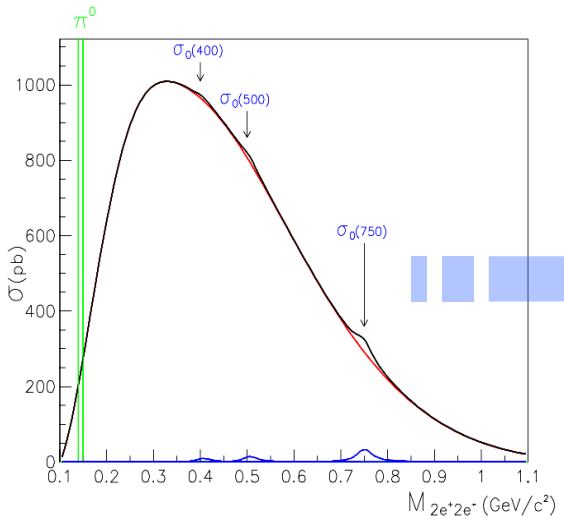
$\delta P / P = 1.0\%$

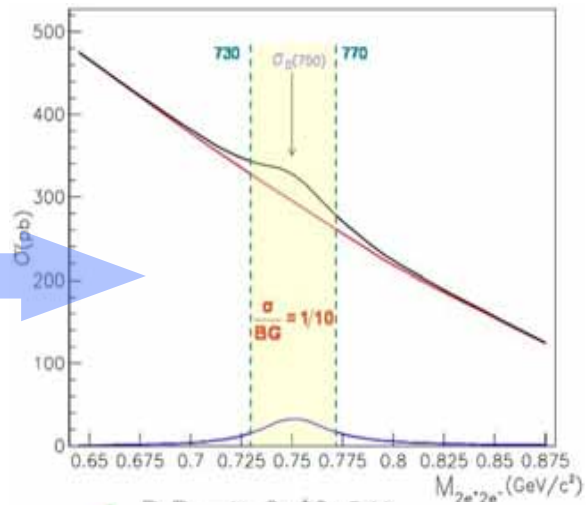
$\delta\Theta_i = 0.05$ mrad

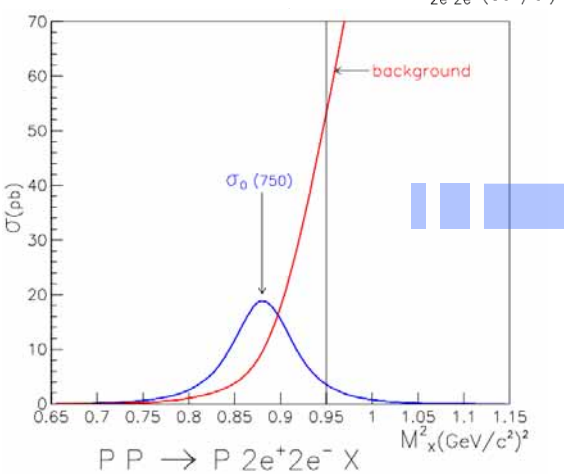
(1event/1pb)

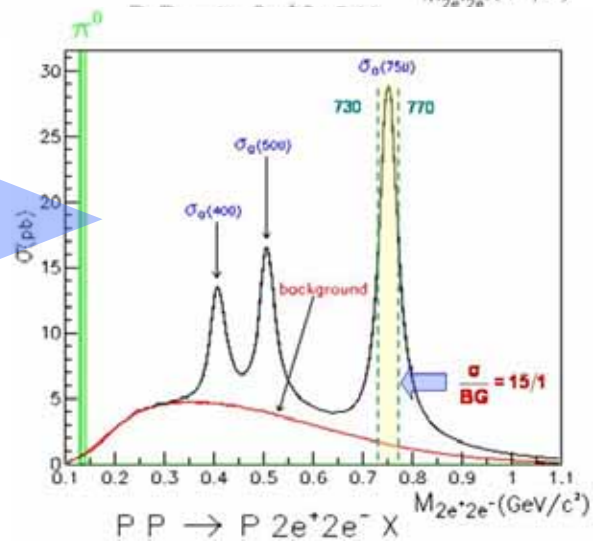
$I_P = 2 \times 10^7$ p/s rate ~ 10 events/hour.

Spectrum of TetraElectrons from the reaction $pp \rightarrow 2e^+ 2e^- X$ at Tp = 4.5 GeV







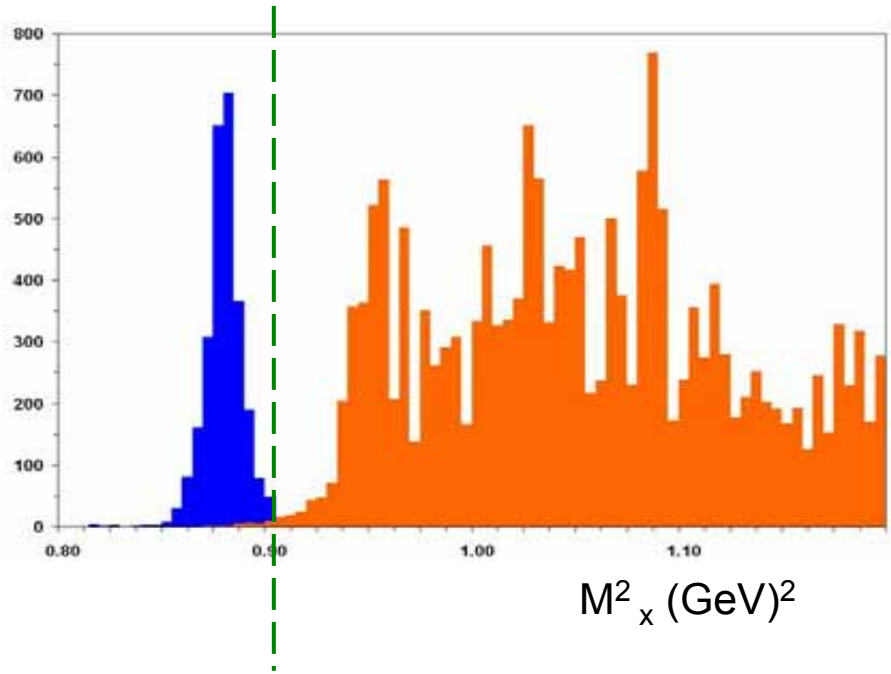


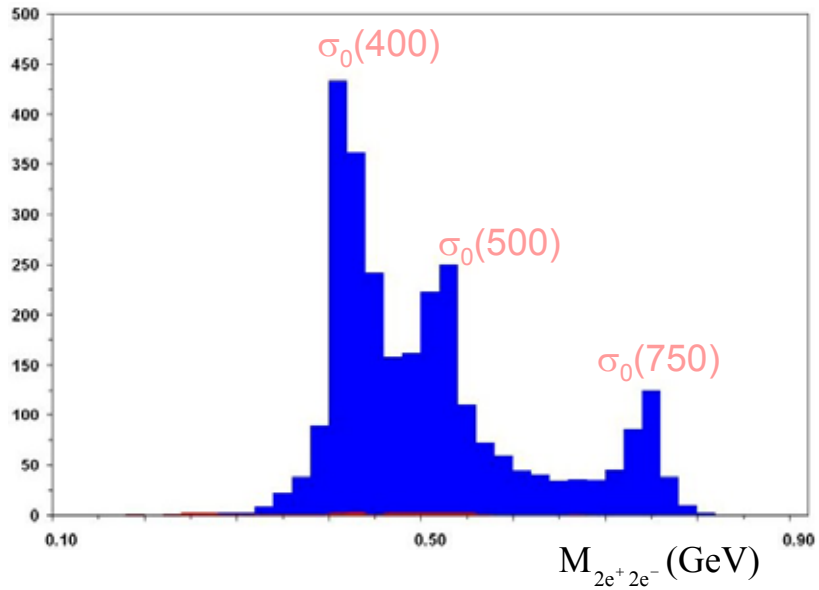
at 1 event/1pb ⇨ 37 S.D. above background [BR(σ0→2e+2e-) = 3 • 10^{-5}]
signal of σ_0 - meson ⇨ up to BR(σ0→2e+2e-) = 10^{-6}
increasing the exposure ⇨ up to BR(σ0→2e+2e-) = 10^{-7}

Spectrum of TetraElectrons

in the reaction $pp \rightarrow p2e^+2e^- X$ at T_p=2.2GeV

For $M^2_x < 0.91 (GeV/c^2)^2$

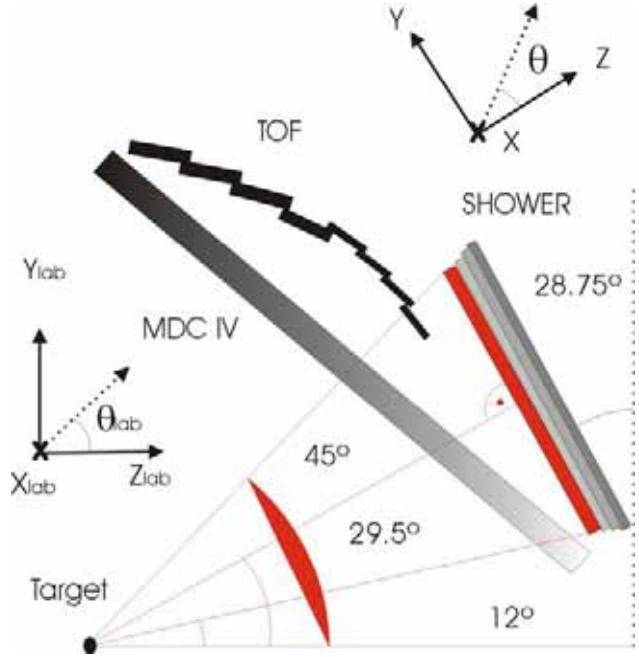


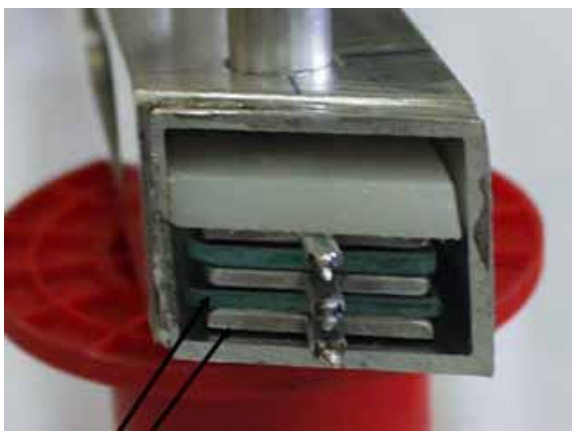


I = 2x10E7 p/s; rate ~ 5 event / hour

Future upgrades & TOFINO replacement by RPC

- *Forward wall*
- *RPC - instead TOFINO*
- *DAQ*
- *Beam line*





Resistive Plate Counter (RPC)

- *Operational parameter matched to HADES overall performance*
  - granularity - 1200 cells (double-hit probability below 20%)
  - Resolution ~100 ps (σ) or better
  - rate capability up to 1 kHz/cm^2 (in some areas)
  - efficiency above 95% for single hits

Summary

- HADES is fully operational Spectrometer
- Preliminary results from first production run $^{12}C + ^{12}C$ 2 AGeV
- A lot of physics ahead for the coming years
  - heavy ion system size dependence
  - p, π, heavy ion: high precision in-medium spectroscopy
- JINR proposal for σ^0 meson study with HADES
- Next run in September 2005 (Ca+Ca at 2 AGeV)
- Replacement of TOFino system by RPC
- Feasibility studies for HADES at SIS100 (<8 AGeV)

Future Experiments

PRELIMINARY INFO

The discussion with the Member of HADES X-board for operation of the Spectrometer on NUCLOTRON was started in June 2005.