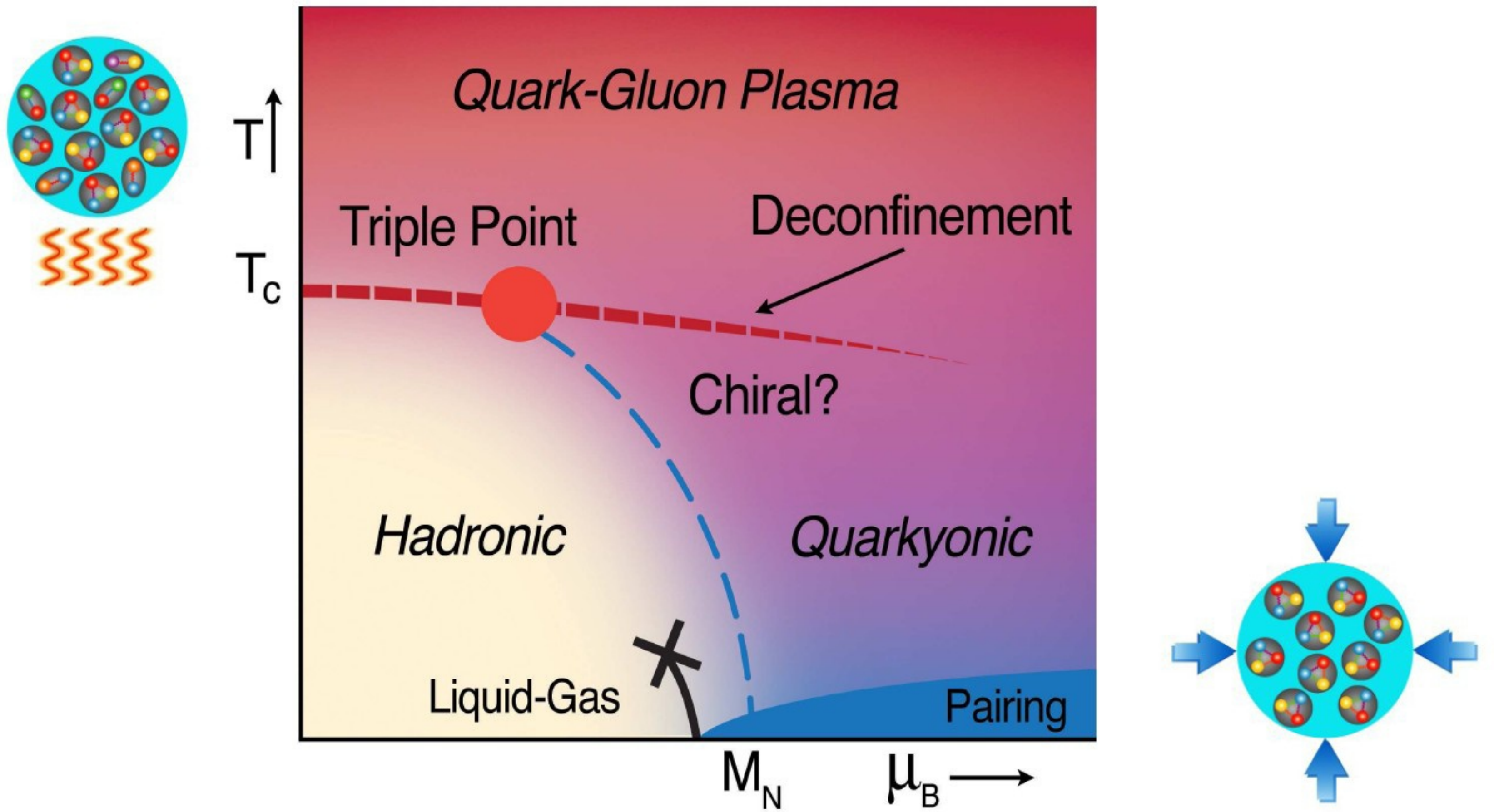
The HADES Experiment at GSI

28.10.2010

Jan Michel

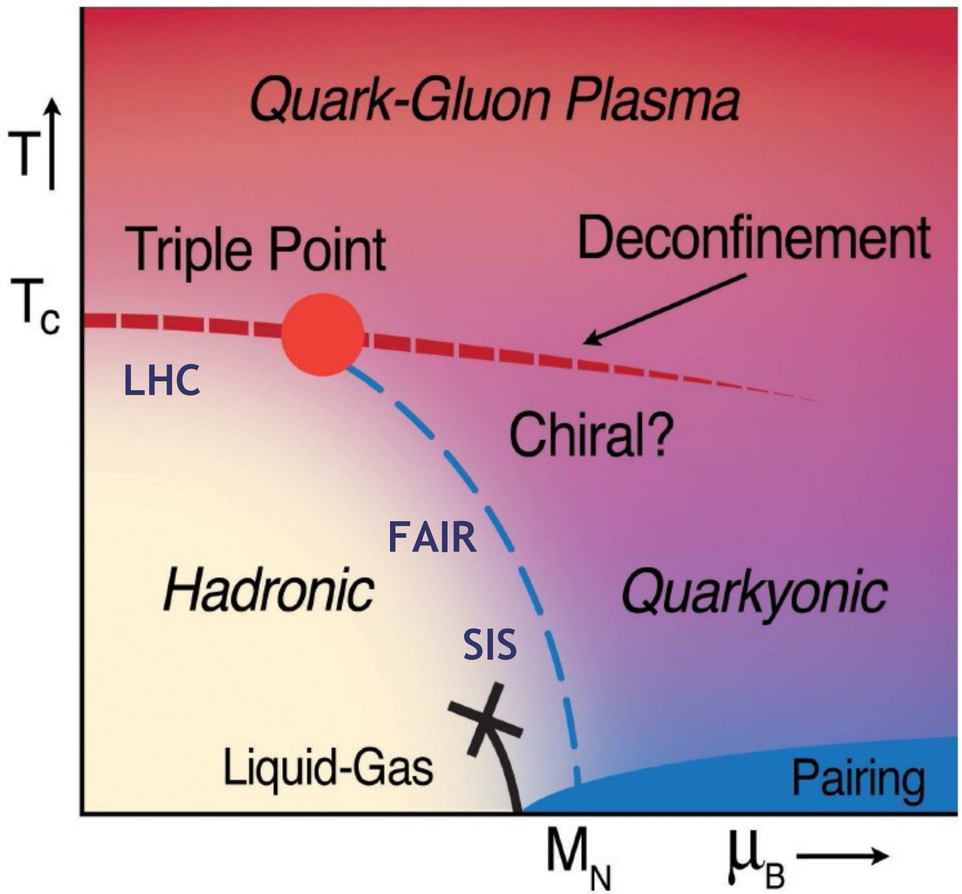
The HADES Experiment at GSI

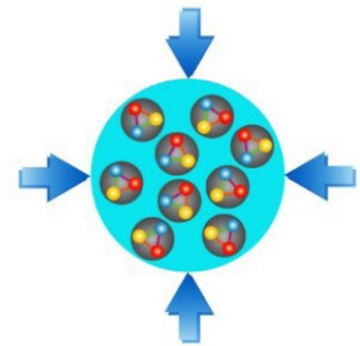
The physics
HADES spectrometer
HADES measurements
The data acquisition system
The future



- Exploring the phase diagram of nuclear matter by heating and compression nuclei
- How do properties of hadrons change inside a medium?

Hadronic Matter

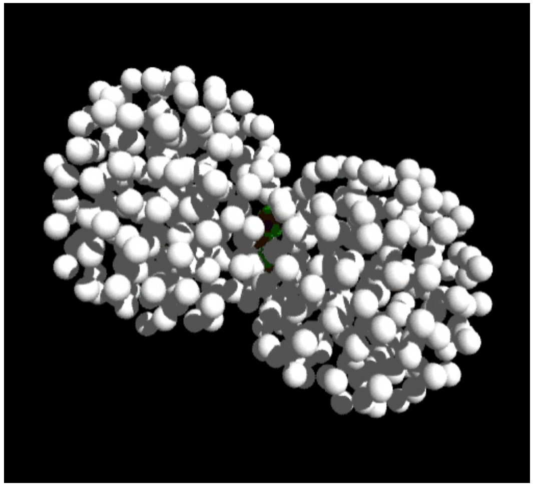




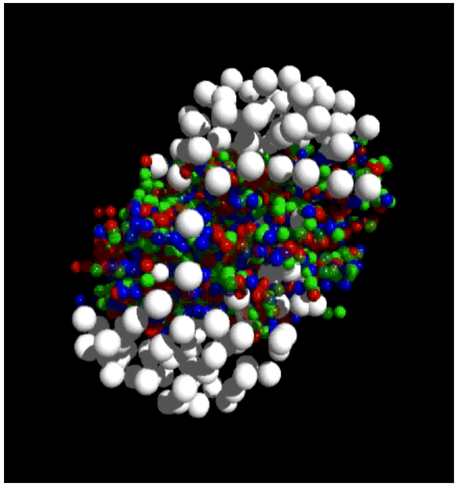
SIS-18:
- E = 1-2 GeV/u
- T < 100 MeV
- ρ = 2-3 ρ0
- $\tau \sim$ 10fm/c

Hadronic Matter

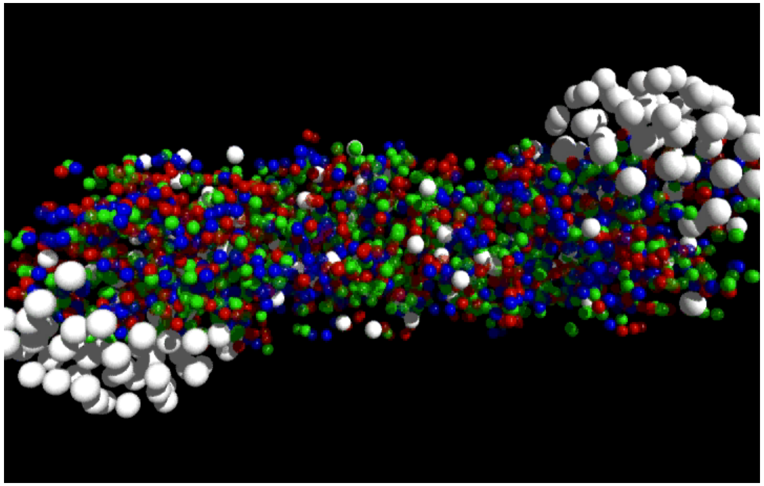
UrQMD, Univ. Frankfurt



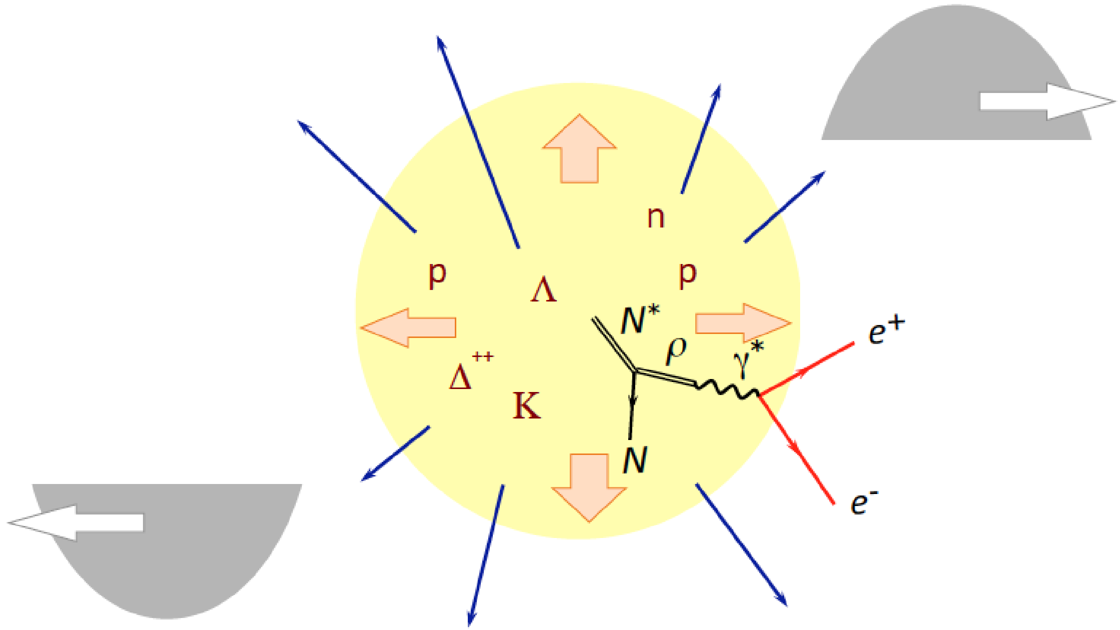
first chance collisions
elementary N-N collisions



hot and dense phase

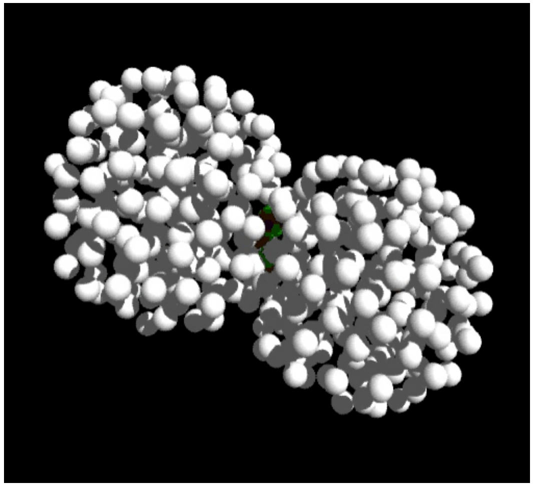


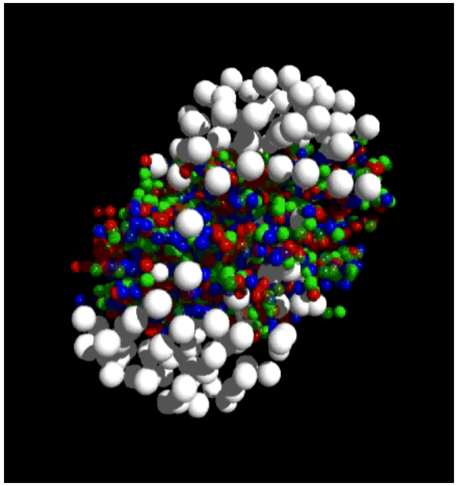
freeze –out

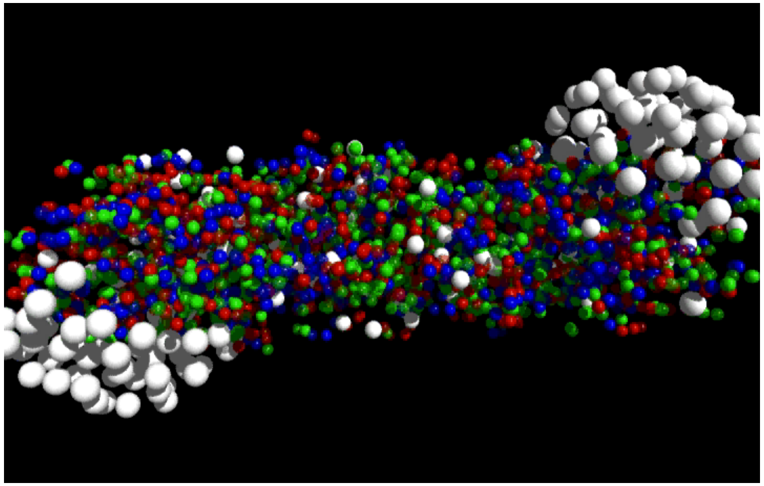


- To gain information about dense, hot matter one needs probes coming from inside the fireball
- Strongly interacting particles can not escape without being scattered multiple times
- Only leptons do carry undistorted information

Heavy Ion Collissions



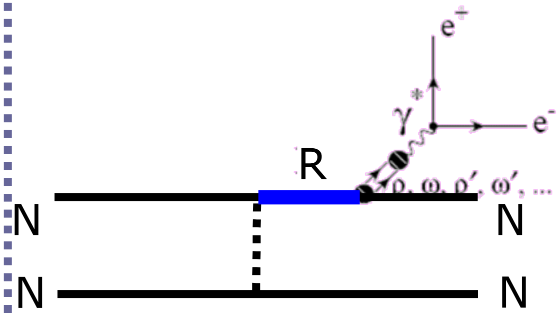


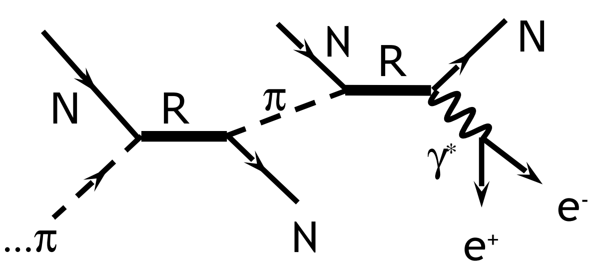


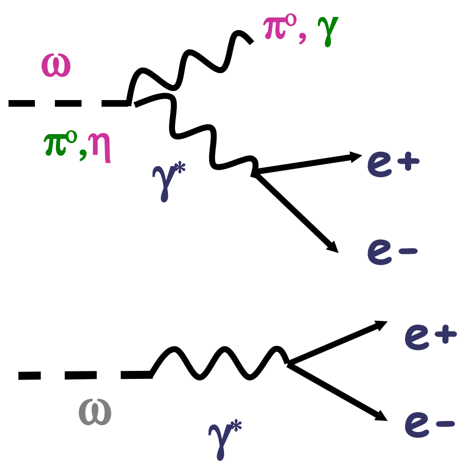
first chance collisions
elementary N-N collisions

hot and dense phase
multistep production
of resonances and mesons

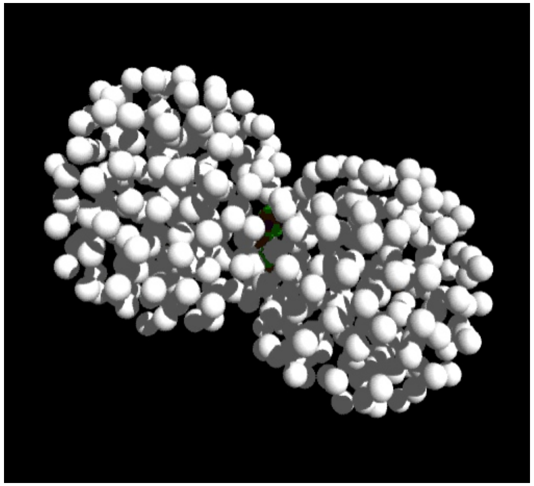
freeze −out
decays of long-lived
mesons: π^0, η, ω



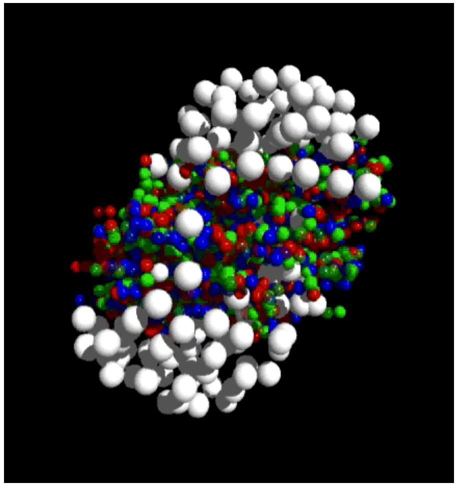




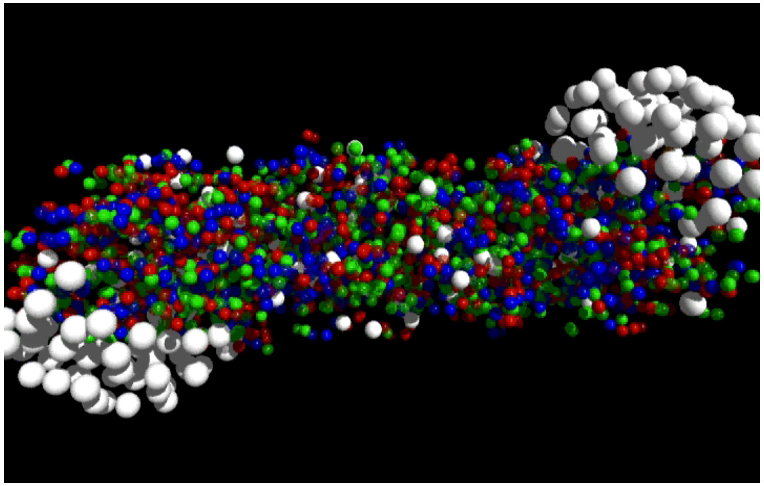
Lepton Pairs in Nuclear Collisions



first chance collisions
elementary N-N collisions



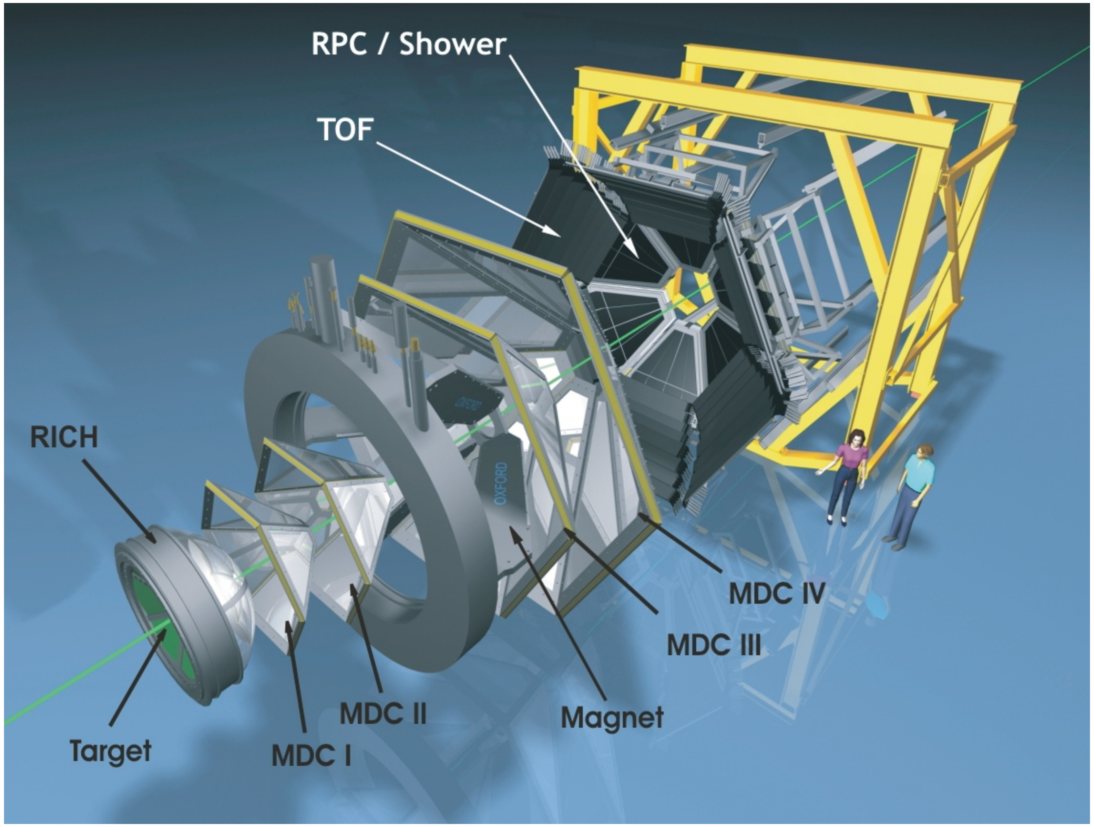
hot and dense phase
multistep production
of resonances and mesons

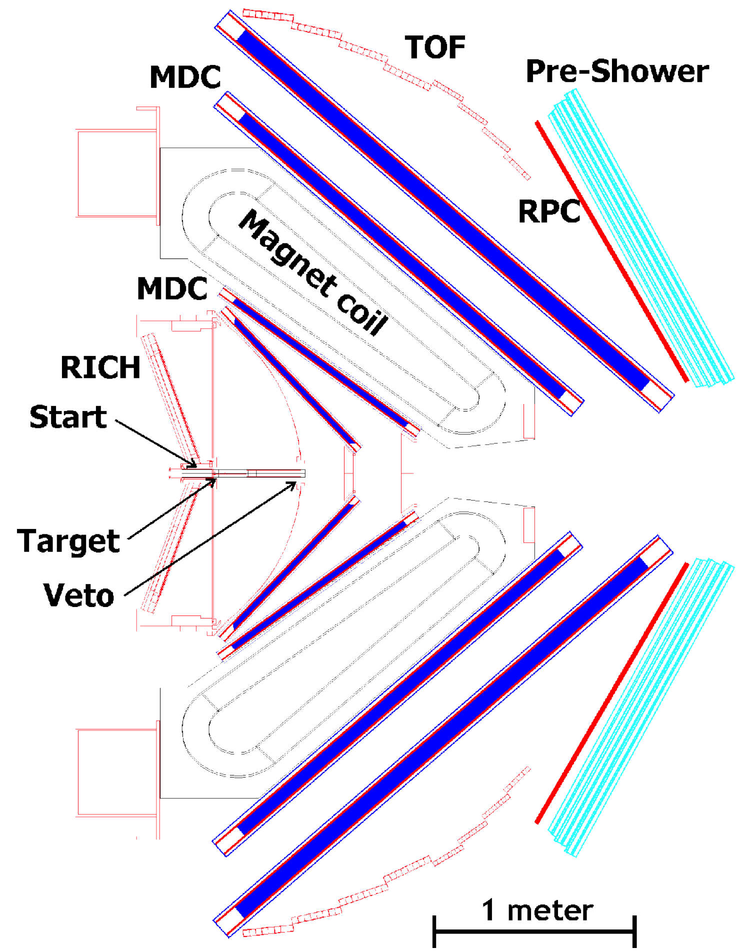


freeze −out
decays of long-lived
mesons: π^0, η, ω

- **Leptons provide undistorted information from inside the fireball**
  - Hadrons are interacting strongly with other particles
- **Decays into leptons are suppressed by a factor of 10^4 compared to hadronic decays**
  - Experiments have to collect vast amounts of events
- **Information from the hot and dense phase is hidden inside background**
  - Long-lived mesons have been measured (TAPS)
  - Elementary collissions have to be understood

The HADES Spectrometer

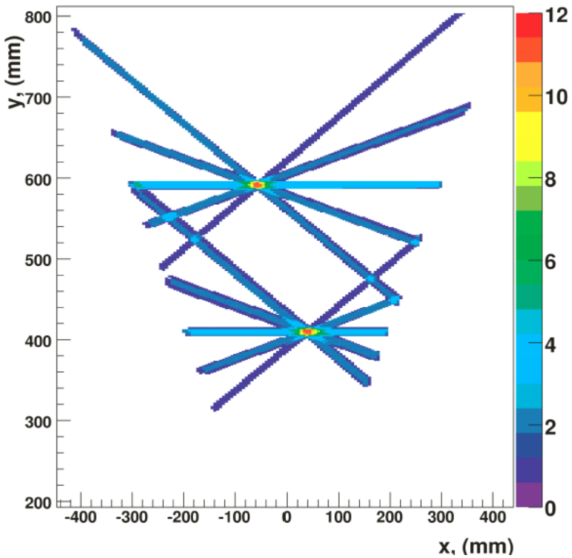


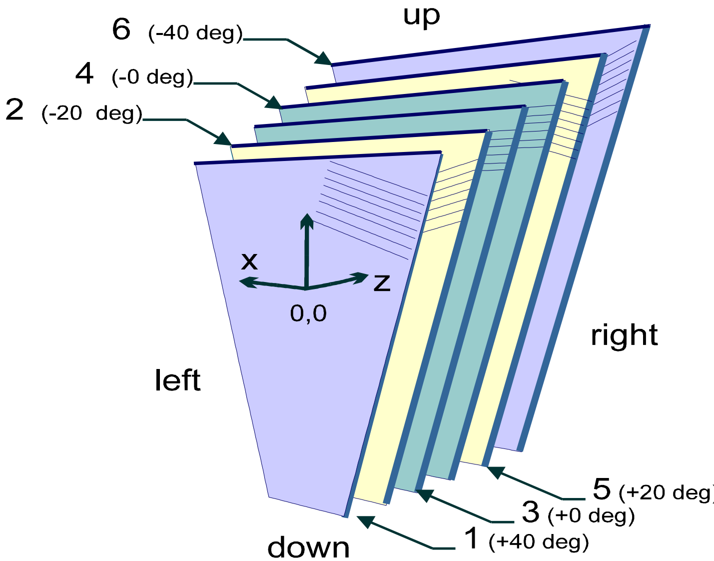


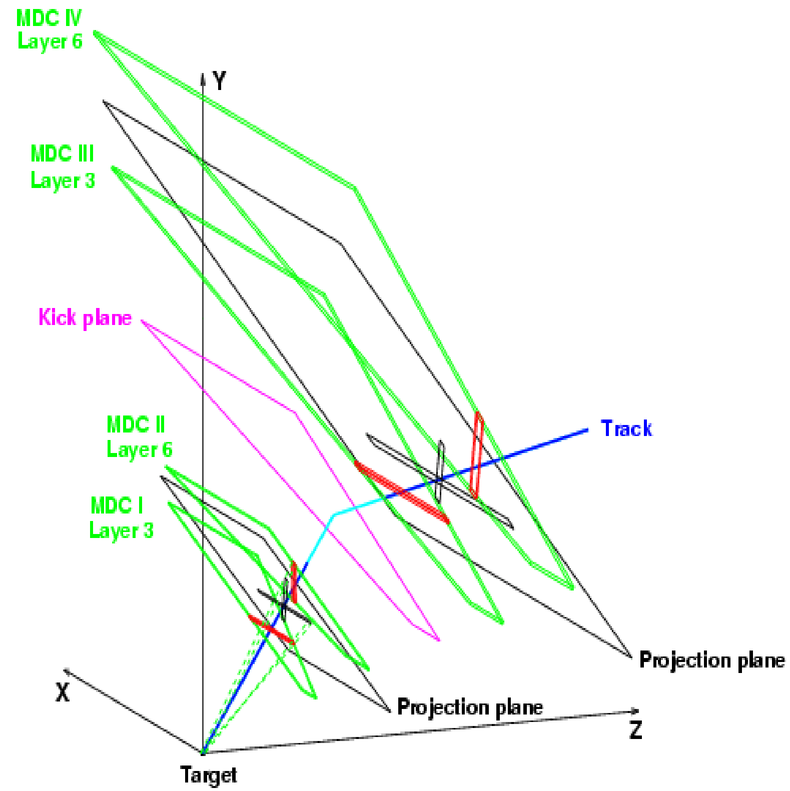
High Acceptance DiElectron Spectrometer

100.000 individual front-end channels
100 kHz event rate
400 Mbyte/s data rate

The HADES Detector


y, (mm)
800
700
600
500
400
300
200
-400 -300 -200 -100 0 100 200 300 400
x, (mm)
12
10
8
6
4
2
0

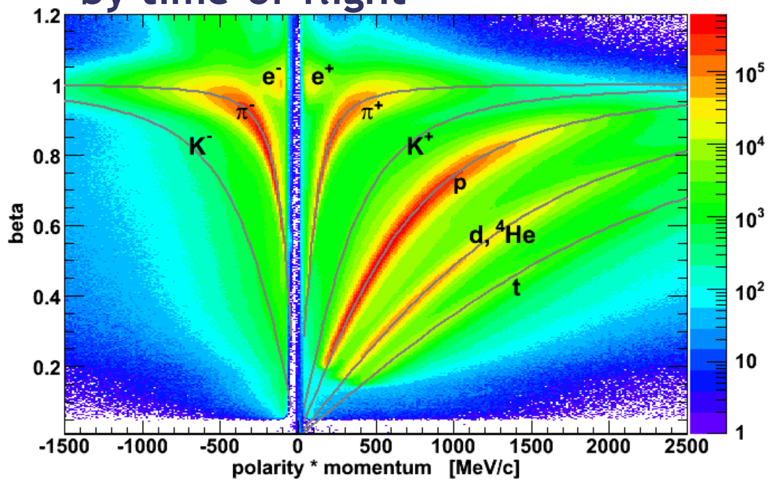

6 (-40 deg)
4 (-0 deg)
2 (-20 deg)
up
x
z
0,0
left
right
down
5 (+20 deg)
3 (+0 deg)
1 (+40 deg)


MDC IV
Layer 6
Y
MDC III
Layer 3
Kick plane
MDC II
Layer 6
Track
MDC I
Layer 3
Projection plane
X
Projection plane
Z
Target

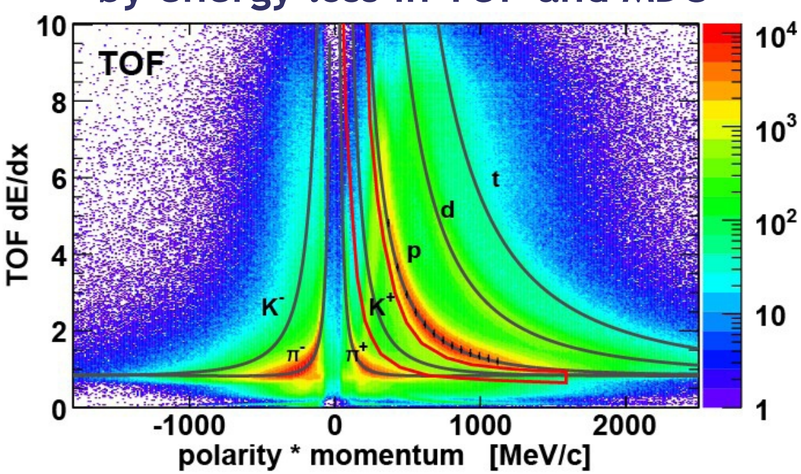
Tracking

Hadron identification

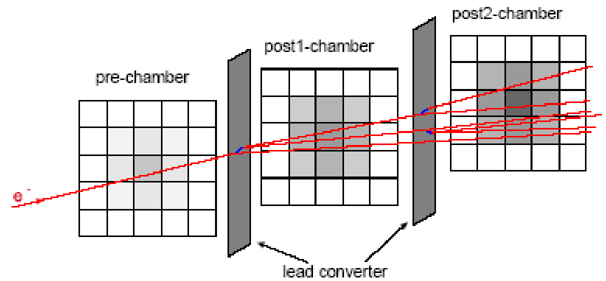
by time-of-flight

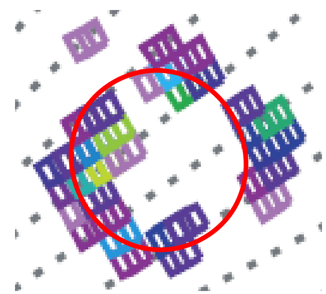


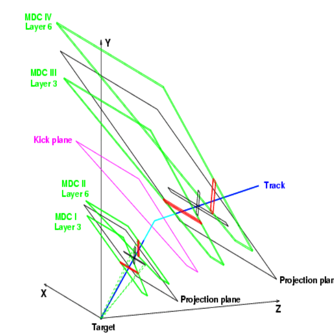
by energy loss in TOF and MDC



Electron identification:
Shower data & RICH rings



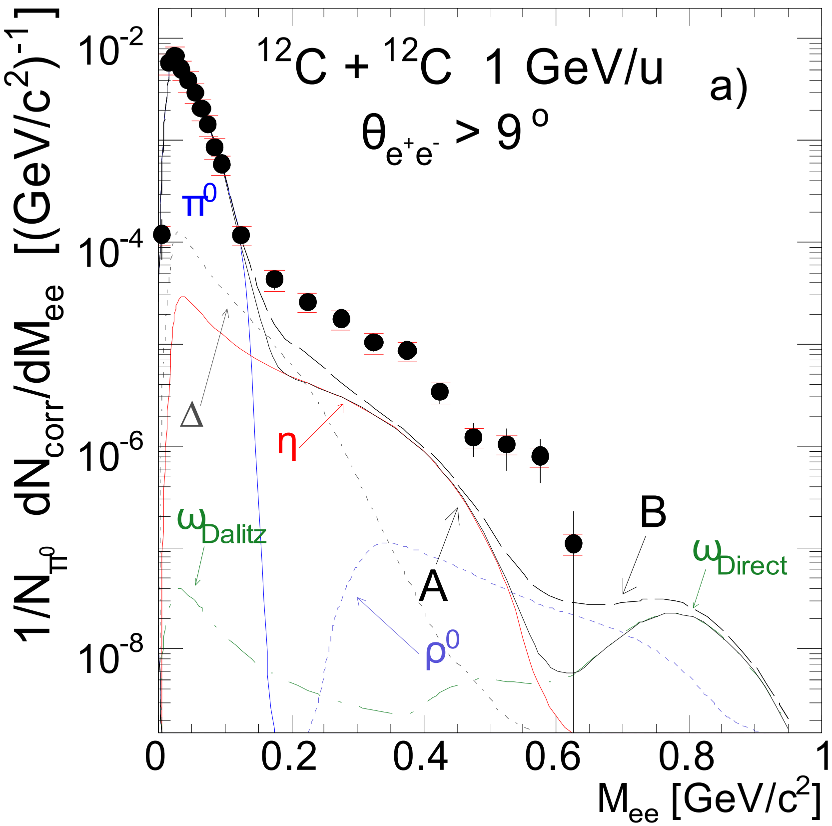




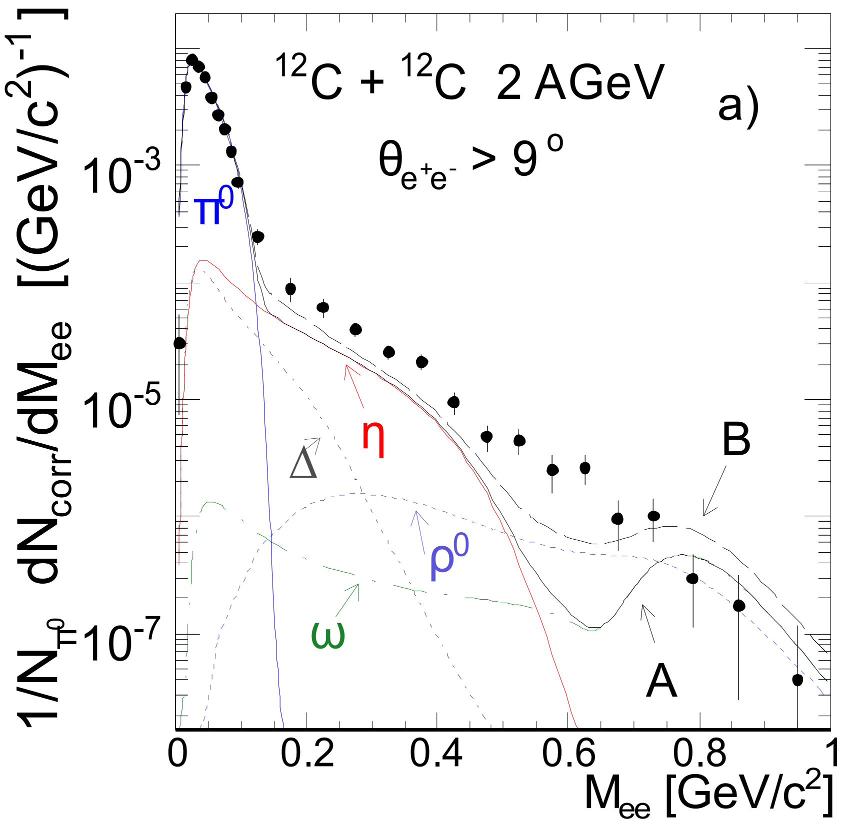
Particle Identification

2002 - 2004: C + C @ 1 / 2 AGeV

2002	C + C 2 AGeV
2004	C + C 1 AGeV

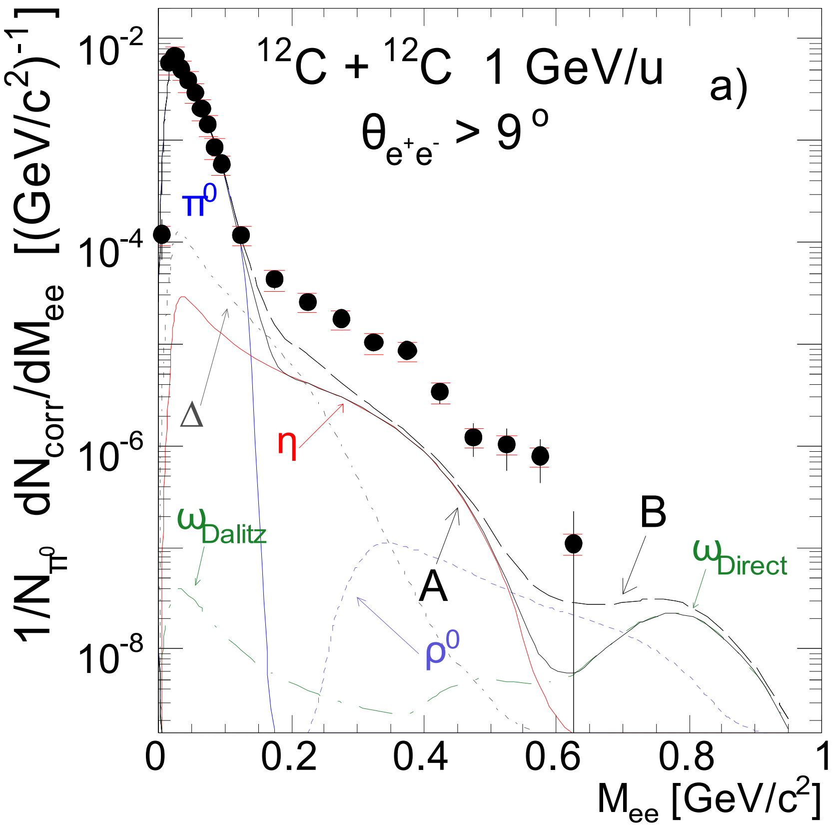


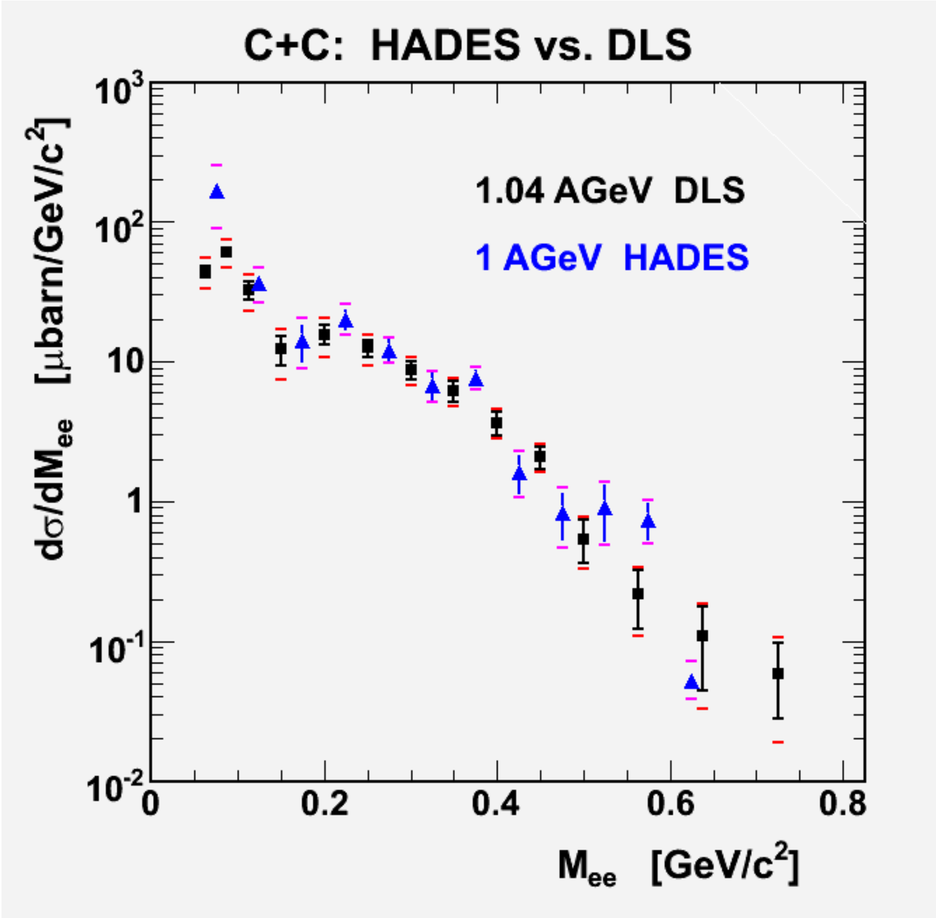
Phys. Lett. B 663 (2008) 43



- Data shows pronounced excess over theoretical calculations
- Shown contributions of long-lived meson decays have been measured by TAPS

2002 - 2004: C + C @ 1 / 2 AGeV



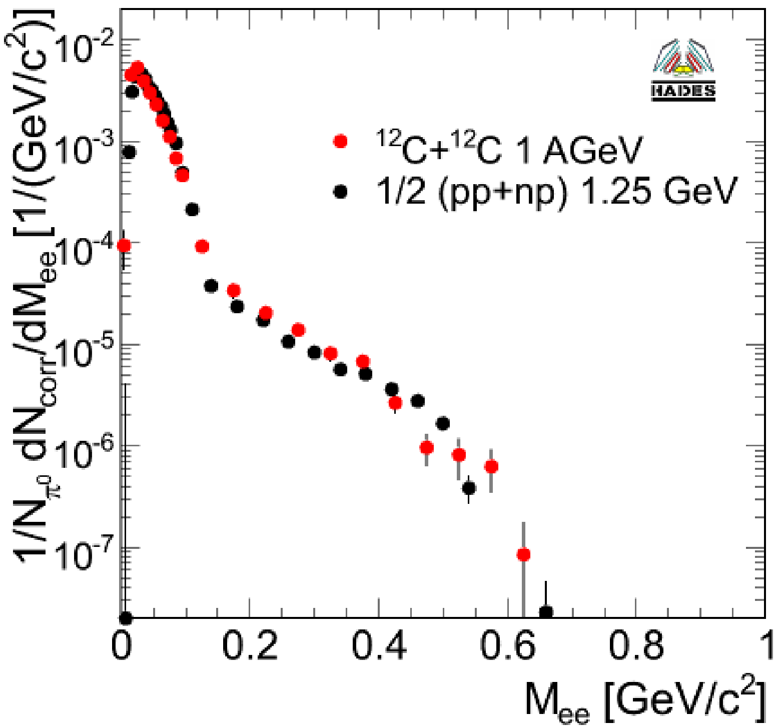


- Comparison with data measured by DLS shows a perfect agreement

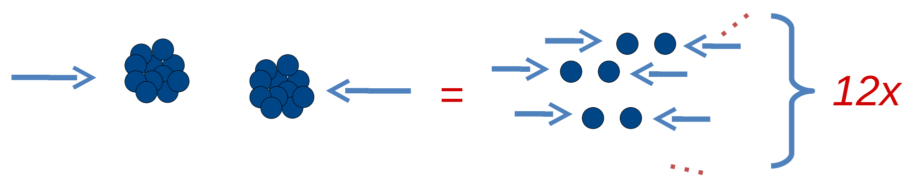
HADES Measurements

2004 - 2007:
Measurement of p+p and n+p reactions

2002	C + C 2 AGeV
2004	C + C 1 AGeV
2004	p + p 2.2 GeV
2006	p + p 1.25 GeV
2007	p + p 3.5 GeV d + p 1.25 AGeV

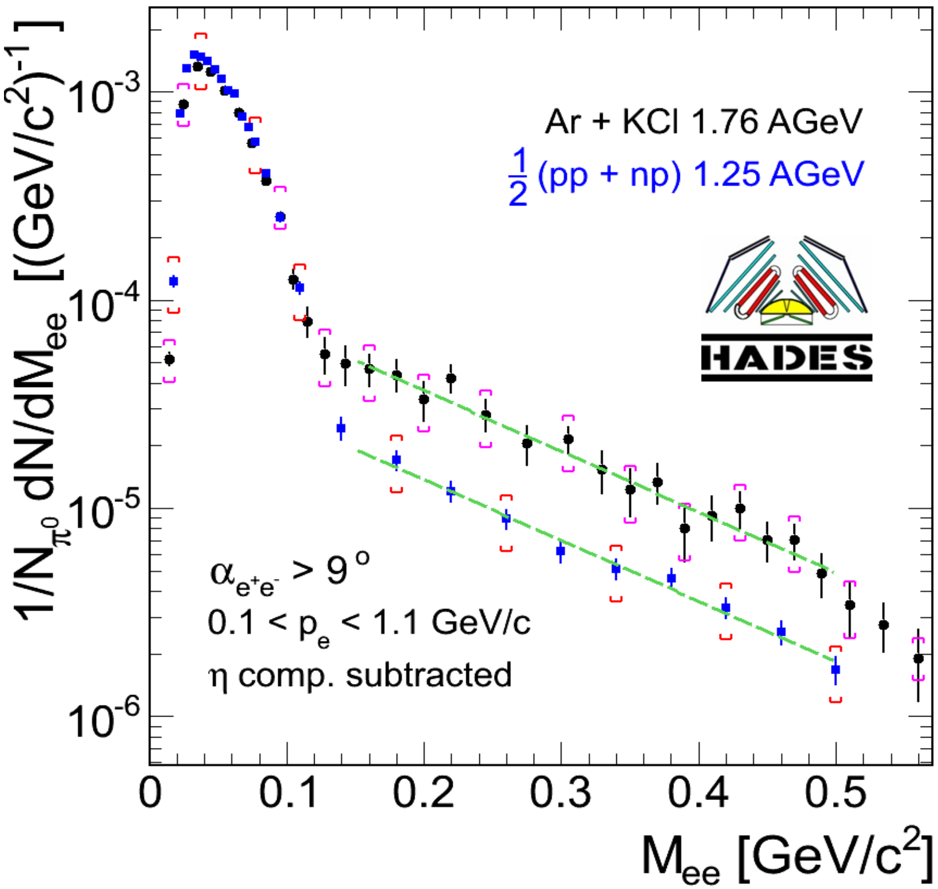


Excess measured in C+C can be explained by elementary pp and np collissions
No in-medium effects yet!



The Origin of the Excess

2005:
Measurement of heavier Ar+KCl system



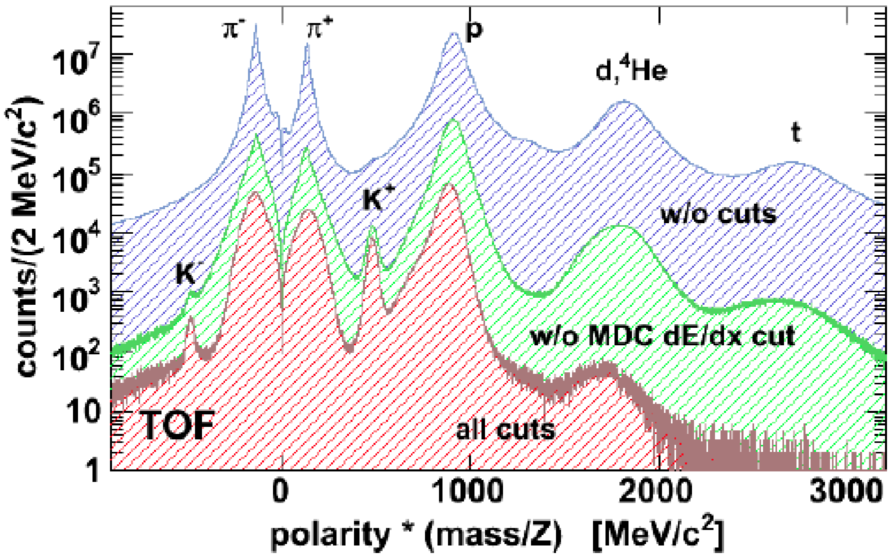
2002	C + C 2 AGeV
2004	C + C 1 AGeV
2004	p + p 2.2 GeV
2006	p + p 1.25 GeV
2007	p + p 3.5 GeV d + p 1.25 AGeV
2005	Ar + KCl 1.75 AGeV

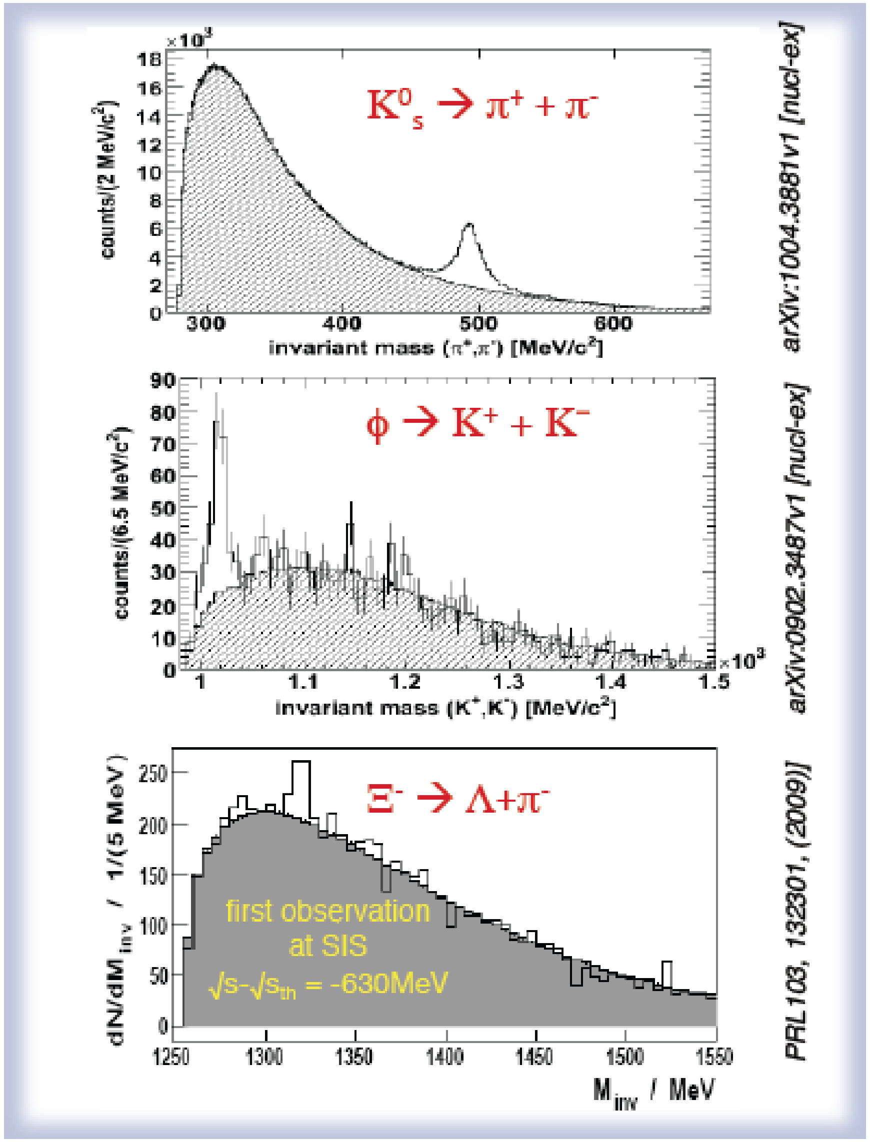
At energies above 0.2 GeV, a Factor 2 - 3 more ee-pairs are seen as in pp & np

To get the complete picture further measurements at even higher masses (Ag + Ag, Au + Au) needed

Heavier Systems

- Hades is not only a dilepton spectrometer, but can also identify hadrons with high precision
- For more detailed analysis more statistics are needed





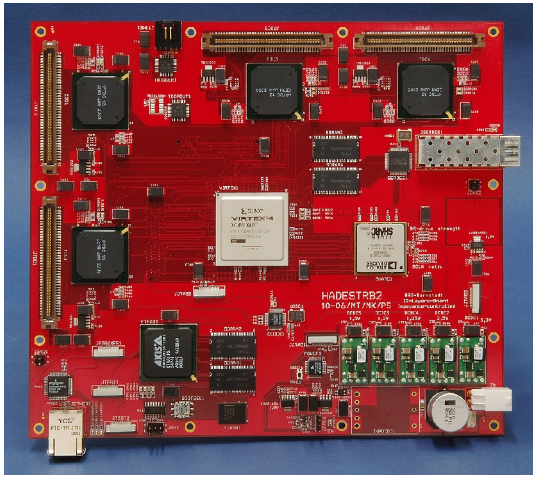
Manuel Lorenz, Univ. Frankfurt

Strangeness Measurements

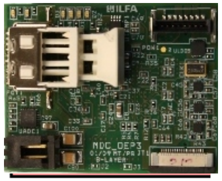
- **Requirements: Heavier Systems + Higher Statistics**

- **The HADES electronics are already more than 10 years old**
- **Data for Ar+KCl was taken at 3 kHz event rate**
  - For Au + Au we would expect 700 Hz

- **HADES Upgrade**
  - Event rate up to 100 kHz (p + p), 20 kHz (Au + Au)
  - Data rate up to 400 Mbyte/s (peak), 250 Mbyte/s (avg)
  - Complete replacement of all read-out electronics
  - New detectors: Forward Wall, RPC



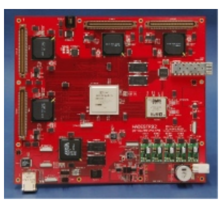
The Data Acquisition System

MDC  x 372

RICH  x 30

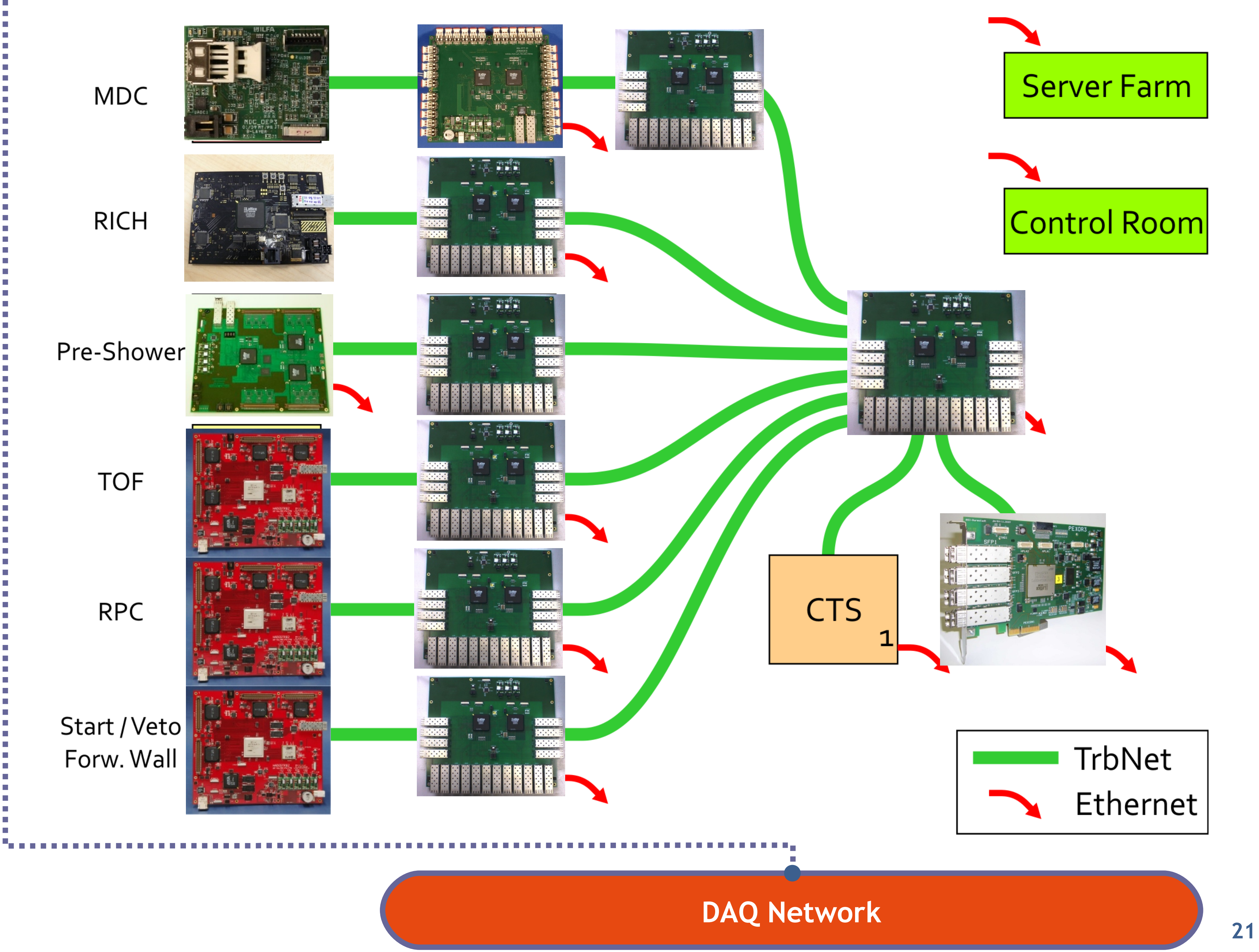
Pre-Shower  x 6

TOF  x 7

RPC  x 24

Start / Veto
Forw. Wall  x 4

DAQ Network


MDC
RICH
Pre-Shower
TOF
RPC
Start / Veto
Forw. Wall
Server Farm
Control Room
CTS
1
TrbNet
Ethernet
DAQ Network

Electronics

- 520 digital PCB (not including FEE)
- 1,500 ADC channels
  (multiplexed from 80,000 signals)
- 30,000 TDC channels
- 100 kHz trigger rate
- 250 MByte/s (avg.), 400 MByte/s (peak) written to disk

Data transport

- 550 FPGAs
- 1050 optical transceivers (SFP & FOT)
- 7,000 m optical fibre (glass-fibre & POF)
- 800 m 1-wire & CAN bus
- 30 Ethernet switchs
- 15 Gbit/s uplink to Eventbuilders
- 10 Gbit/s uplink to storage (Lustre / Tape)

DAQ Power Supply

- > 4,000 voltage regulators
- 9 power supplies
- 5.5 kW total power (FEE only)

Server farm

- 160 TB hard disks
- 44 CPU cores
- 500 TB tape storage / beamtime

DAQ in numbers

- All boards are custom designed
- Data digitization (ADC, TDC...)
- Front-end configuration
- controlled by FPGA
  ("Field Programmable Gate Array")

Electronics

- All boards are custom designed
- Data digitization (ADC, TDC...)
- Front-end configuration
- controlled by FPGA
  (“Field Programmable Gate Array”)

x 1.000.000

+

+

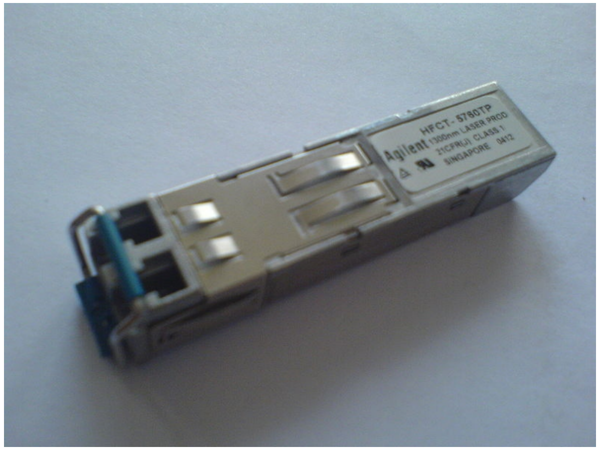
+

+ fixed special blocks like memory, multipliers...

- Like in normal electronics, all fucntions run in parallel, not serialized as in a CPU
  - A big number of small tasks can be done at the same time

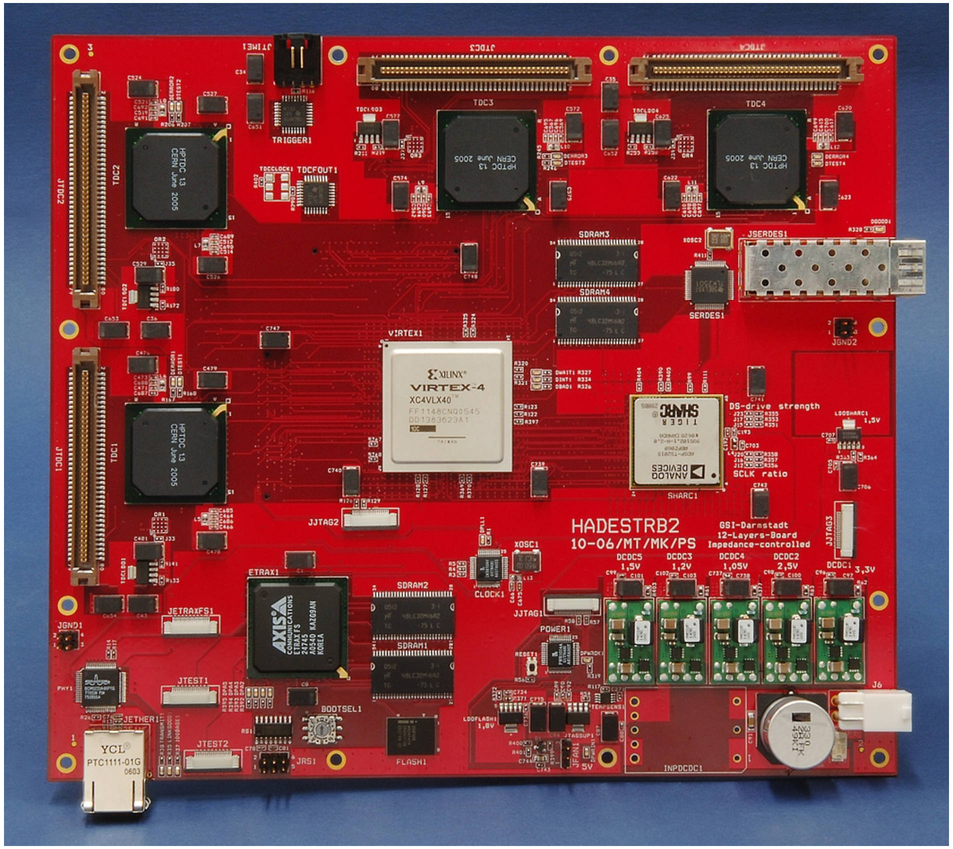
- All boards are custom designed
- Data digitization (ADC, TDC...)
- Front-end configuration
- controlled by FPGA
  ("Field Programmable Gate Array")

- Optical links for sending data
  - Smaller cable form factor
  - Less electromagnetic noise



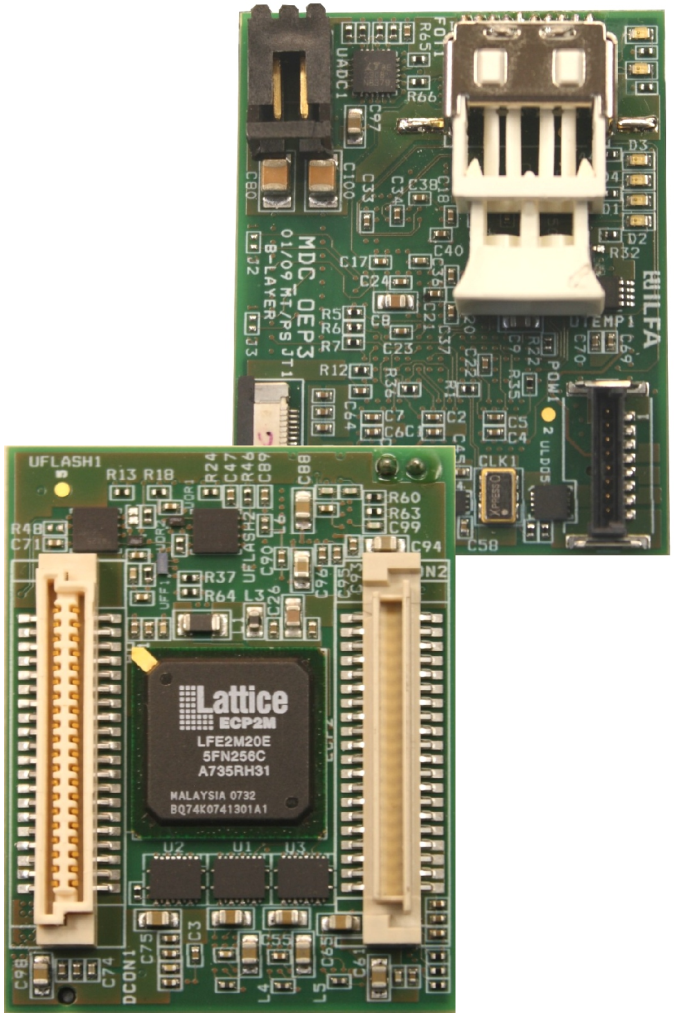
Electronics

- Virtex 4 FPGA
- TigerSharc DSP
- Etrax CPU (Linux & Ethernet)
- 2 GBit/s optical link
- 128 TDC channels (time resolution: 30 ps)
- On the back: Connector for AddOn-Boards
- Already used in several beamtimes
- ... and by other experiments, e.g. for detector tests



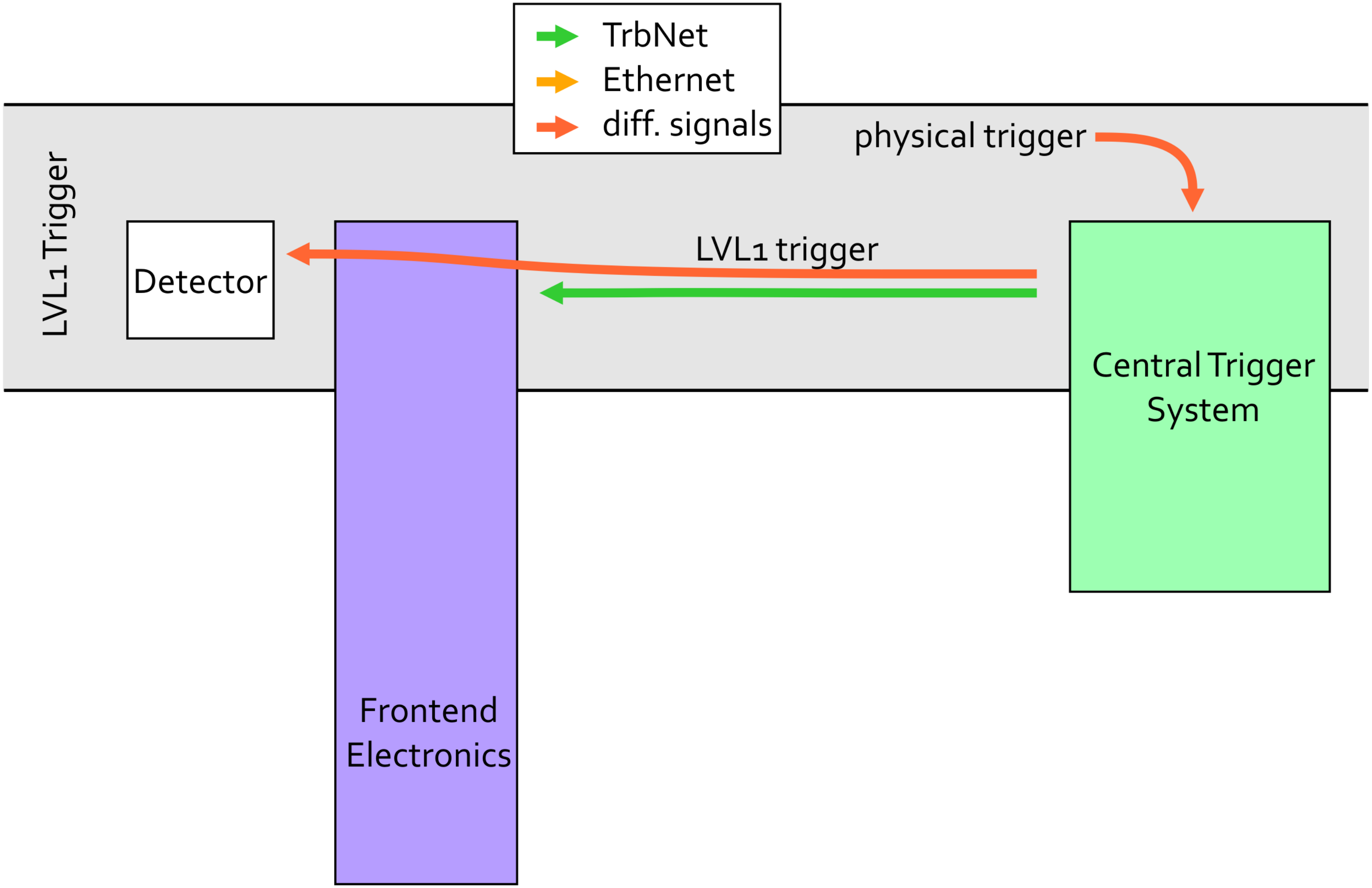
TRB - Trigger and Readout Board

- Lattice ECP2M-20 configures, controls and read data from FEE boards
- FEE and OEP need many voltages:
  5V, 3.3V, 1.2V, 1V, +3V, -3V
- All voltages are monitored, 4 are regulated on-board
- 2 Flash ROMs to store different FPGA designs
- Temperature sensor
- 250 Mbit/s optical transceiver
- … and all on a board measuring just 4 x 5 cm²!



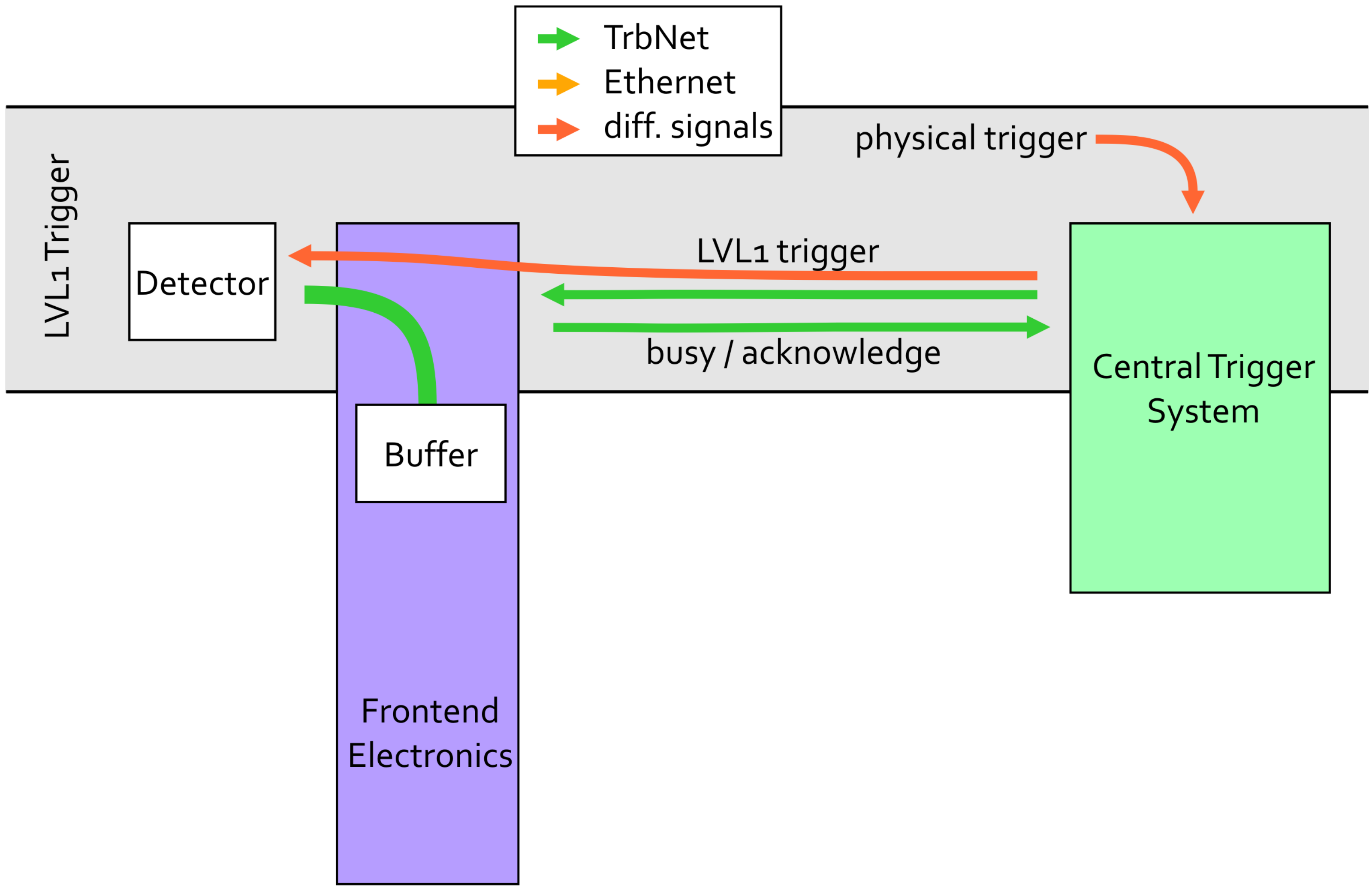
The Read-out System

- Trigger Source: Signal in Start, but not in Veto and TOF multiplicity above threshold
- Trigger is accepted, sent to FEE. Further triggers are blocked.



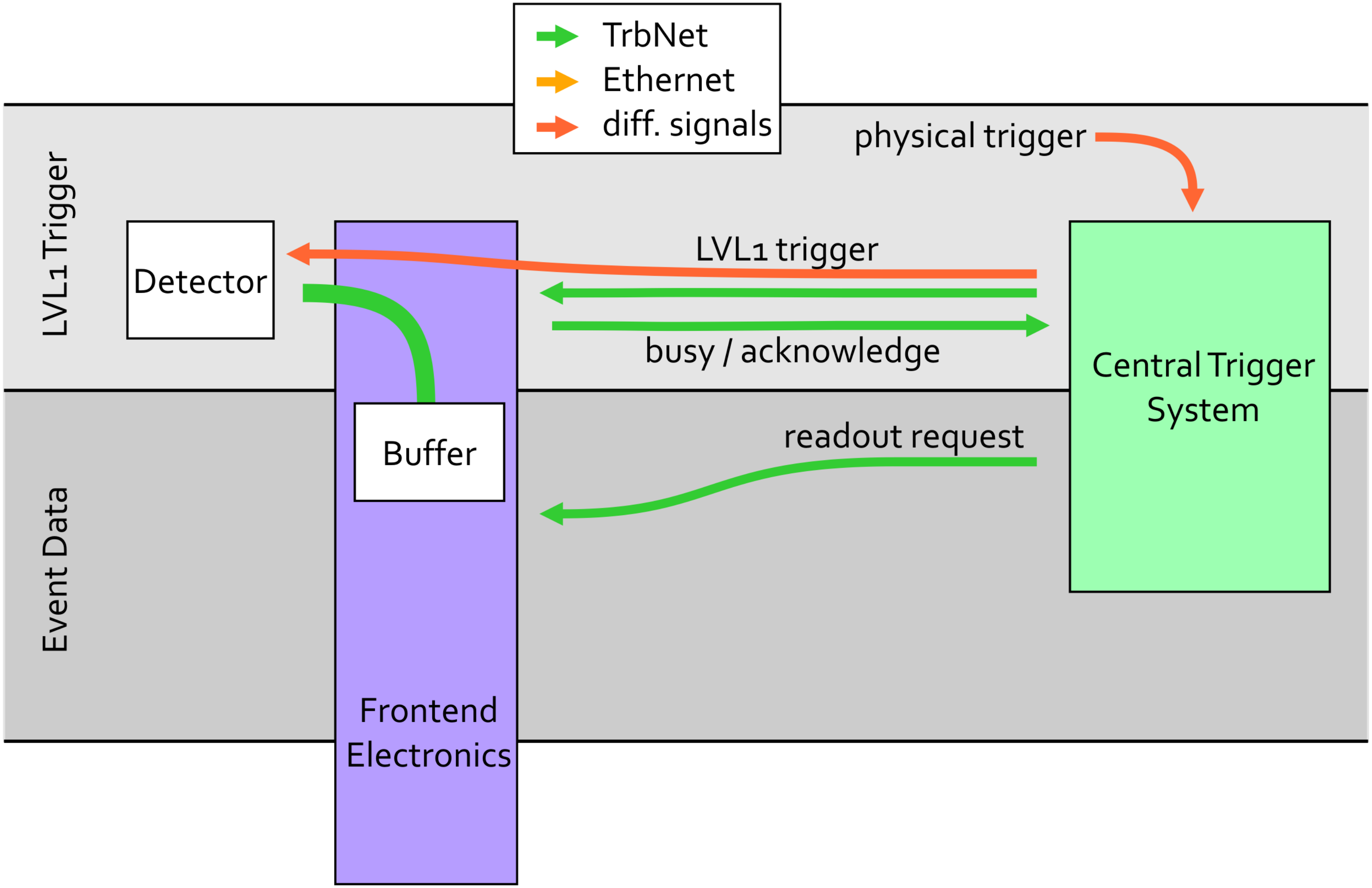
The Trigger Process

- **FEE collect data, send back acknowledge to CTS**



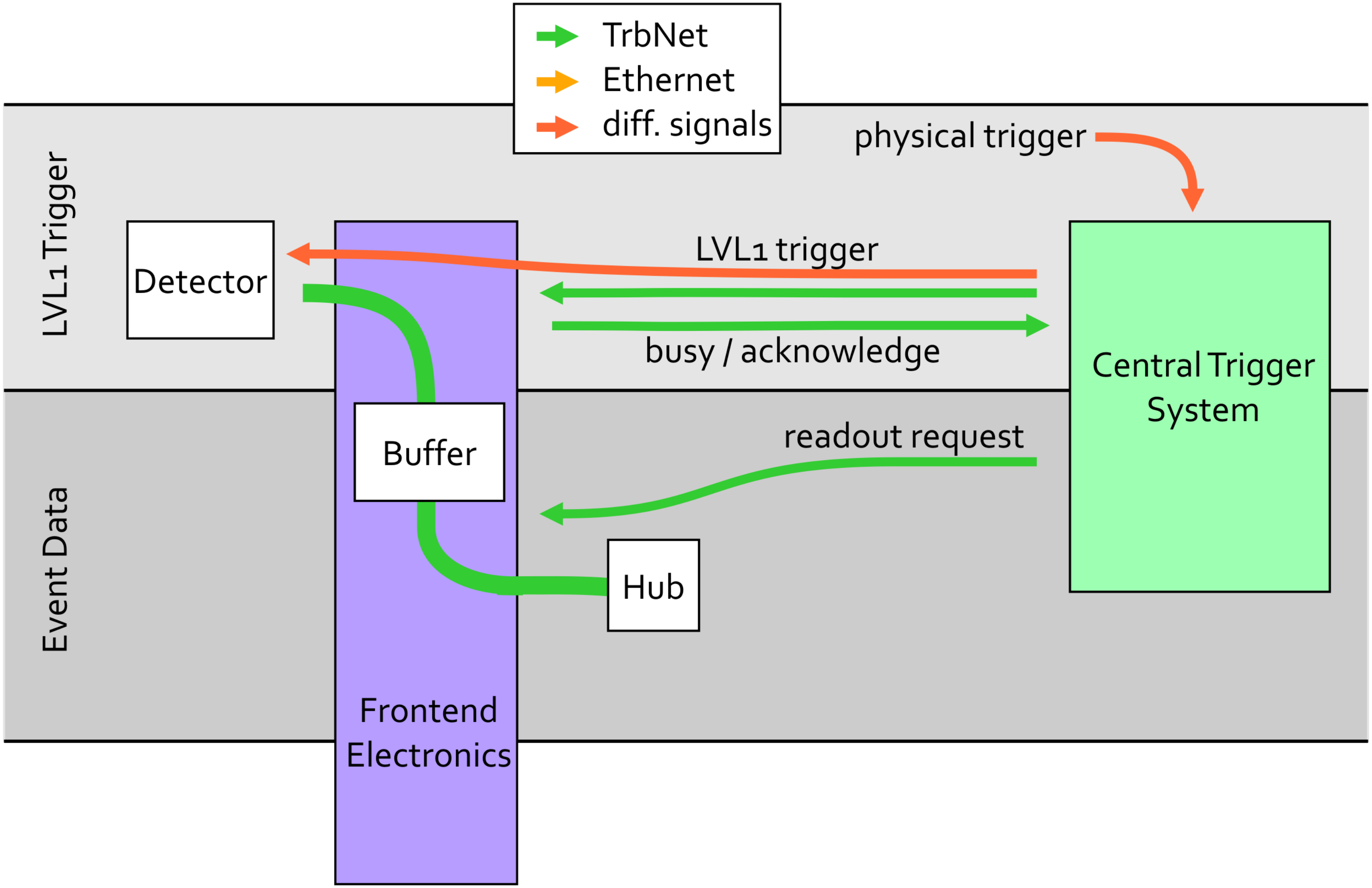
The Trigger Process

- Data is stored in internal buffers until read-out request arrives



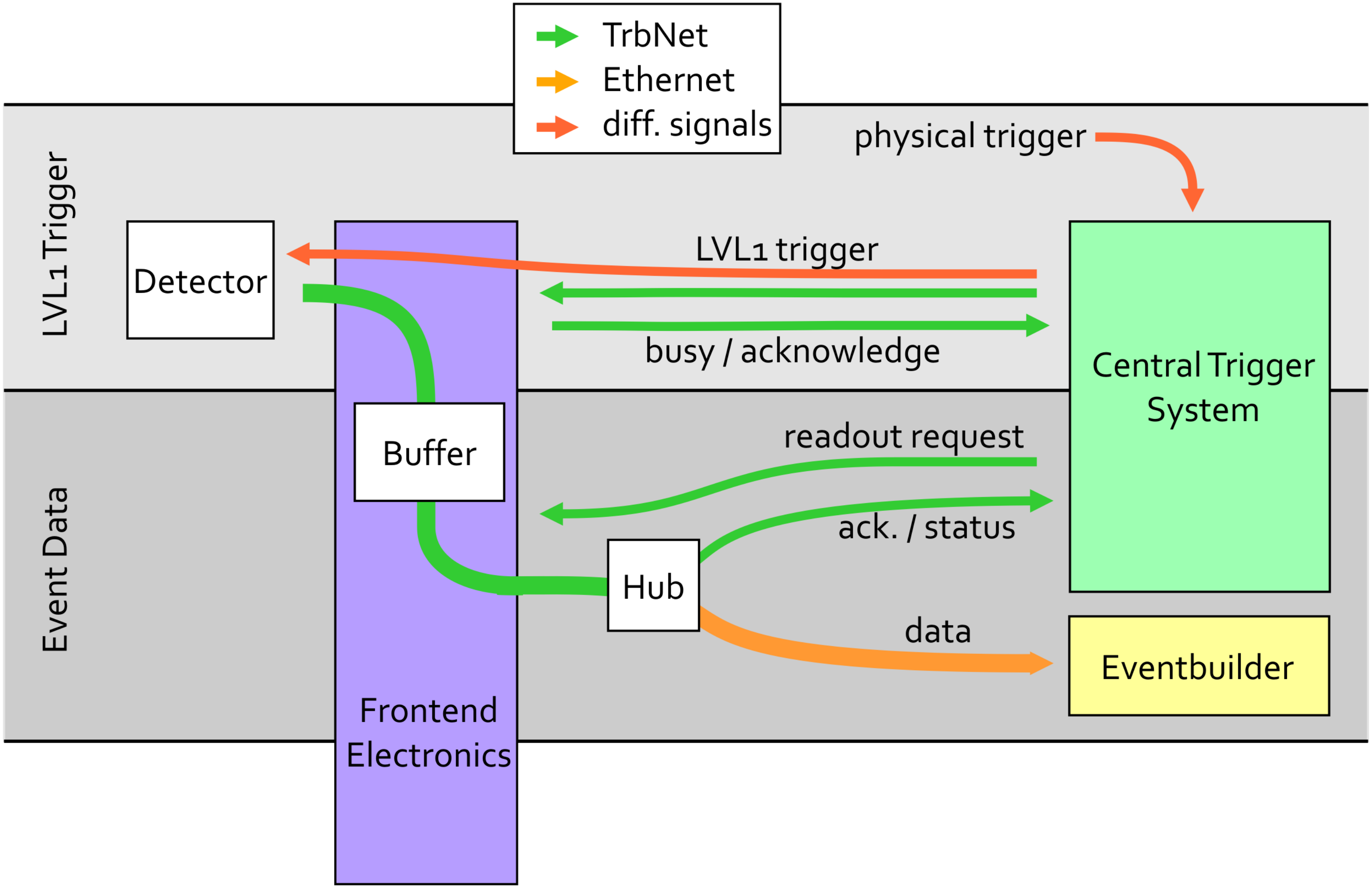
The Readout Process

- **Data is forwarded through the network**



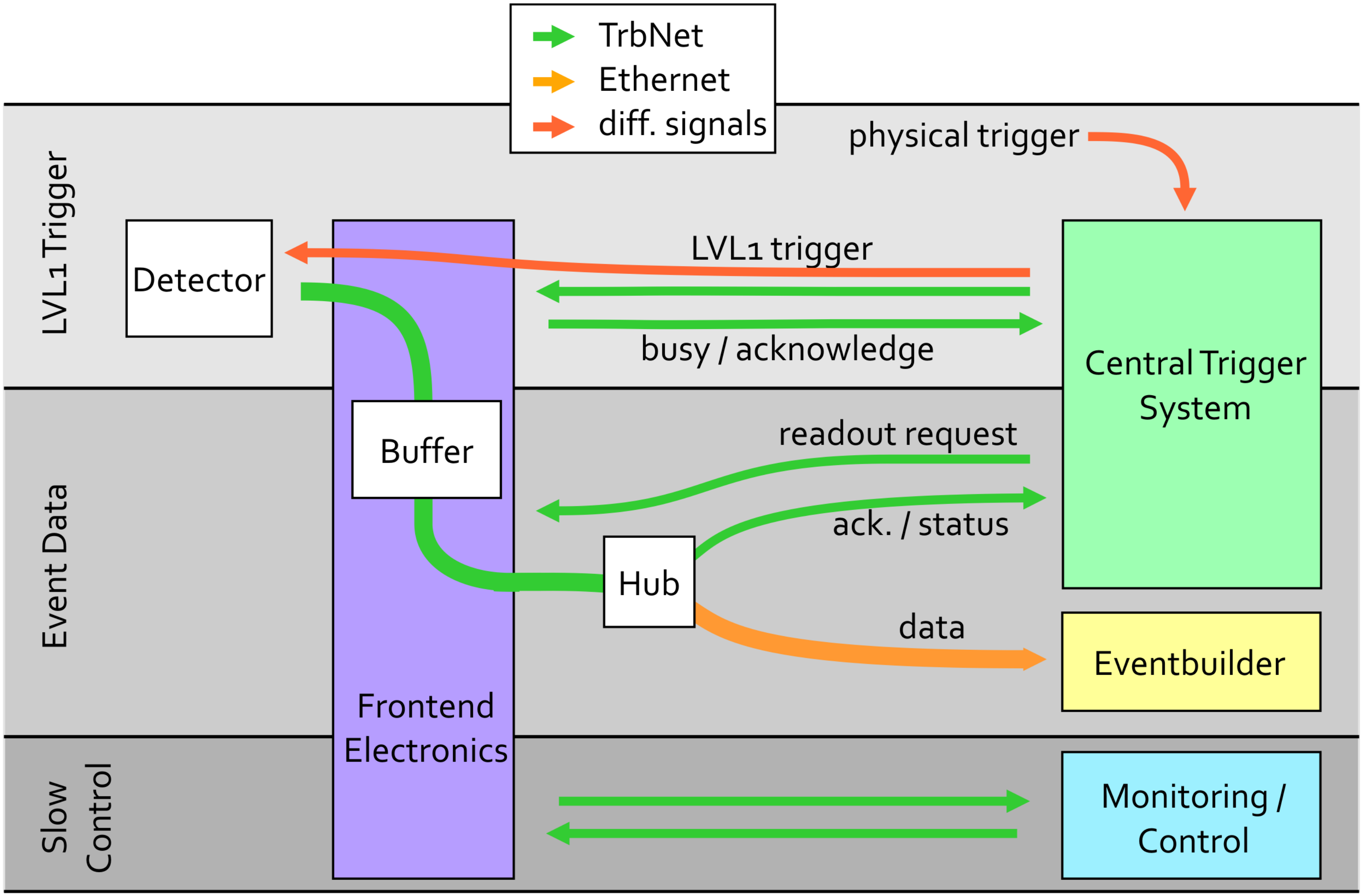
The Readout Process

- … and sent to server farm via Ethernet

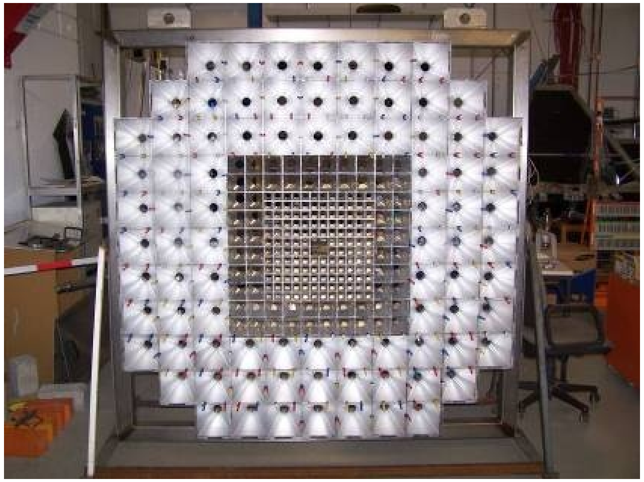


The Readout Process

- **All FEE are accessible with slow control - reading status & statistics, writing configuration**



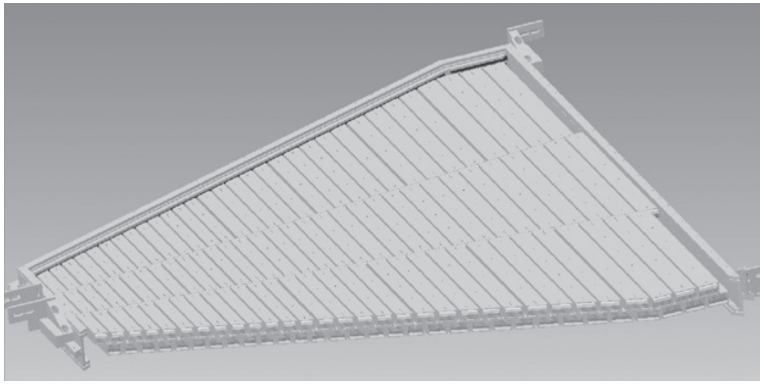
Slow Control

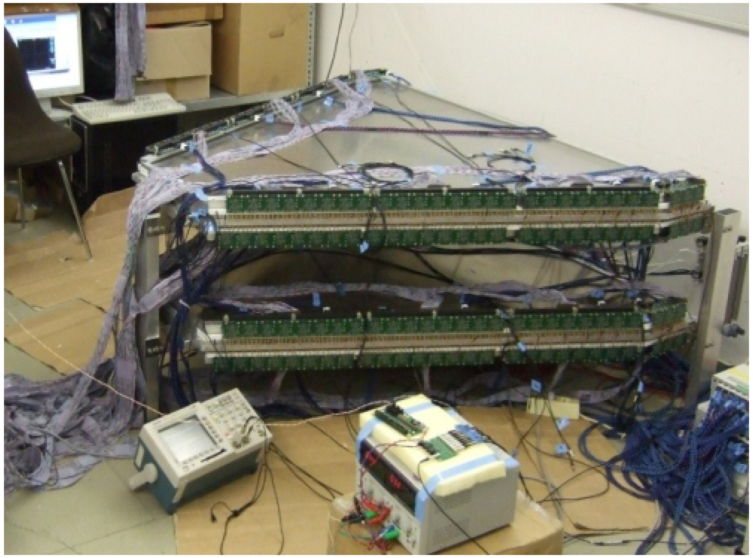


Forward Wall

- **Upgrade of detectors**
  - Resistive Plate Chambers (RPC)
    - Better time resolution in inner part of detector
    - Higher spatial resolution
  - Covering higher angular region with Forward Wall
    - Determine reaction plane
    - Measure reaction

Resistive Plate Chambers (RPC)





2008 - 2010: Hades Upgrade

- **We finished a commissioning beamtime just two days ago**
  - DAQ is operating stably
  - Performance is at or even above design values
  - Few issues with detectors have been identified & need to be solved

- **Production beamtime Au + Au @ 1.25 AGeV is scheduled for the beginning of next year**

2010	Comissioning: **Au + Ca, Ni, Pb, U**

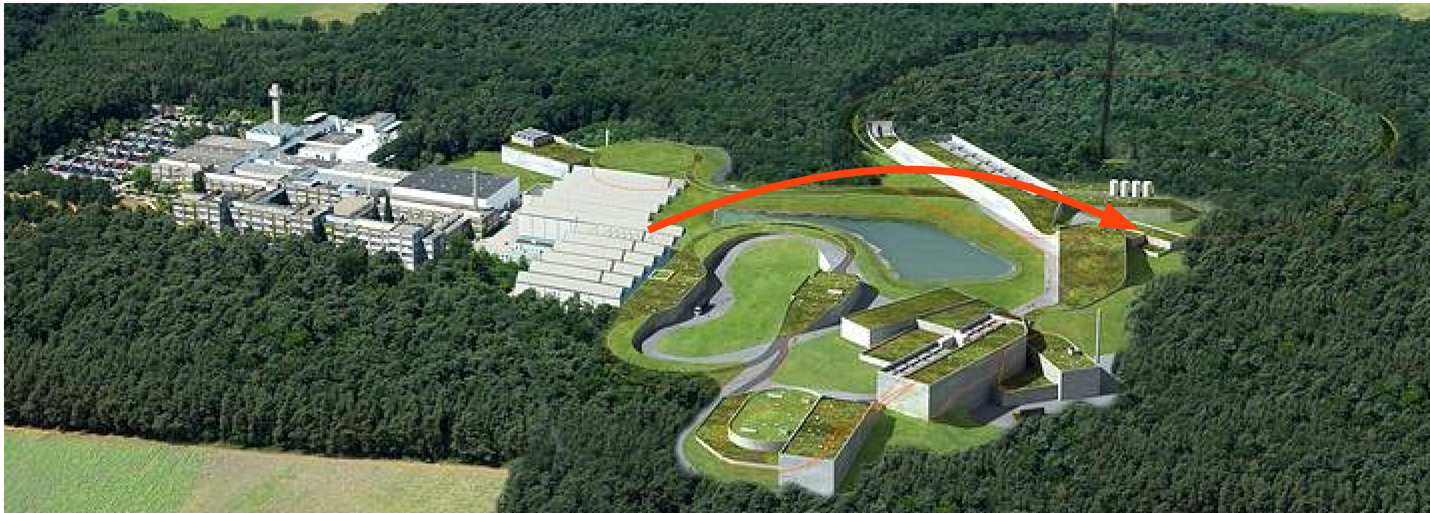
2002	**C + C 2 AGeV**
2004	**C + C 1 AGeV**
2004	**p + p 2.2 GeV**
2005	**Ar + KCl 1.75 AGeV**
2006	**p + p 1.25 GeV**
2007	**p + p 3.5 GeV** **d + p 1.25 AGeV**
2008	**p + Nb 3.5 GeV**

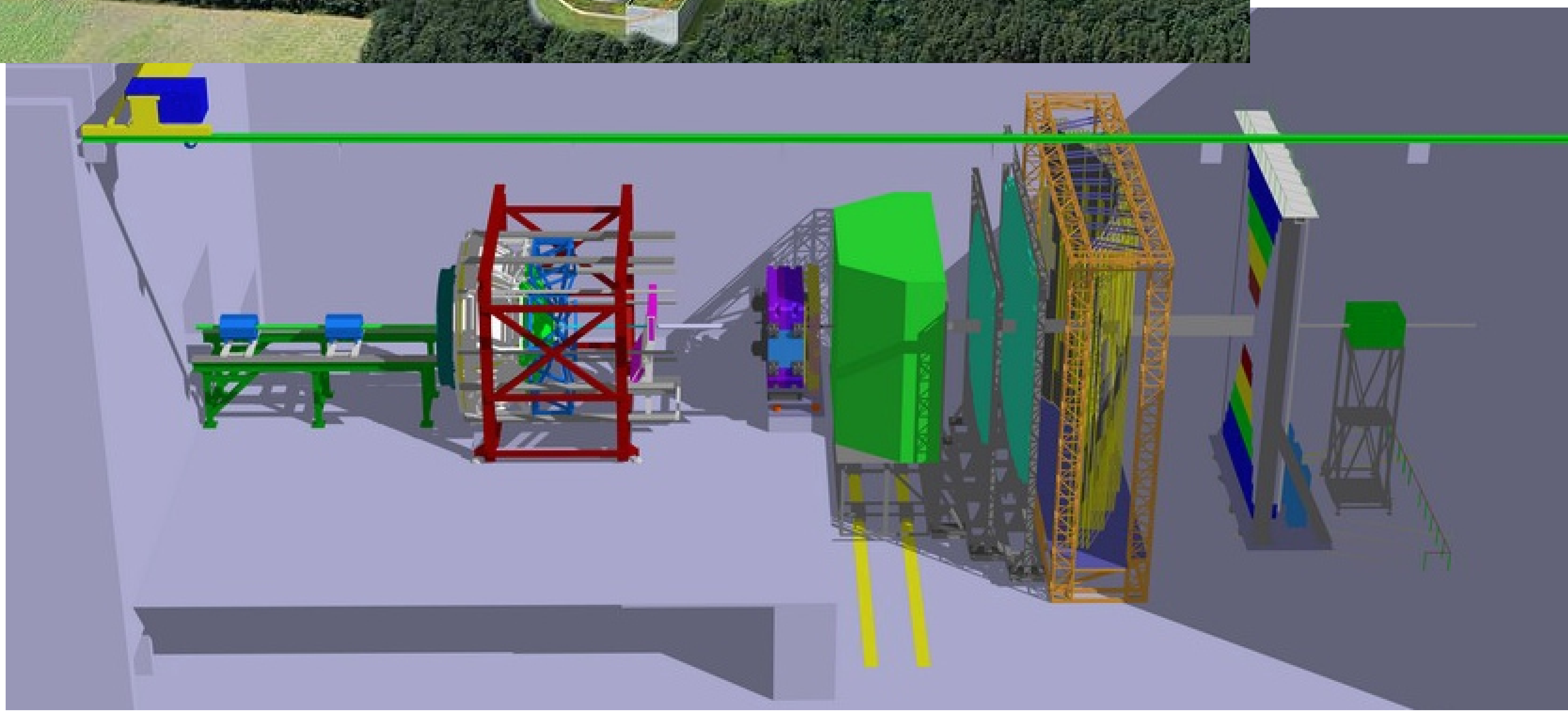
2010	Comissioning: **Au + Ca, Ni, Pb, U**

2011	**Au + Au 1.25 AGeV**

2012 - 2016	**Ni + Ni, Ag + Ag, Au + Au,** **p + π, N + π**

The Future of HADES





The Future of HADES

HADES

GOETHE UNIVERSITÄT FRANKFURT AM MAIN

The HADES Experiment at GSI

HGS-HIRe for FAIR
Helmholtz Graduate School for Hadron and Ion Research

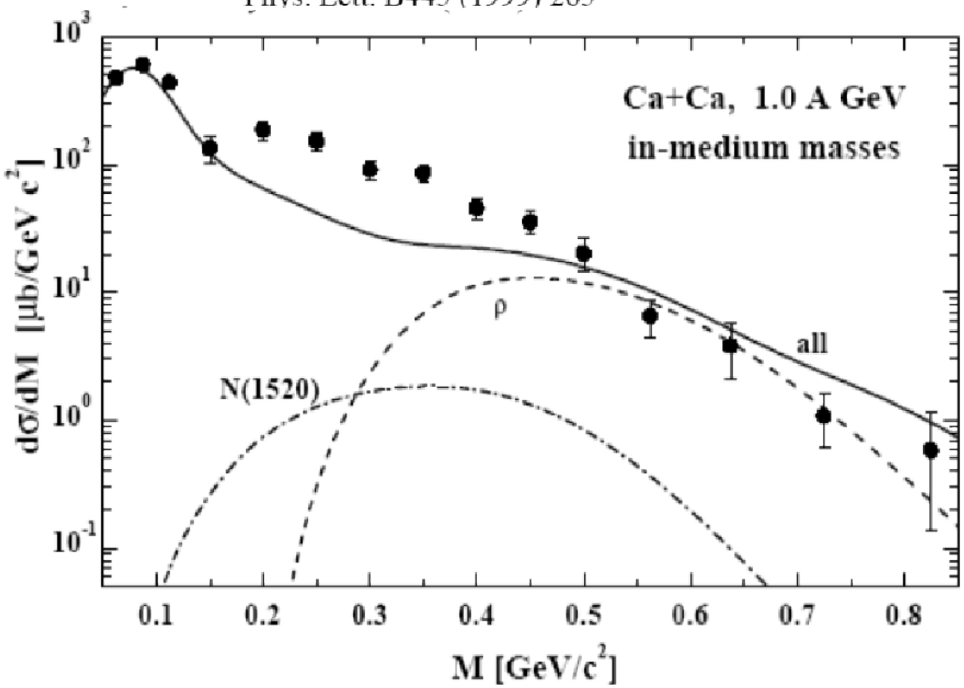
GSI

More slides

1997: DLS @ Bevalac/LBL
Di-leptons in C+C and Ca+Ca collisions
Finds excess that can not be explained by theoretical models

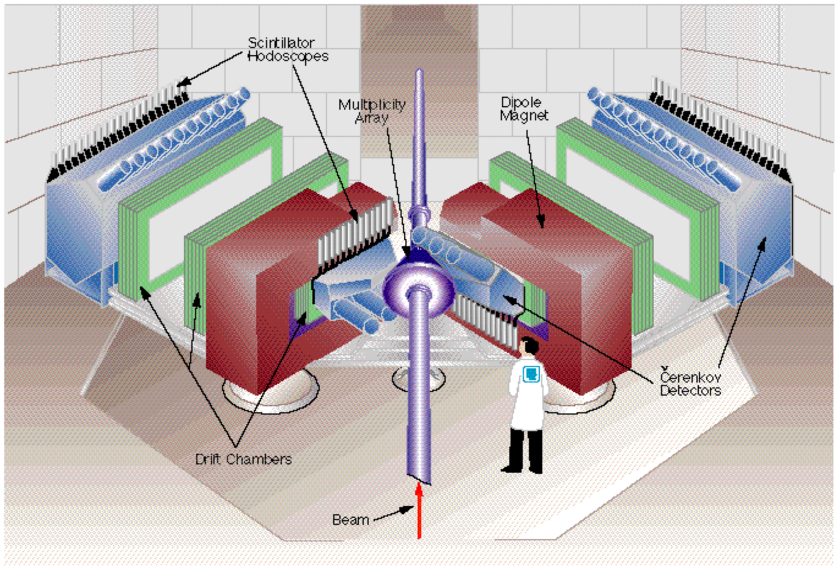
Calculation: **E.L.Bratkovskaya et al.**

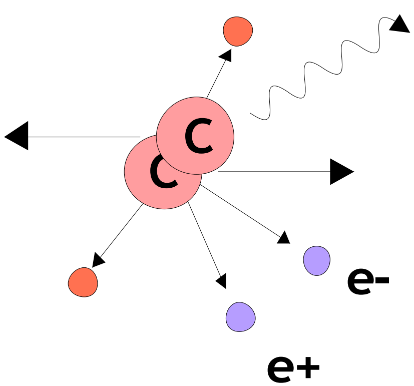
Phys. Lett. B445 (1999) 265



DLS Data: **R.J. Porter et al.:** Phys.Rev.Lett. 79 (1997) 1229

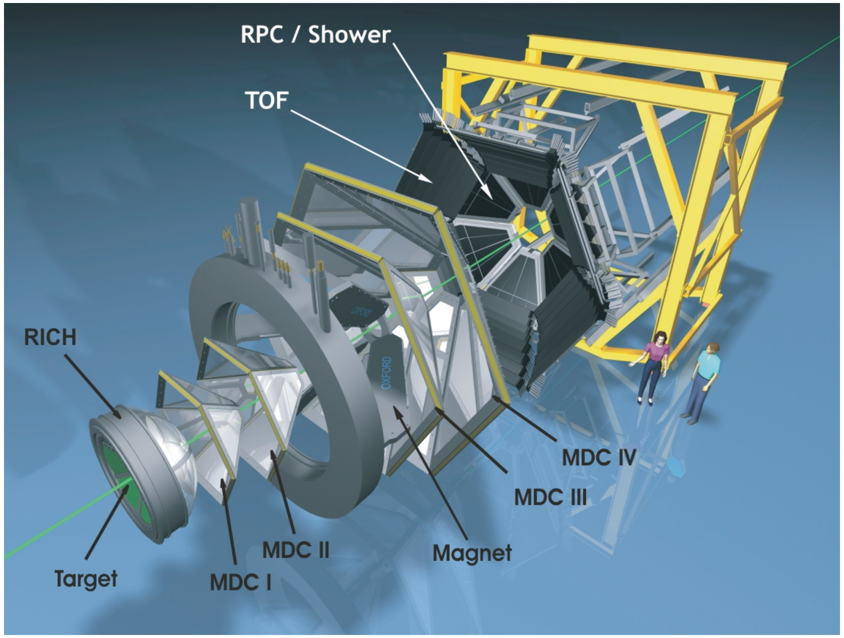
DiLepton Spectrometer



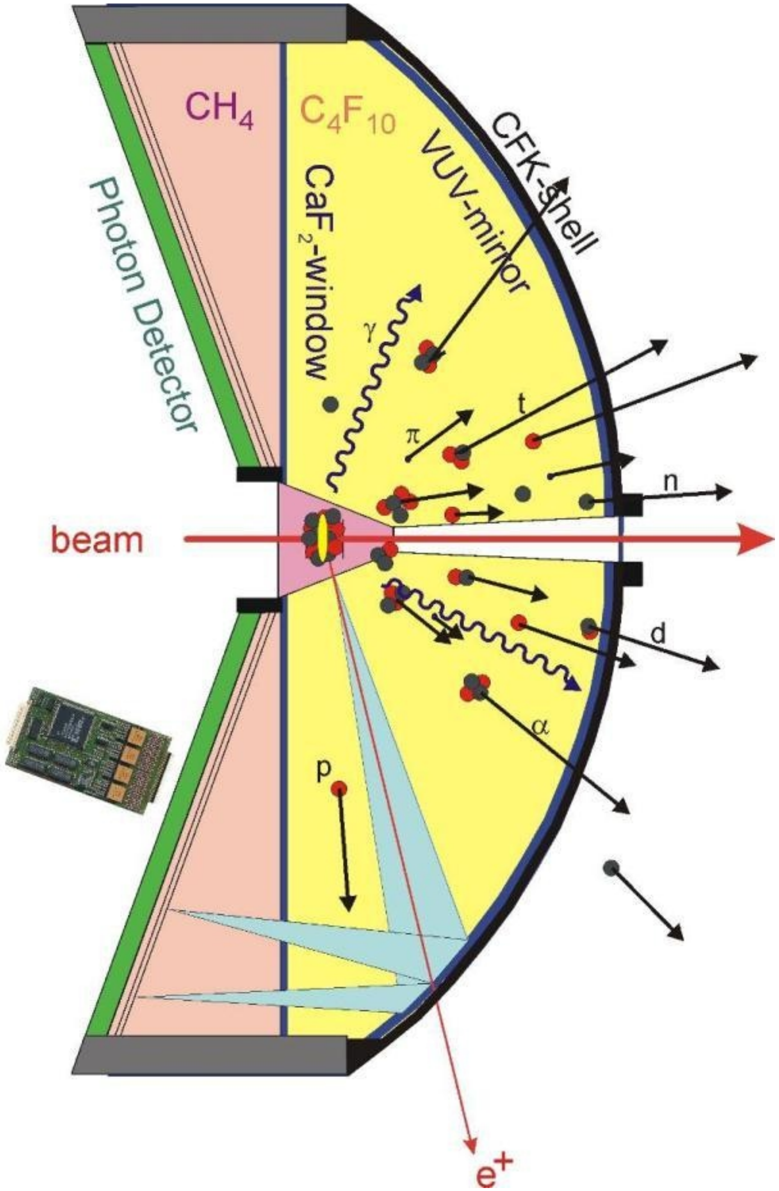


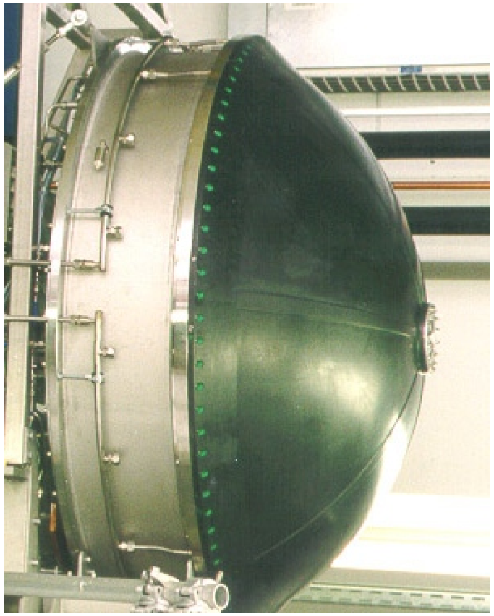
DLS

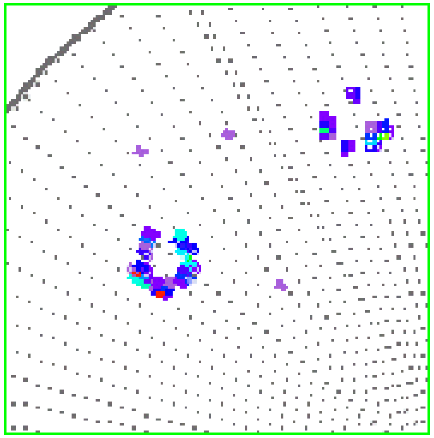
2002 - 2008: HADES @ GSI
Remeasures the same collisions



The next step







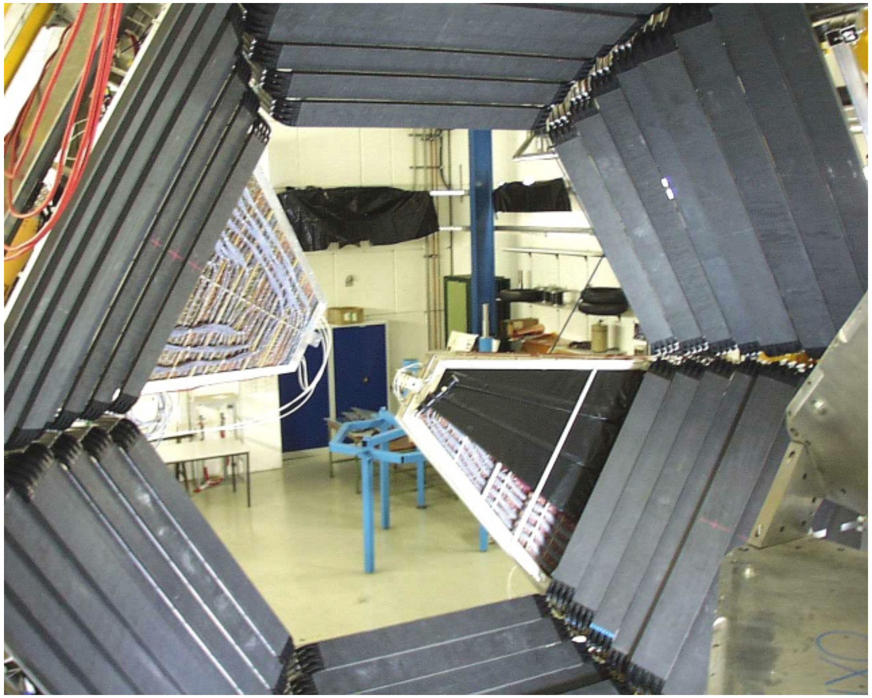
Electron identification

Only particles with γ above 18 produce Cherenkov light (at SIS energies, only electrons)

A mirror reflects the light to 30,000 photon detectors

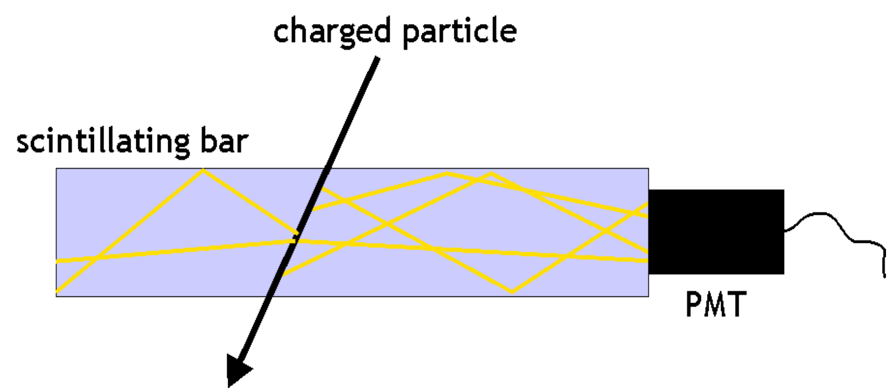
The Ring Imaging Cherenkov Detector (RICH)

Scintillating bars produce light measured by photo-multipliers on both ends



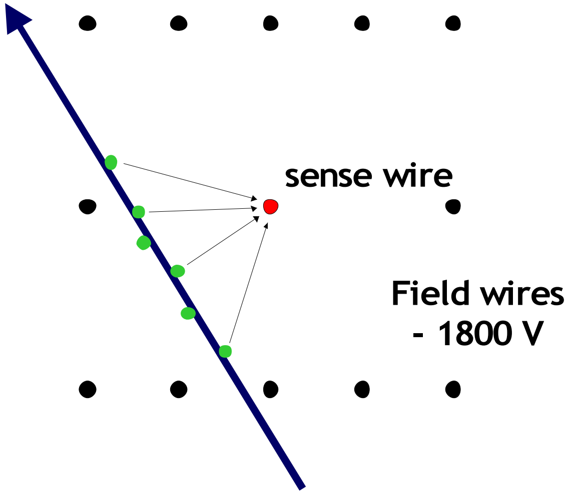
Measurements:

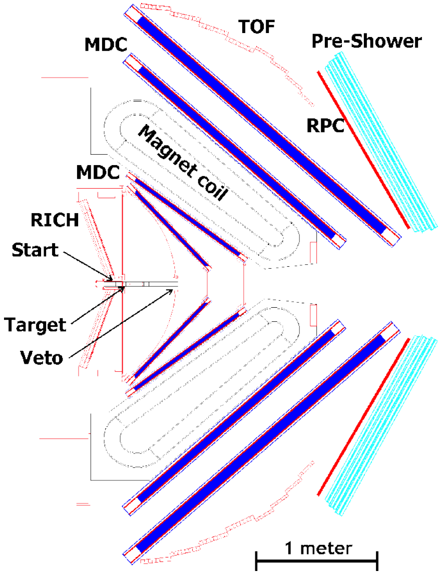
- Time-of-flight (resolution Δt = 100 ps)
- Position (Δx = 2 -3 cm)
- Energy loss in scintillator (dE/dx)
- 384 channels

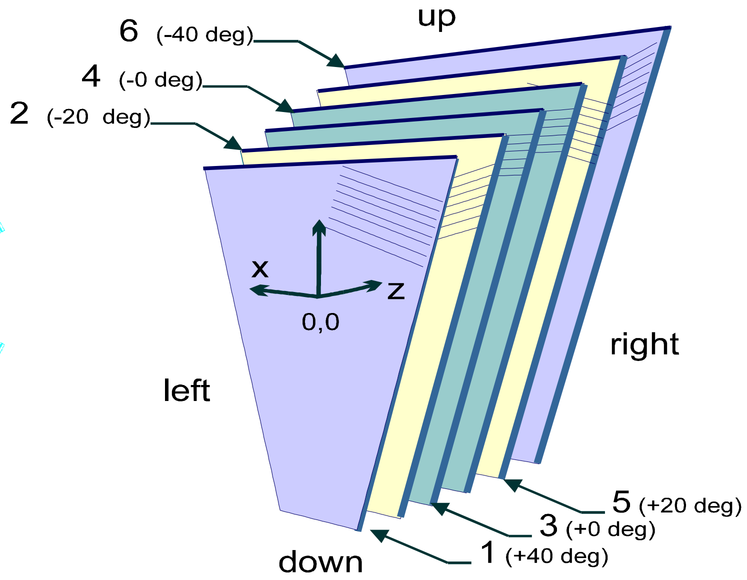


Time-of-Flight Wall (TOF)

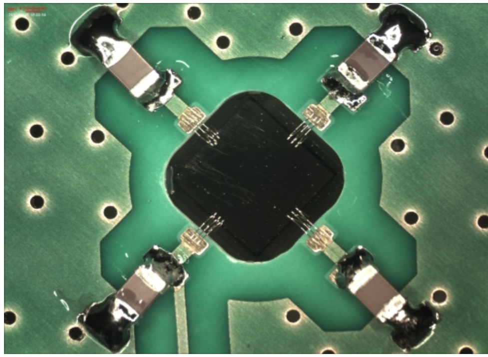
- 24 chambers, 12 before, 12 behind the magnet
-

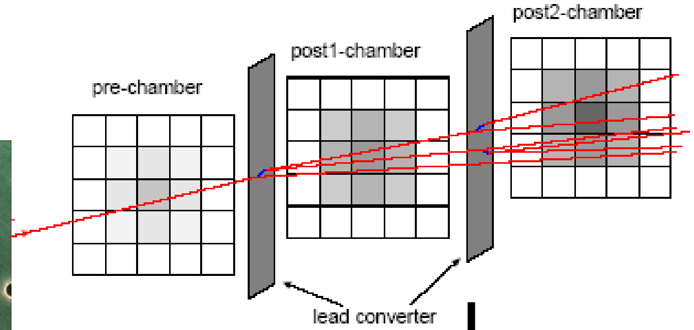


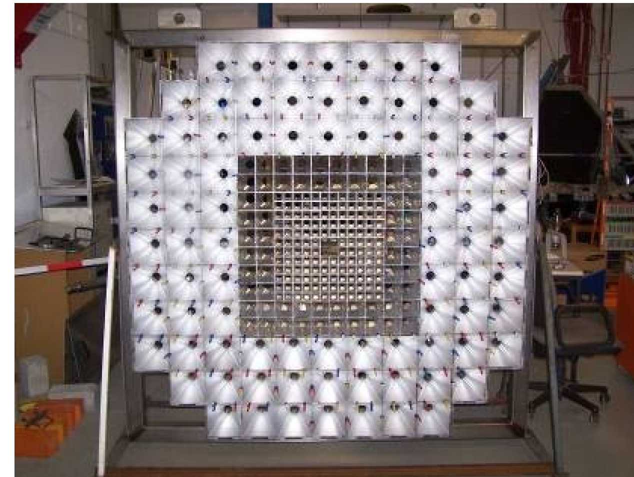


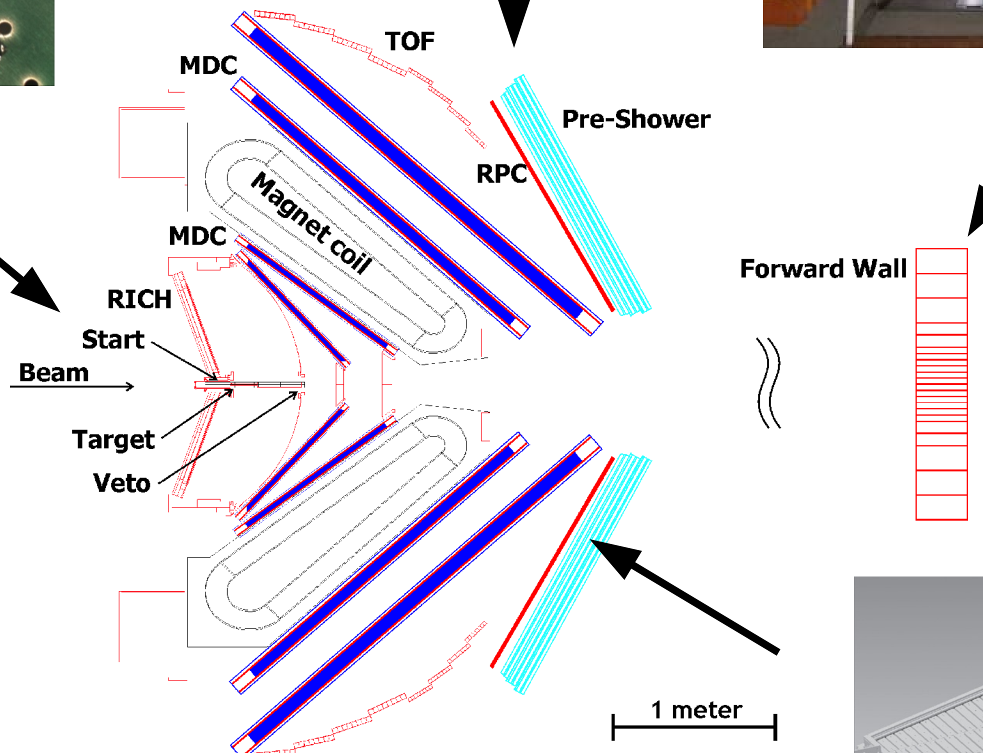


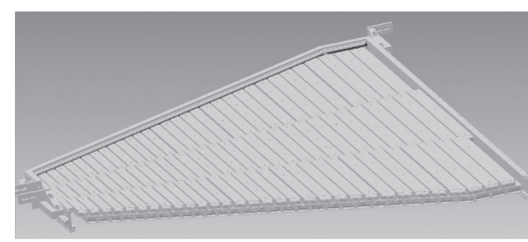
Multiwire Drift Chambers (MDC)



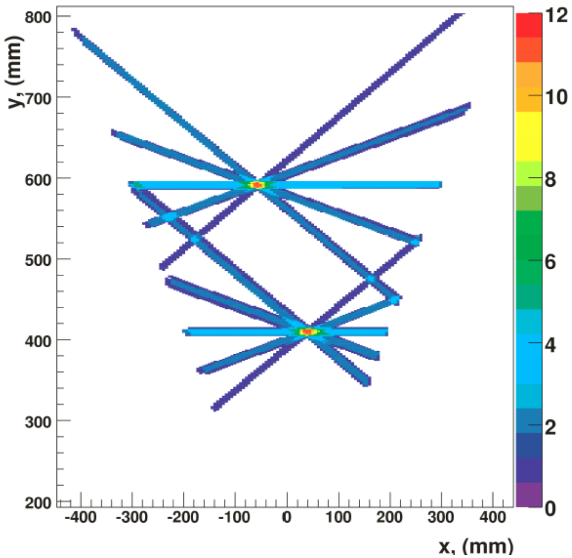

pre-chamber
post1-chamber
post2-chamber
lead converter

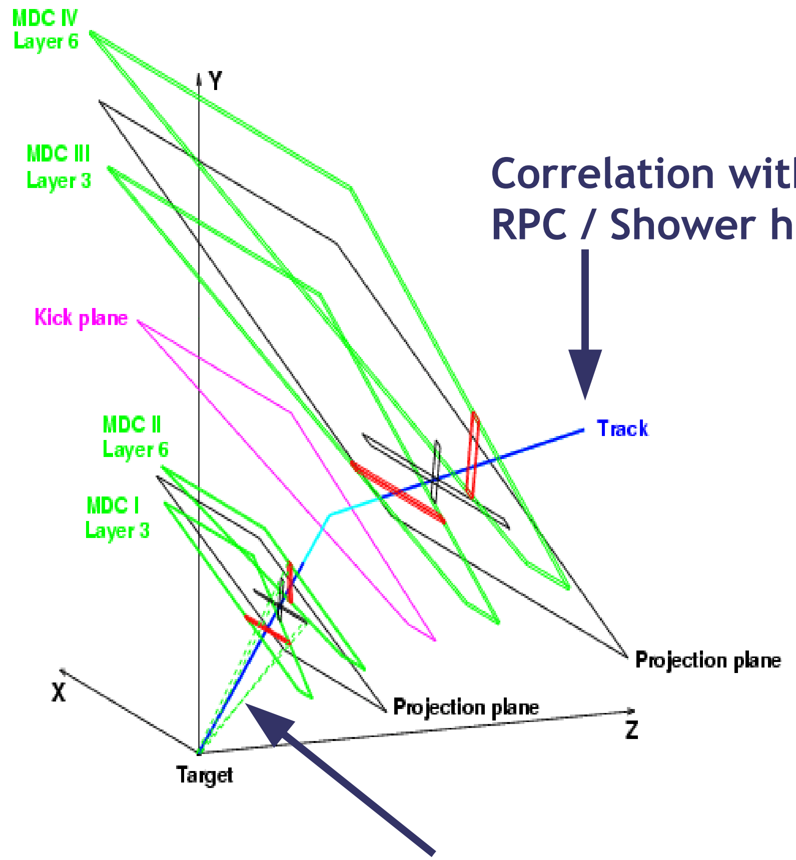



TOF
MDC
Pre-Shower
RPC
Magnet coil
MDC
Forward Wall
RICH
Start
Beam
Target
Veto
1 meter



Detectors

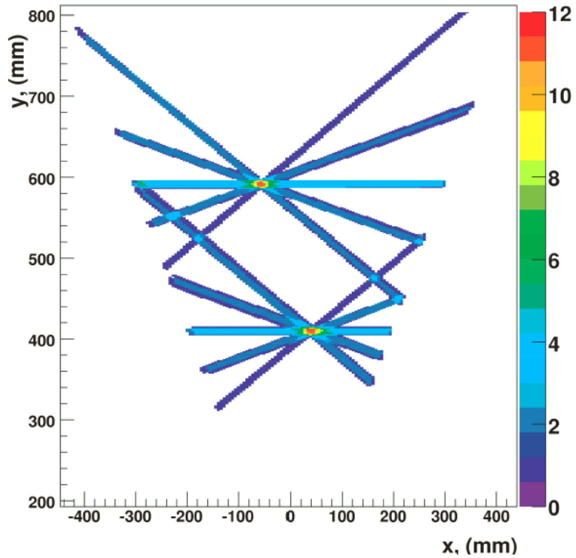


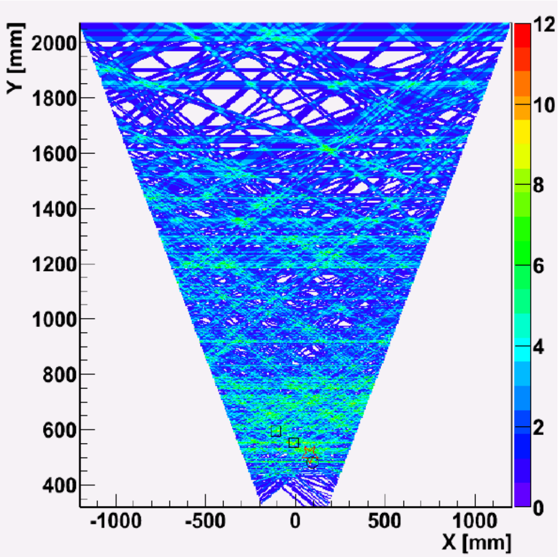


Correlation with TOF / RPC / Shower hit

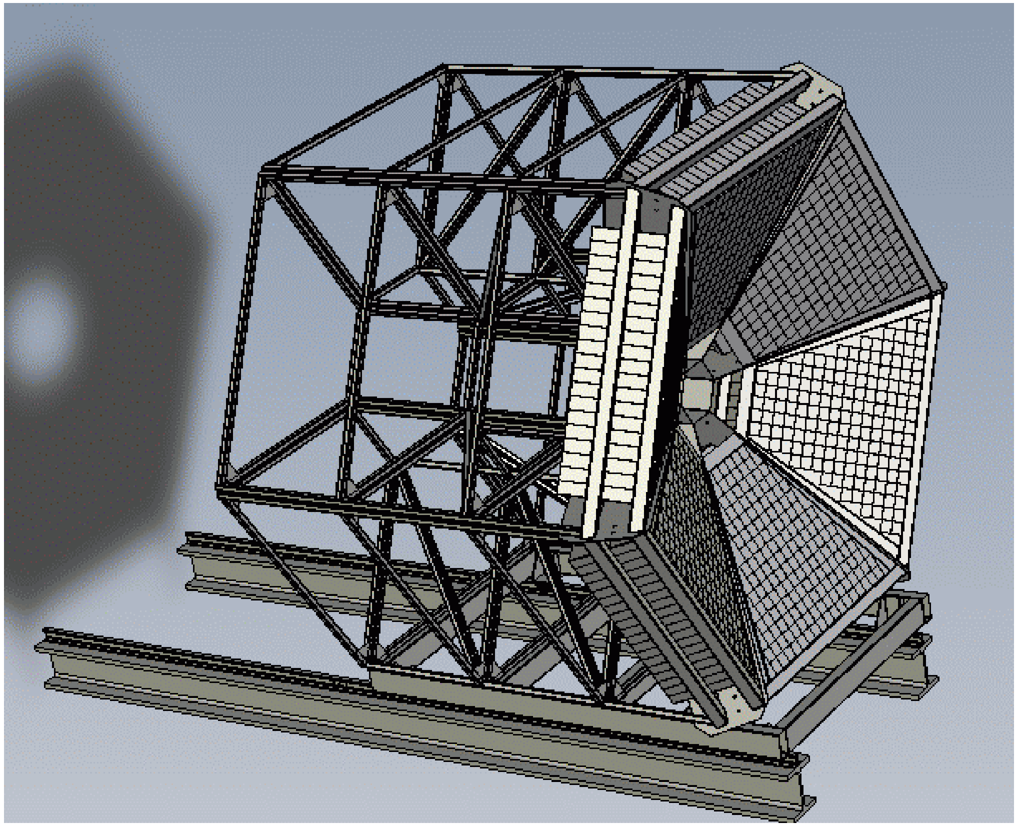
Correlation with RICH rings

Tracking


y, (mm)
x, (mm)
800
700
600
500
400
300
200
-400
-300
-200
-100
0
100
200
300
400
12
10
8
6
4
2
0


Y [mm]
X [mm]
2000
1800
1600
1400
1200
1000
800
600
400
-1000
-500
0
500
1000
12
10
8
6
4
2
0

Tracking

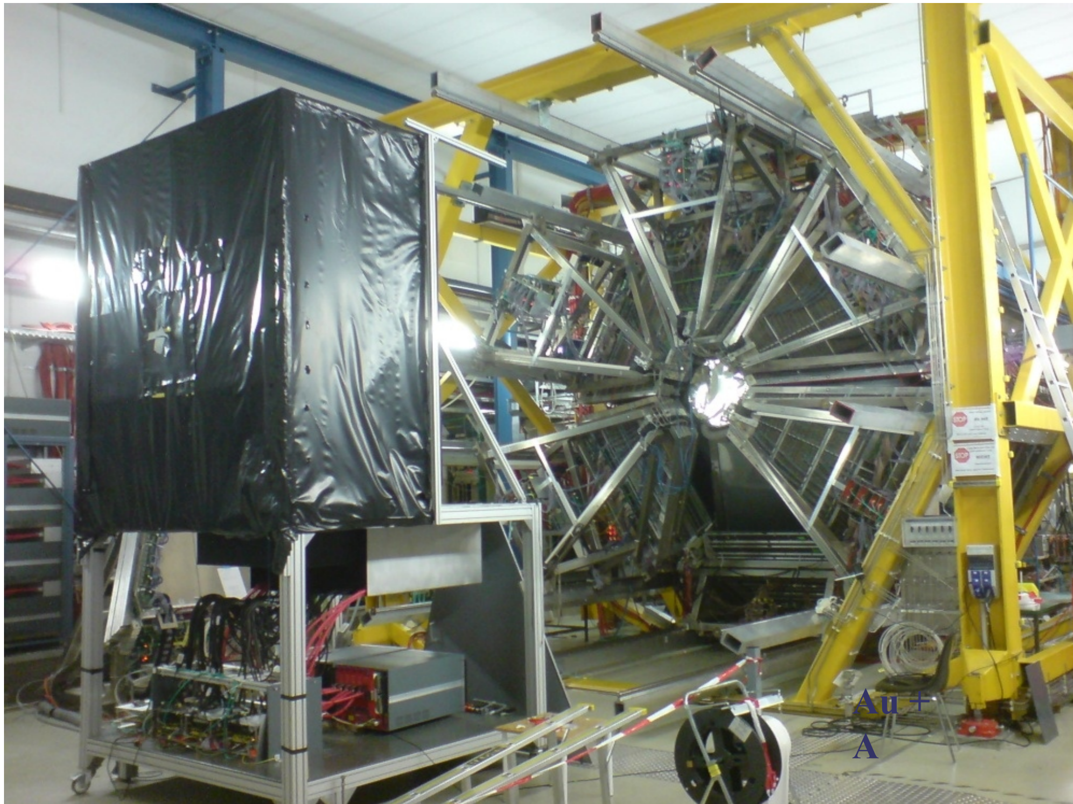


- 1000 channel lead glass calorimeter
- Replaces pre-Shower detector
- Provides better particle ID at high energies

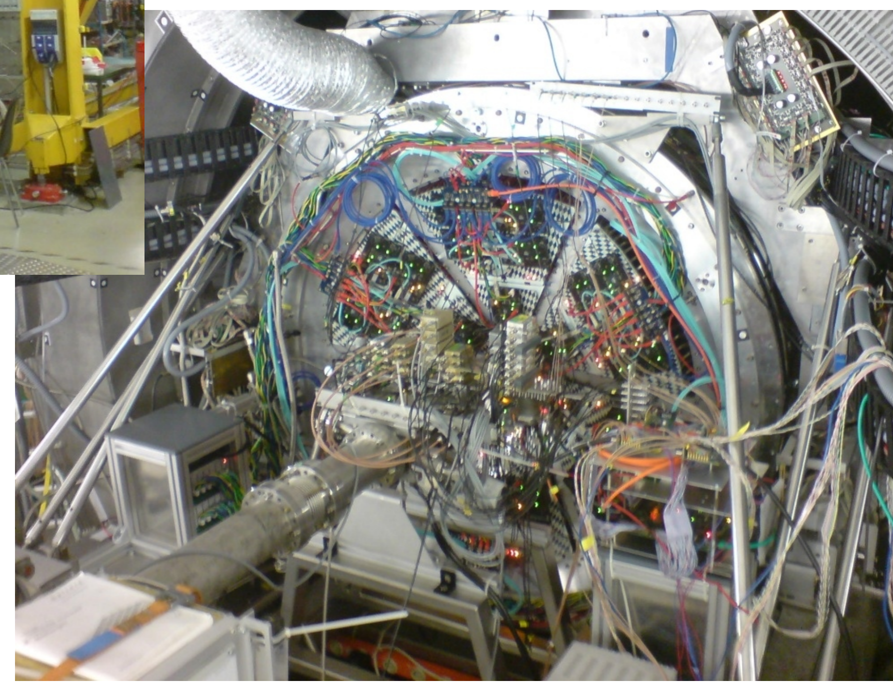
2012 - 2016	Ni + Ni, Ag + Ag, Au + Au, p + π, N + π

> 2016	2 – 8 AGeV @ SIS100 / FAIR

The Future of HADES



2002	C + C 2 AGeV
2004	C + C 1 AGeV
2004	p + p 2.2 GeV
2005	Ar + KCl 1.75 AGeV
2006	p + p 1.25 GeV
2007	p + p 3.5 GeV d + p 1.25 AGeV
2008	p + Nb 3.5 GeV



HADES “in reality”