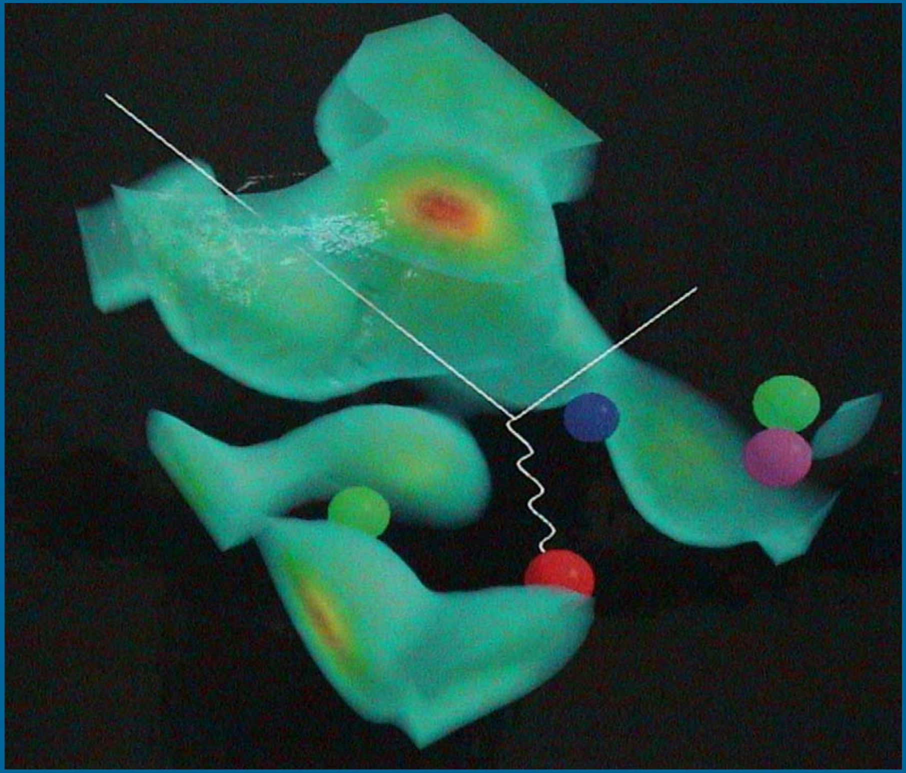
PANDA: Experiments to Study the Properties of Charm in Dense Hadronic Matter

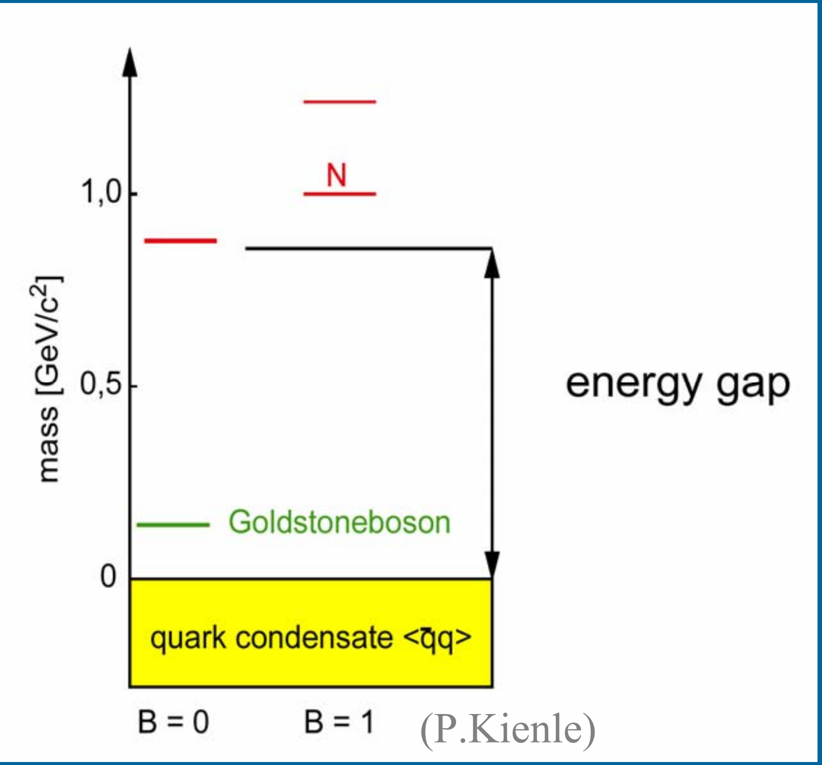
- Overview of the PANDA Pbar-A Program
- The Pbar Facility
- The PANDA Detector
- Selected Simulation Results

Why Are Hadrons So Heavy?



Hadron Masses

Protons = (uud) ? $\begin{cases} 2M_u + M_d \sim 15\ \text{MeV}/c^2 \\ M_p = 938\ \text{MeV}/c^2 \end{cases}$



no low mass hadrons (except π, K, η)

spontaneously broken chiral symmetry

Spontaneous Breaking of Chiral Symmetry

Although the QCD Lagrangian is symmetric, the ground state need not be. (e.g. Fe below T_{Curie})

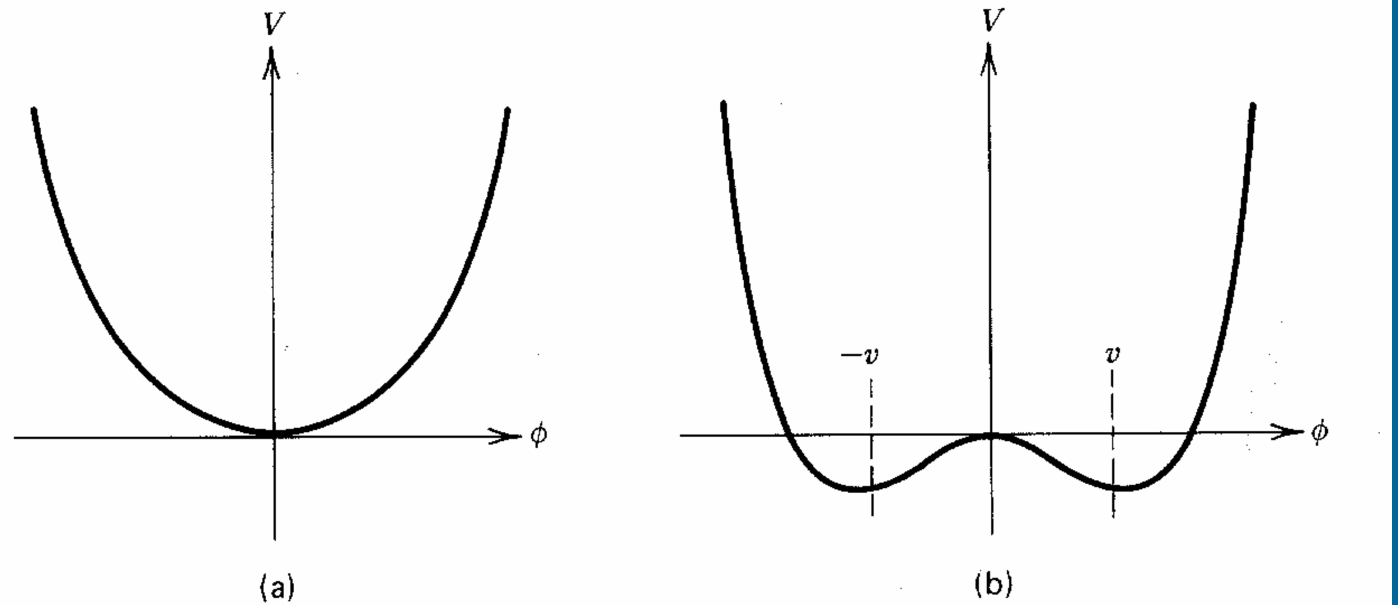
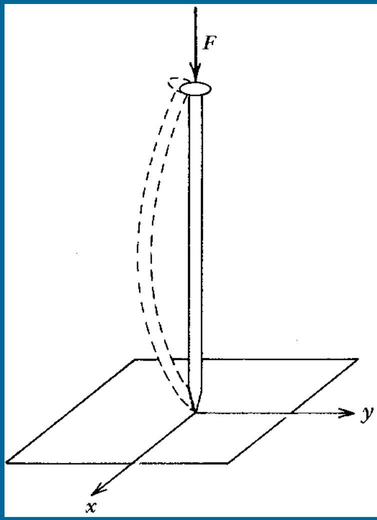


Fig. 14.3 The potential $V(\phi) = \frac{1}{2}\mu^2\phi^2 + \frac{1}{4}\lambda\phi^4$ for (a) $\mu^2 > 0$ and (b) $\mu^2 < 0$, and $\lambda > 0$.

Example:



Quark Condensate

The QCD vacuum is not empty $\langle q\bar{q} \rangle \neq 0$

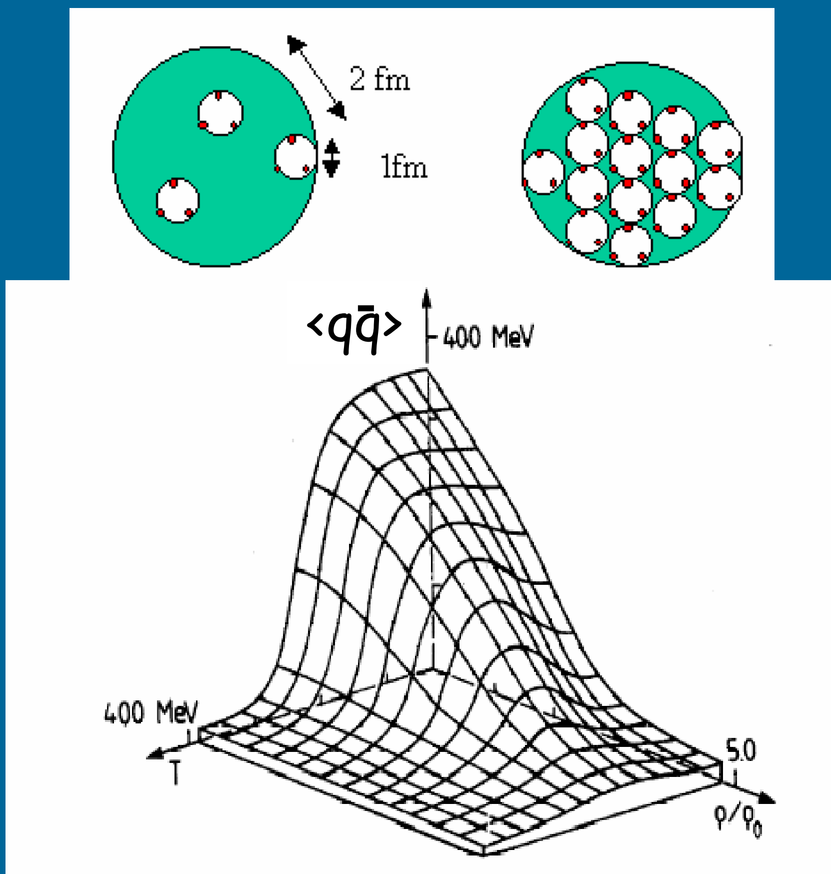
Hadron masses are generated by the strong interaction with <q$\bar{q}$> (also with gluon condensate)

The density of the quark condensate will change as a function of temperature and density in nuclei.

This should lead to modifications of the hadron's spectral properties.

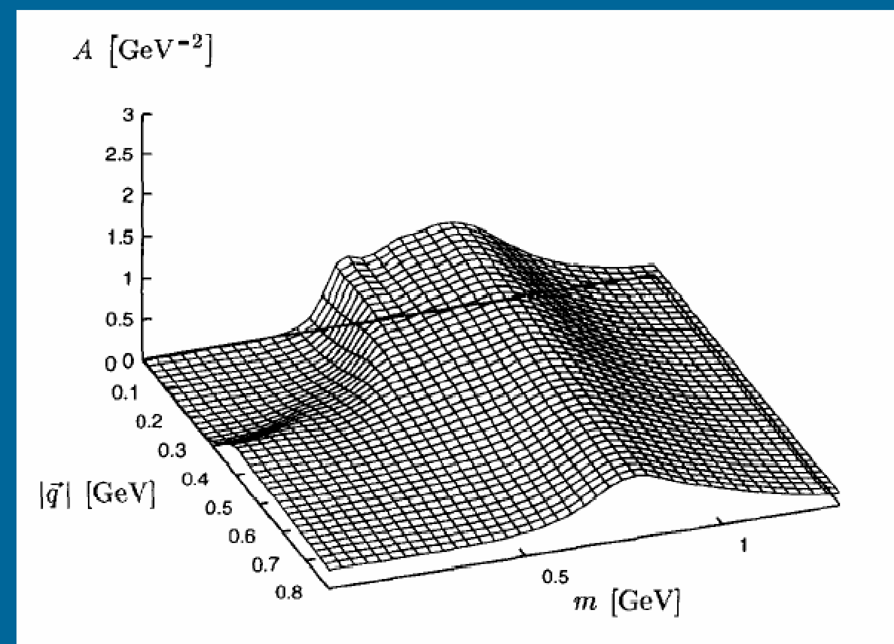
Hadrons in the Nuclear Medium

Reduction of <q̄q>



S.Klimt et al., Nucl. Phys. **A515**, 429 (1990).

Spectral functions



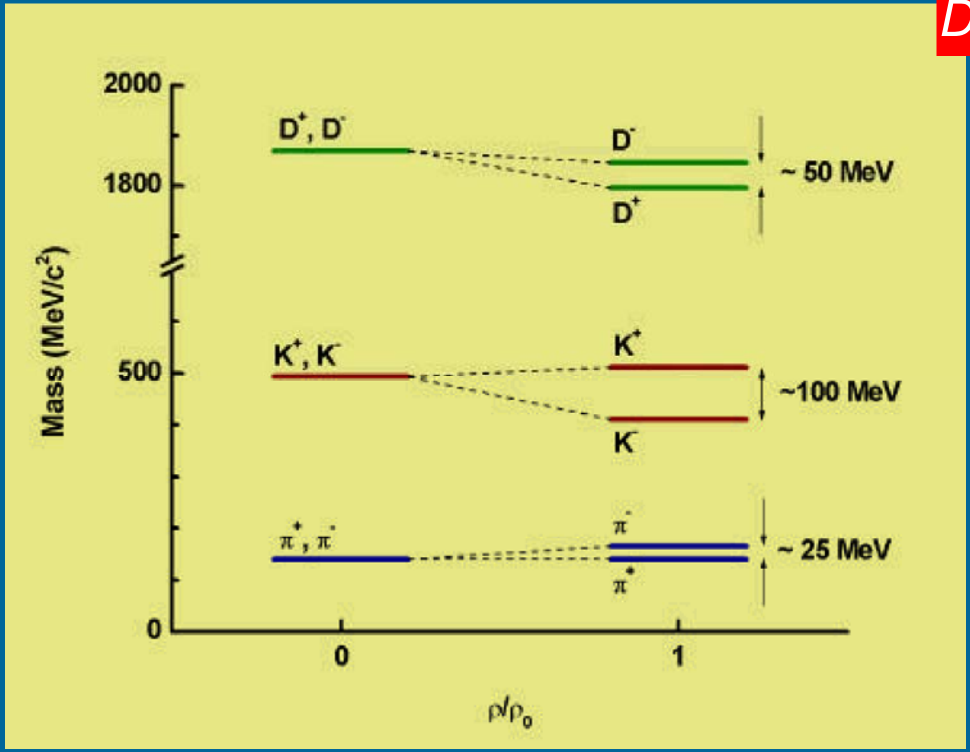
W.Peters et al., Nucl. Phys. **A632**, 109 (1998).

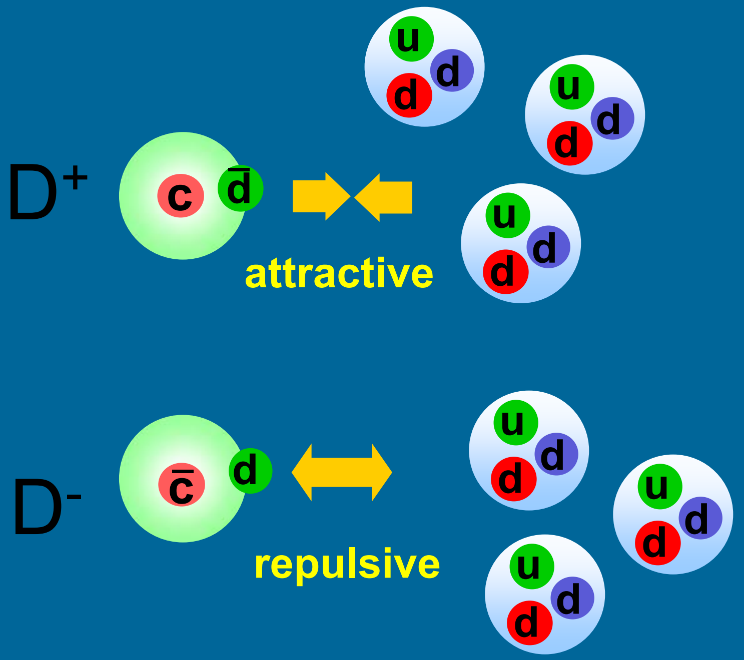
Hadron Production in the Nuclear Medium

Mass of particles may change in dense matter

$K^-(s\bar{u}):\ m_s/m_u \approx 40$

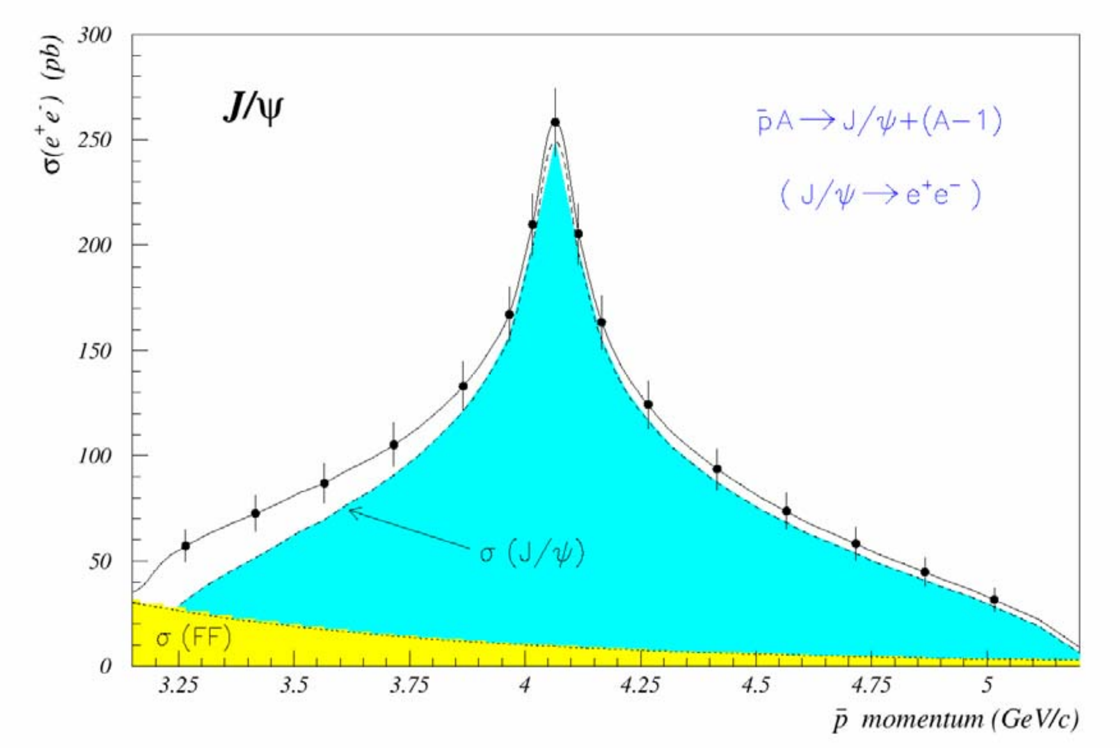
$D^+(c\bar{d}):\ m_c/m_d \approx 200 \Rightarrow$ **Quark atom**





J/Ψ Absorption in Nuclei

J/Ψ absorption cross section in nuclear matter
$\bar{p} + A \rightarrow J/\Psi + (A-1)$



Advantages of $\bar{p}$-A Reactions Compared to A-A

Much lower momentum for heavy produced particles (2 GeV for “free”)

(Effects are smaller at high momentum)

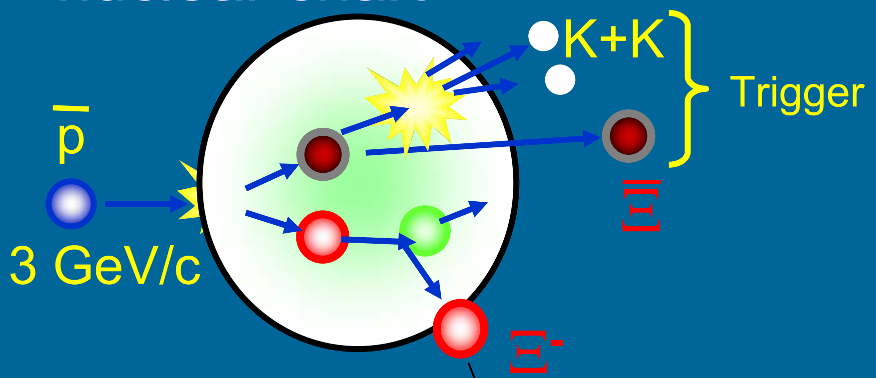
Open charm mass region (H atom of QCD) @HESR

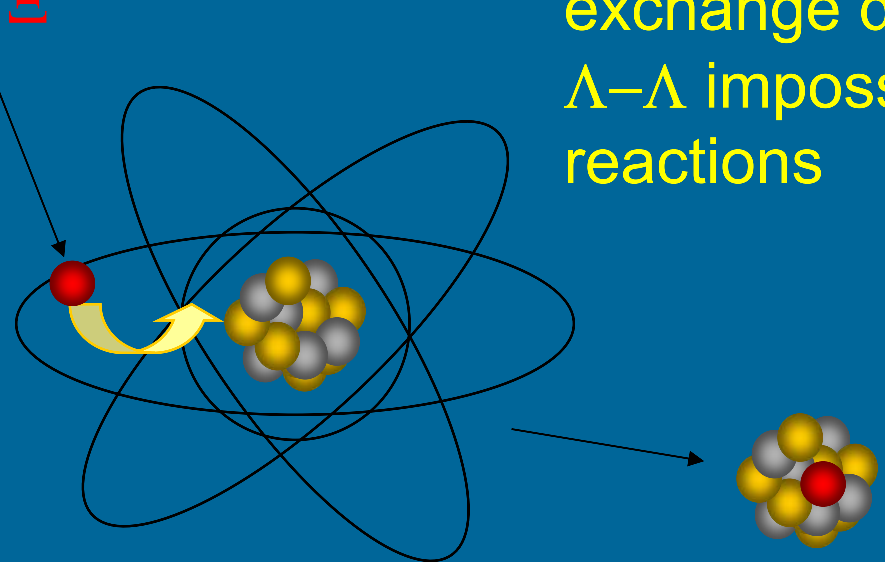
(single light quark)

Well defined nuclear environment (T and ρ)

Strange Baryons in Nuclear Fields

Hypernuclei open a 3rd dimension (strangeness) in the nuclear chart

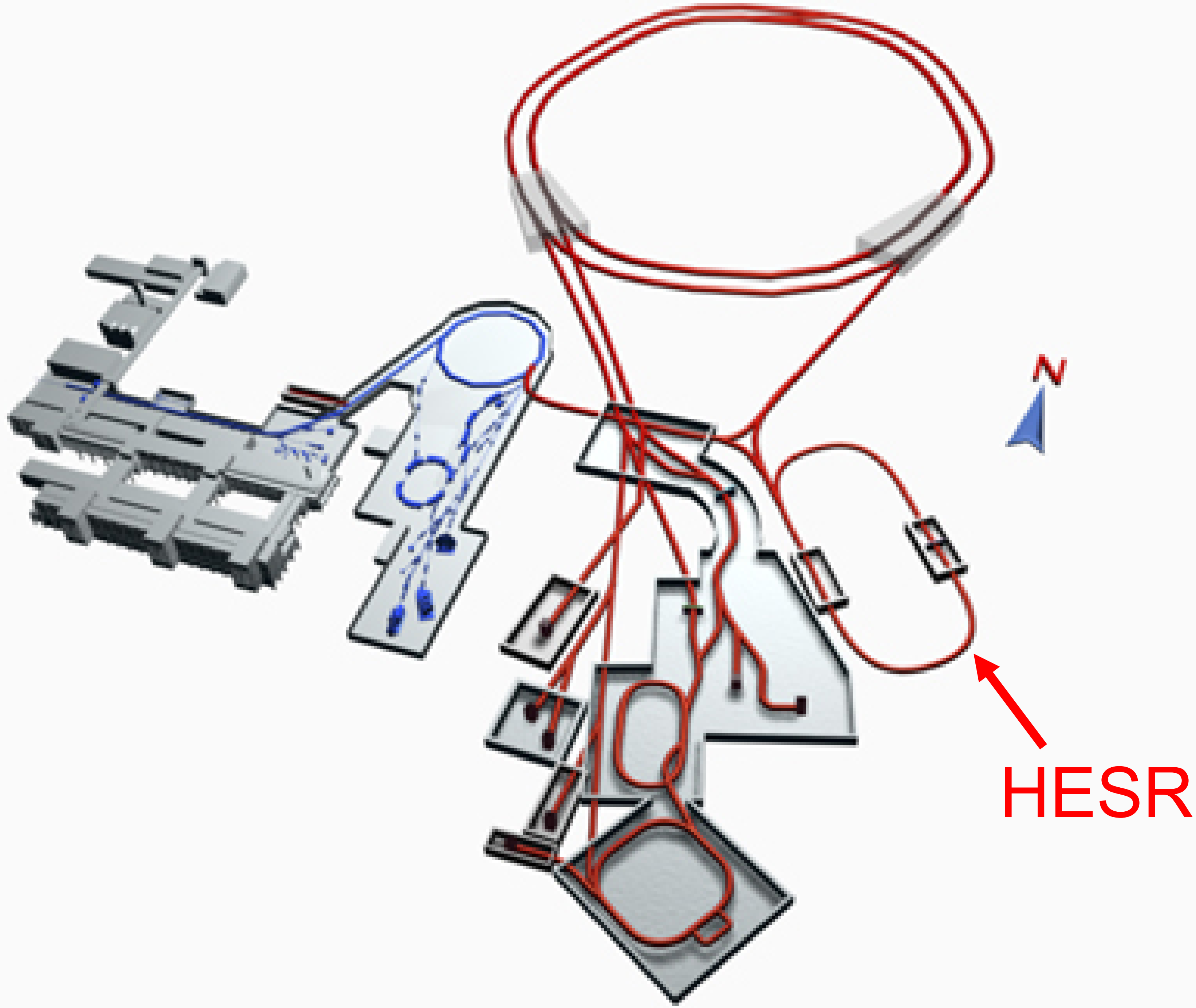




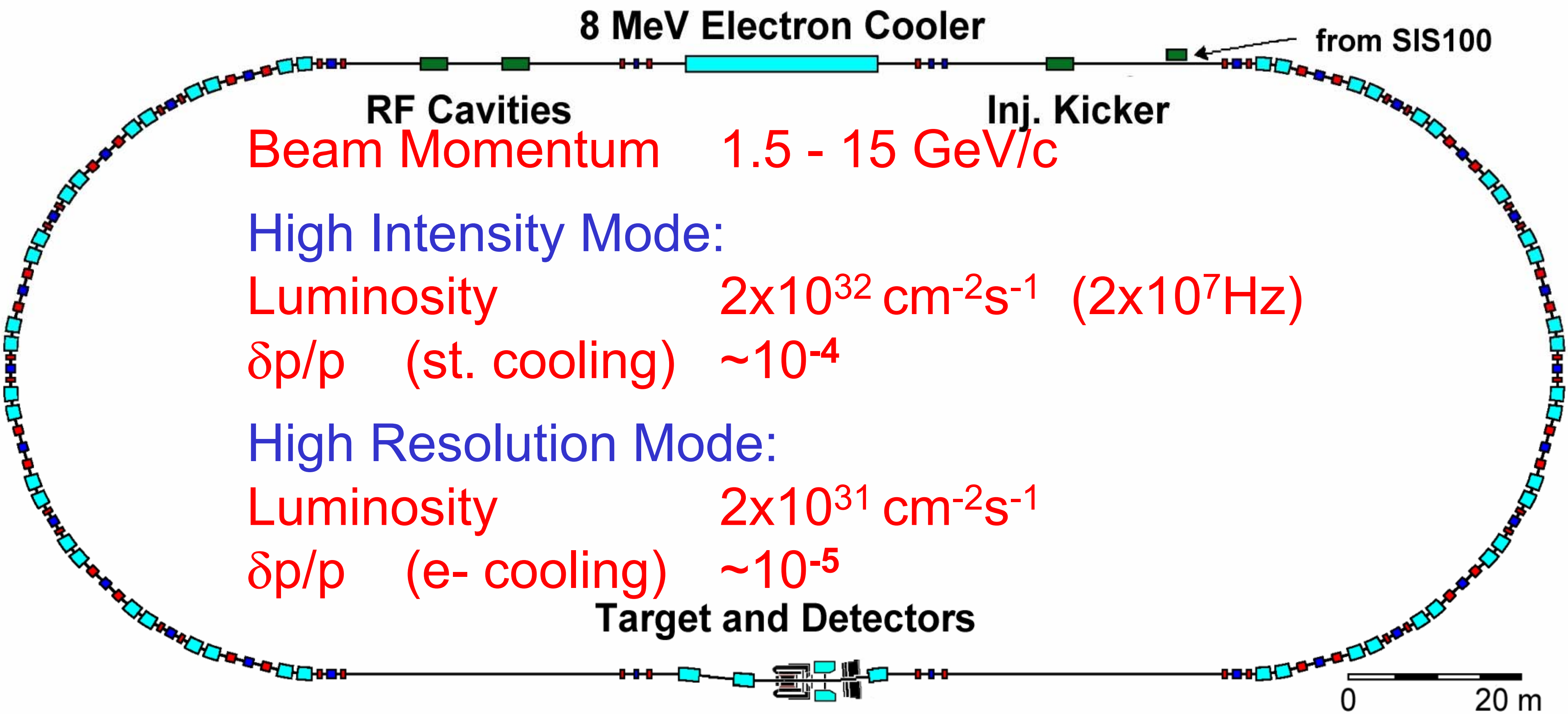
- Double-hypernuclei:
  very little data
- Baryon-baryon interactions:
  Λ-N only short ranged (no 1π exchange due to isospin)
  Λ–Λ impossible in scattering reactions

Ξ^-(dss) **p**(uud) → Λ(uds)

The Experimental Facility


N
HESR

HESR: High Energy Storage Ring



Beam Momentum 1.5 - 15 GeV/c

High Intensity Mode:

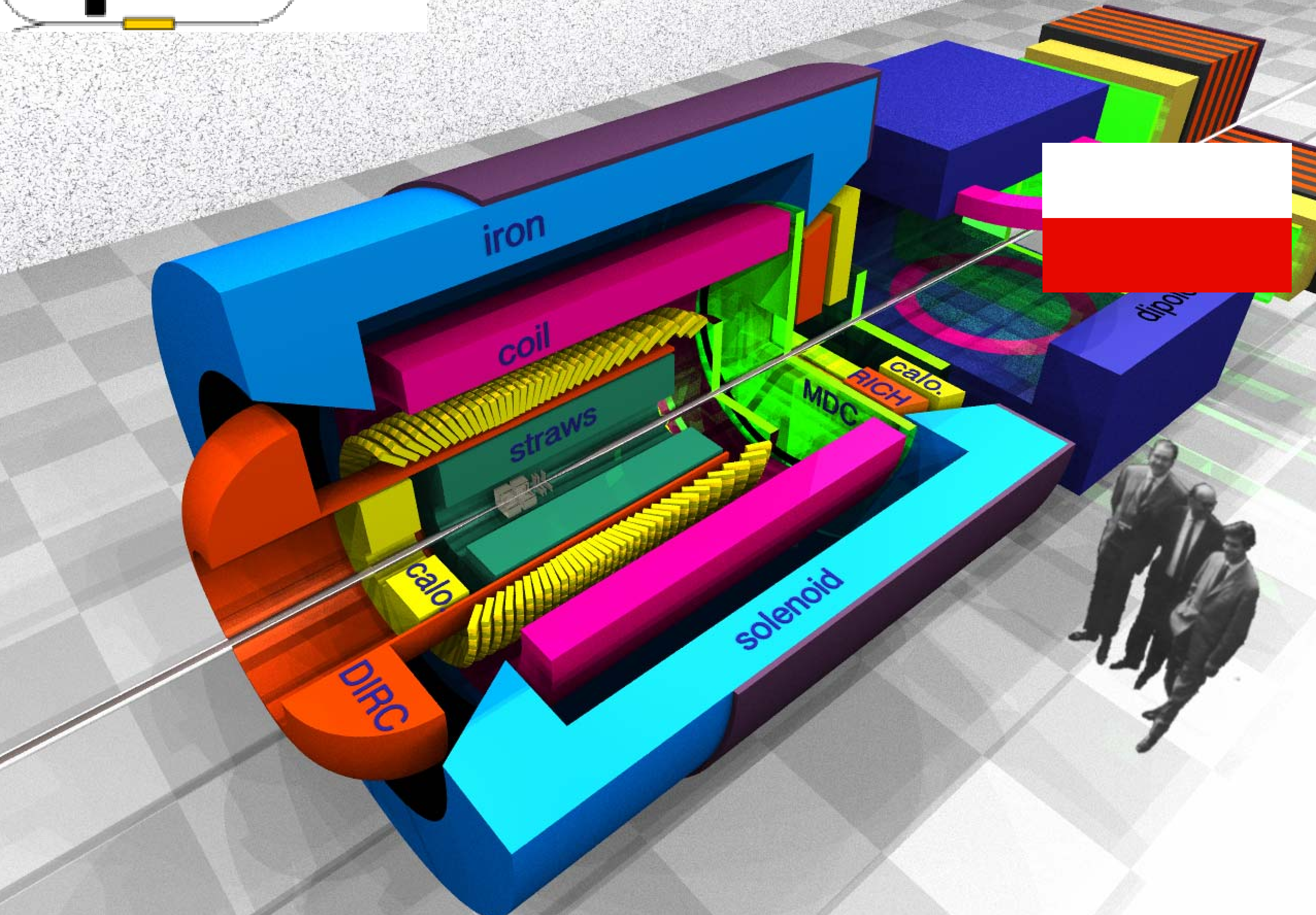
Luminosity 2×10^{32} $cm^{-2}s^{-1}$ (2×10^{7}Hz)

$\delta p/p$ (st. cooling) $\sim10^{-4}$

High Resolution Mode:

Luminosity 2×10^{31} $cm^{-2}s^{-1}$

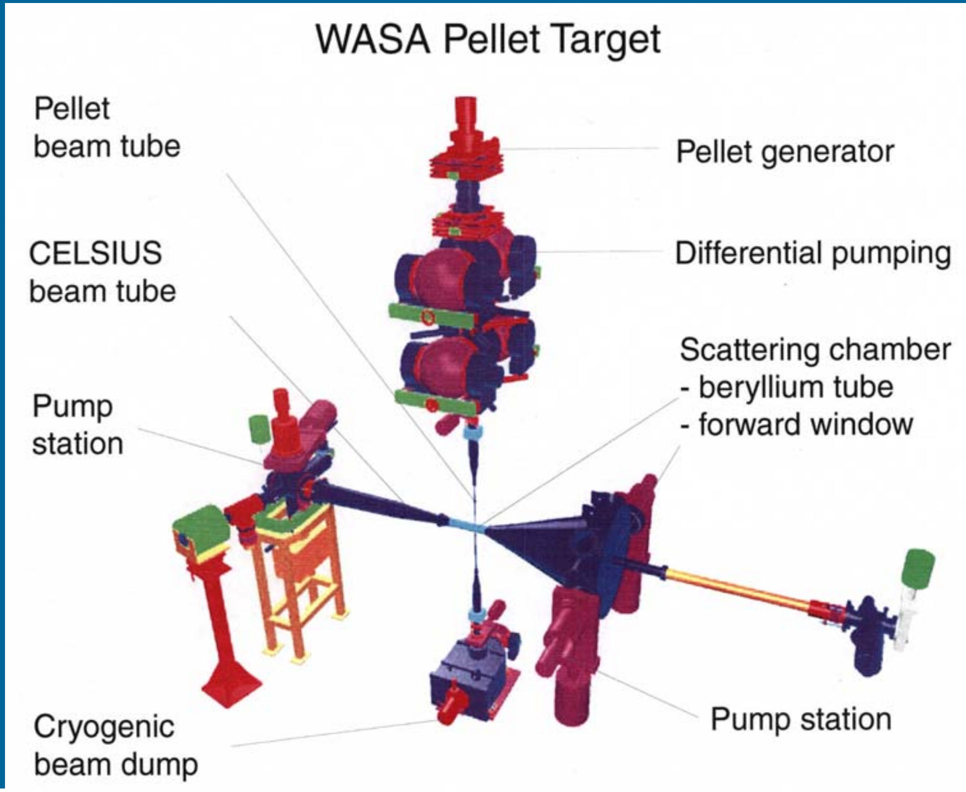
$\delta p/p$ (e- cooling) $\sim10^{-5}$

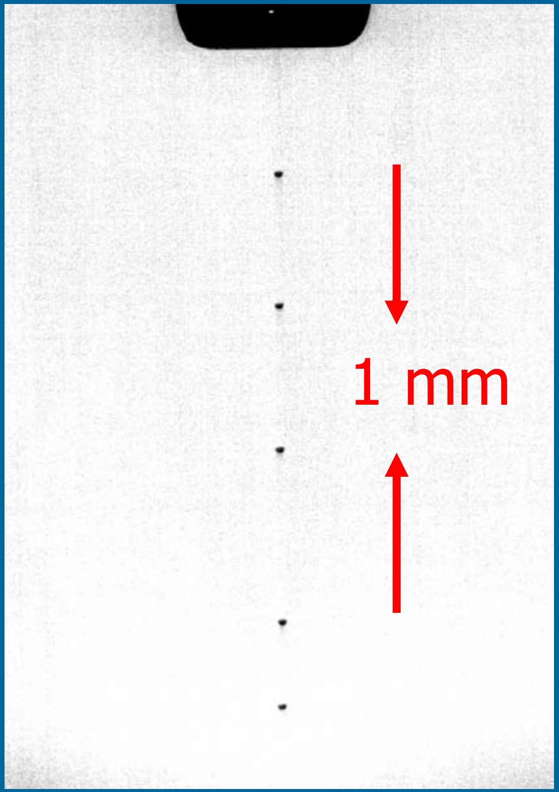

iron
coil
straws
calo.
DIRC
solenoid
MDC
RICH
calo.

Target

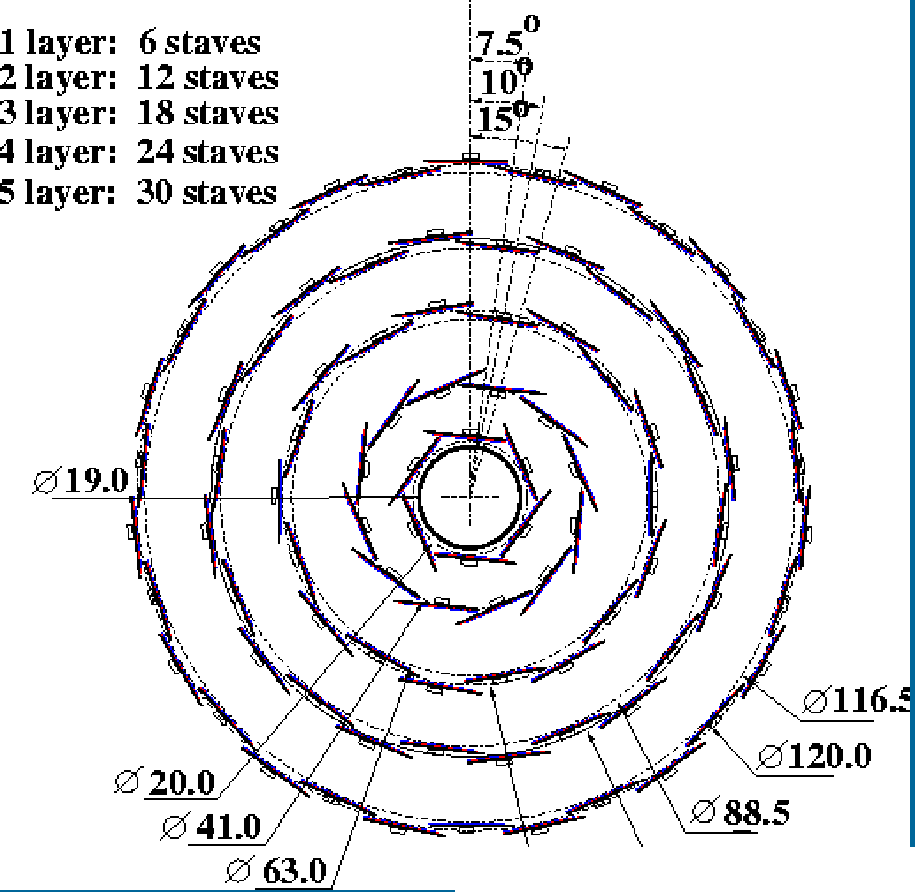
- A fiber/wire target will be needed for D physics,
- A pellet target is conceived:

  10^{16} atoms/cm^2 for D=20-40 μm



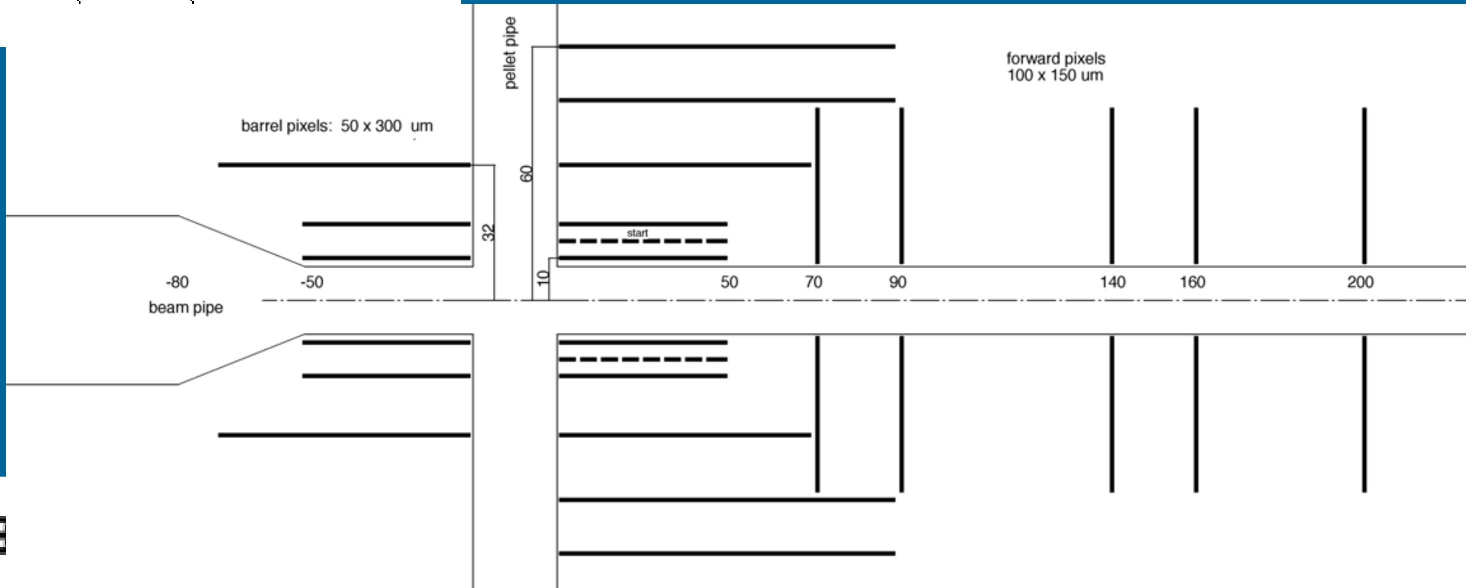


Micro Vertexing



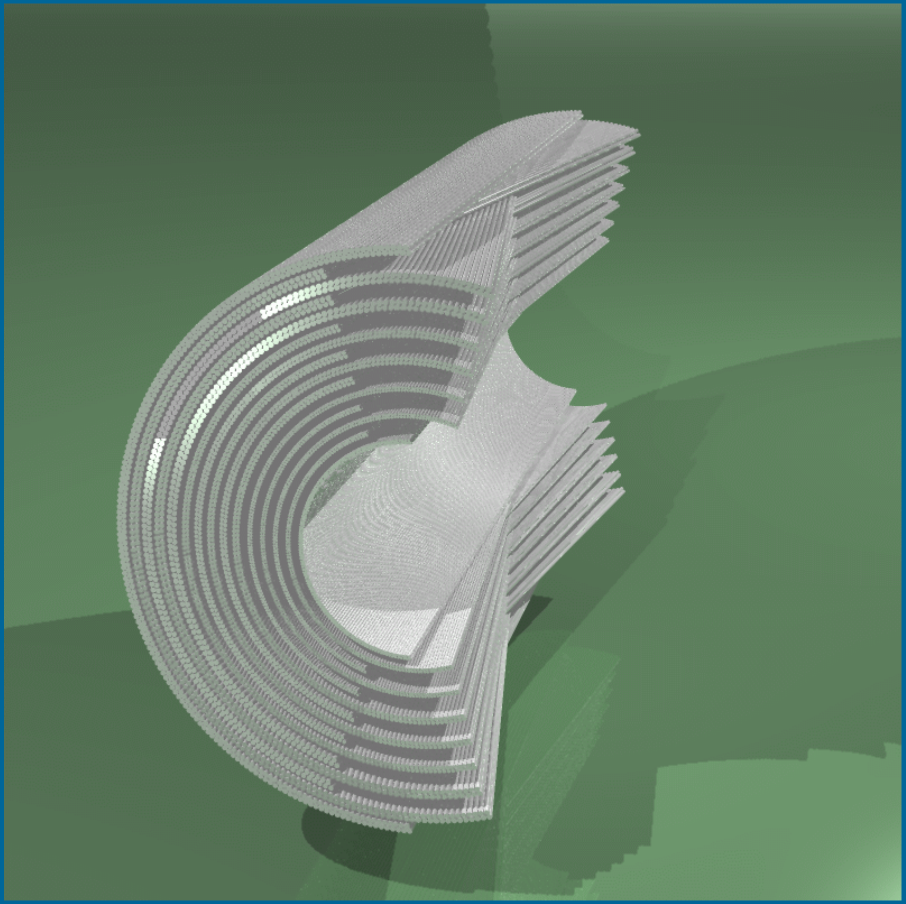
7.2 mio. barrel pixels
50 x 300 µm

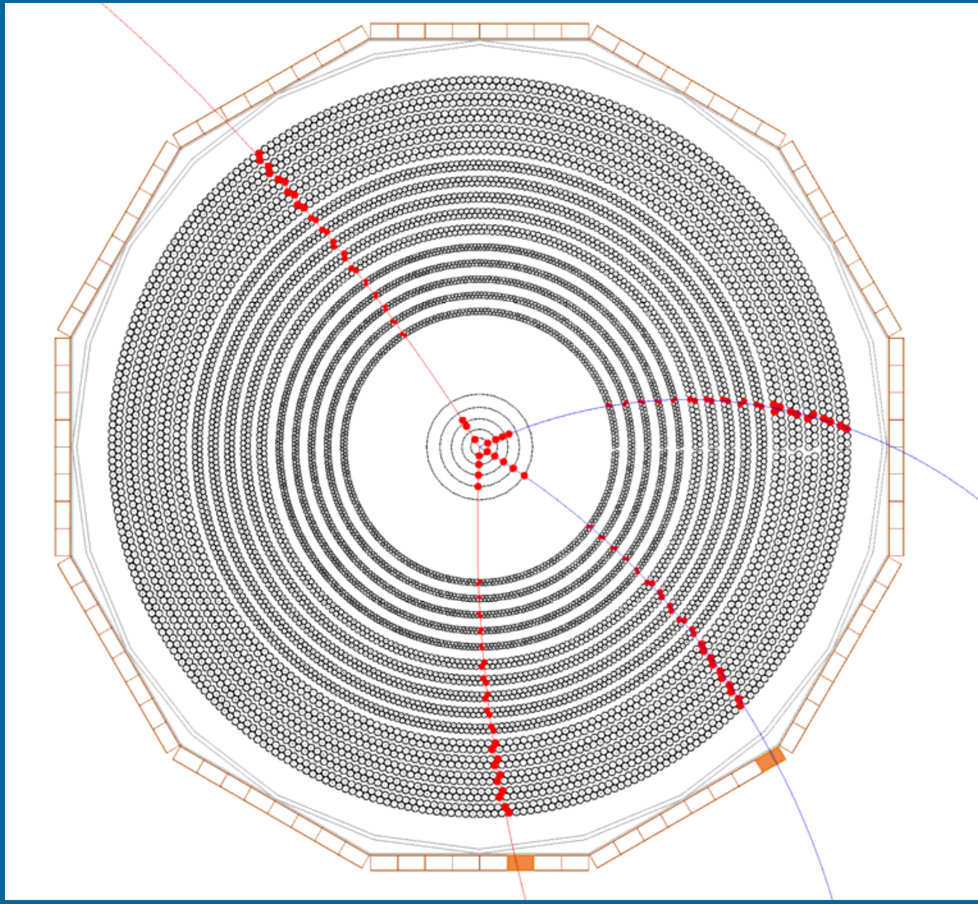
2 mio. forward pixels
100 x 150 µm



Central Tracking Detectors

- MVD: (Si) 5 layers
- Straw-Tubes: 15 skewed double-layers
- Mini-Drift-Chambers

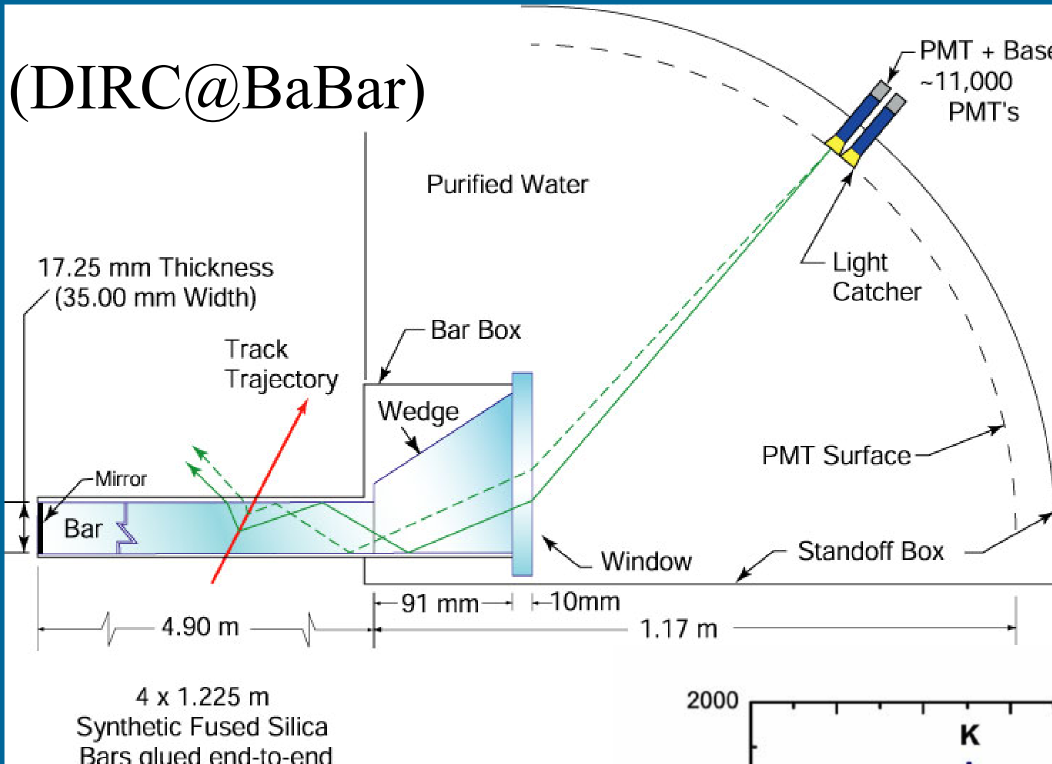


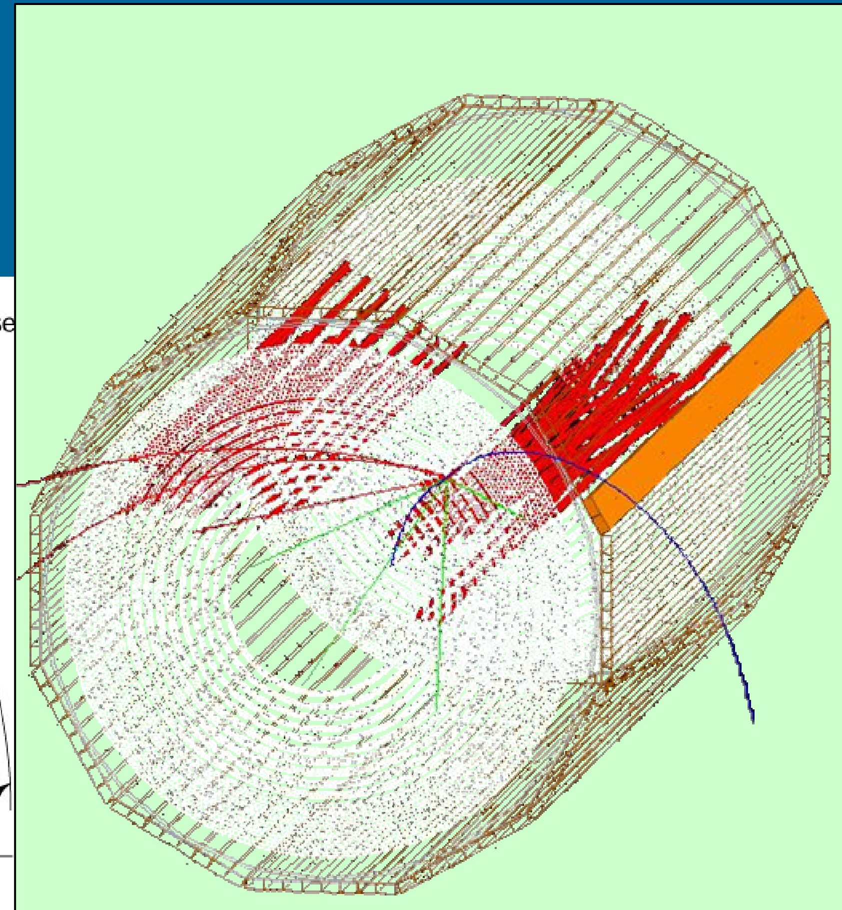


example event: $\bar{p}p \rightarrow \phi\,\phi \rightarrow 4K$

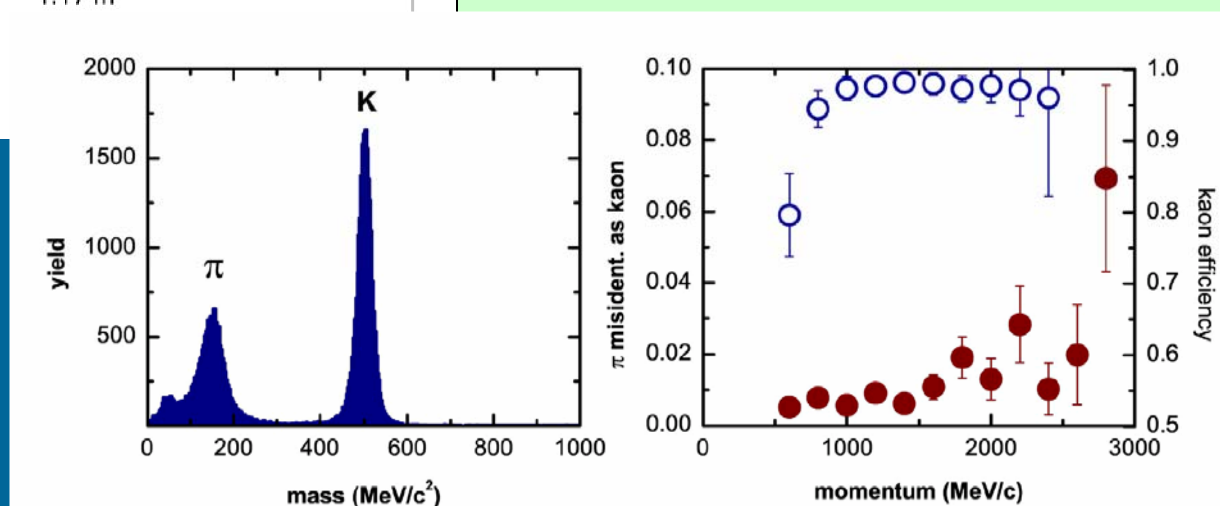
PID with DIRC

(DIRC@BaBar)



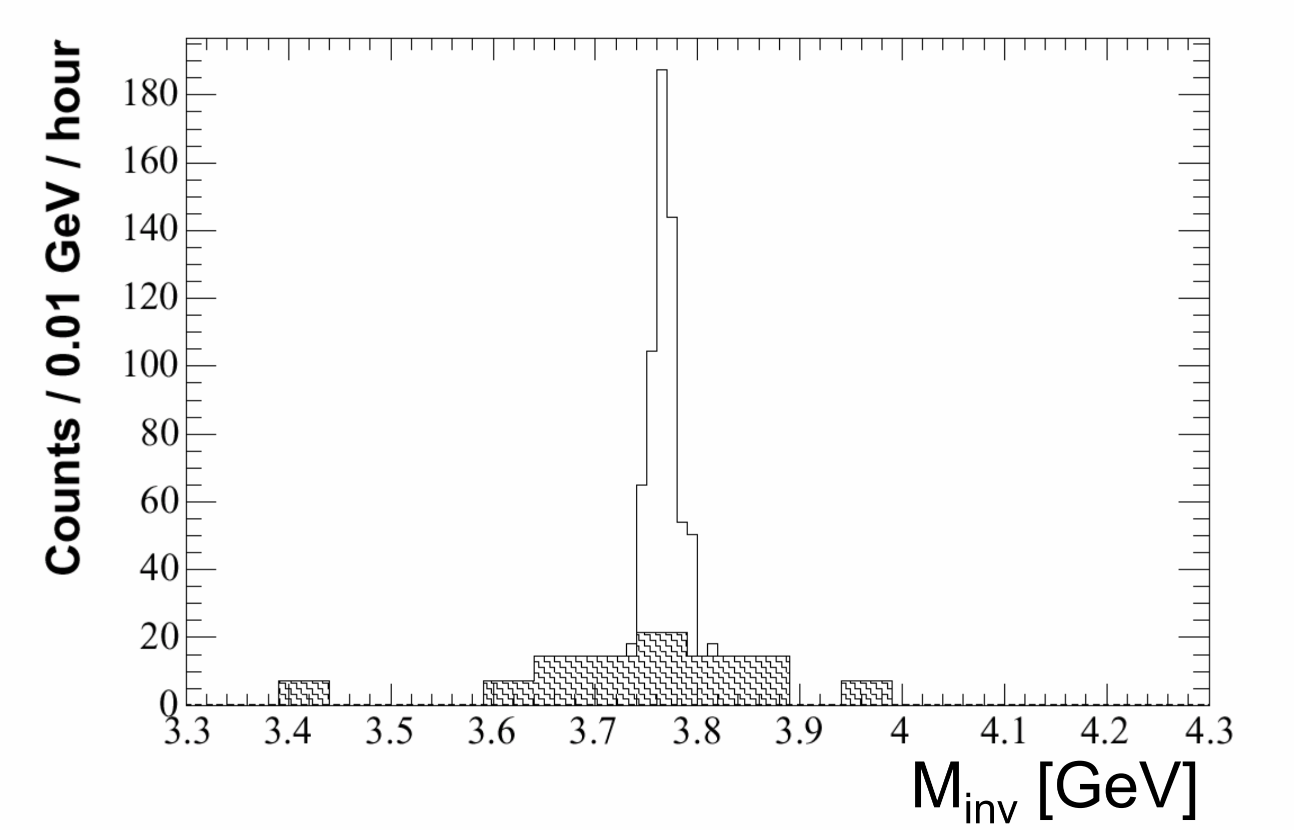


GEANT4 simulation
for HESR:



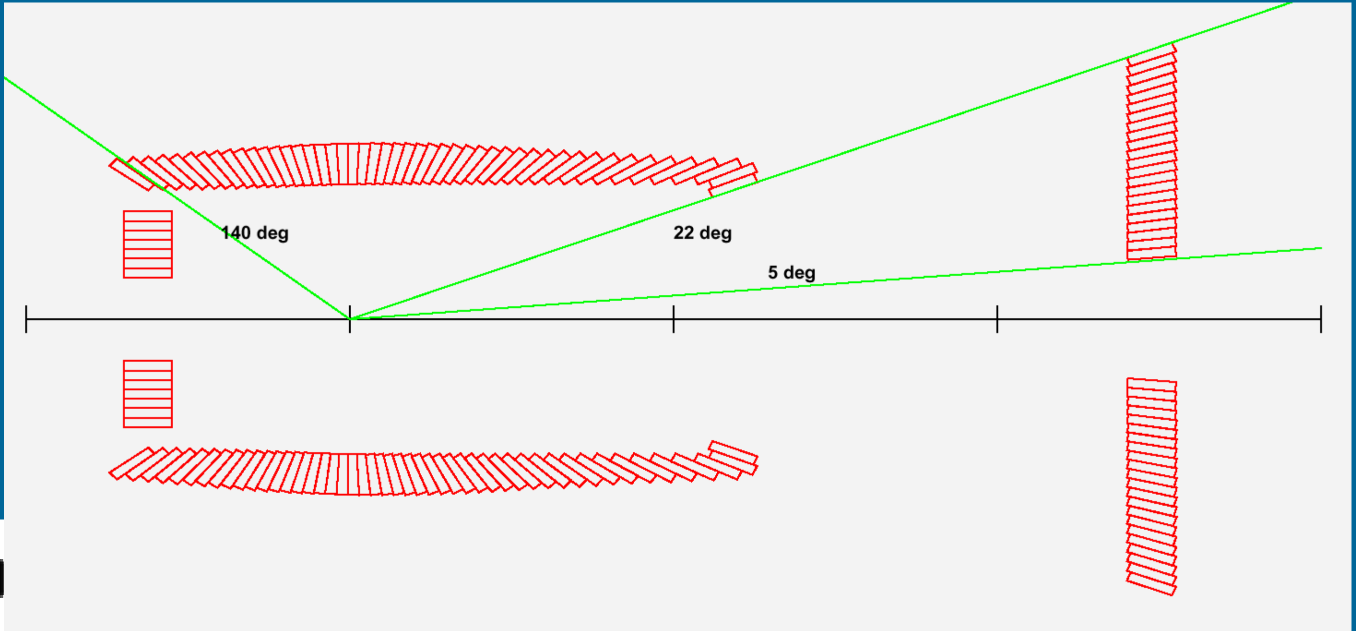
Open Charm

As an example of the Pbar P → Ψ(3770) → DD Analysis
Peak to background of about 6:1



Electromagnetic Calorimeter

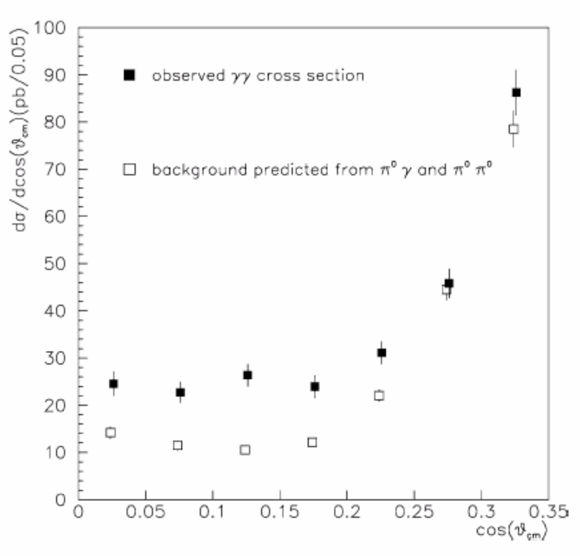
Detector material	$PbWO_4$
Photo sensors	Avalanche Photo Diodes
Crystal size	$\approx$ 35 x 35 x 150 mm^3 (i.e. 1.5 x 1.5 R_M^2 x 17 X_0)
Energy resolution	1.54 % / $\sqrt{E[GeV]}$ + 0.3 %
Time resolution	$\sigma \approx$ 130 ps (N.B. with PMT!)
Total number of crystals	7150

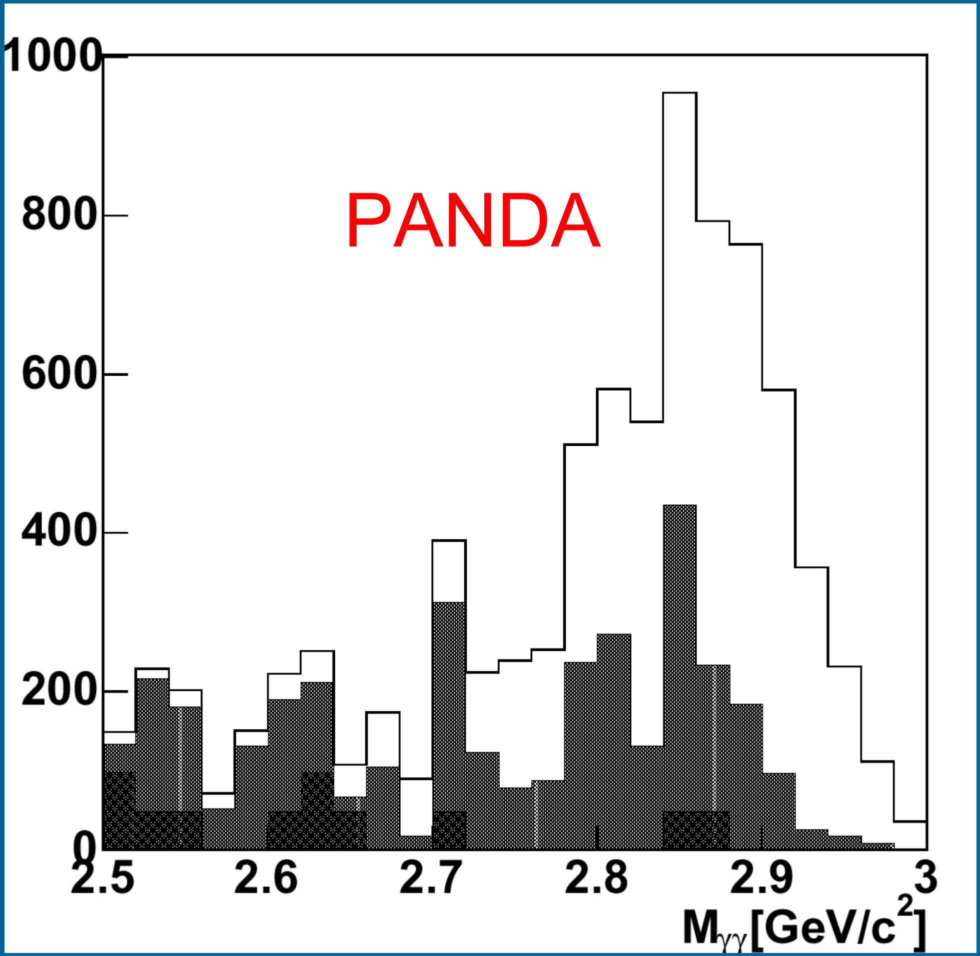


Detection of Rare Neutral Channels

As an example:
$\eta_c \rightarrow \gamma\gamma$ (full phase space)

Comparison with E835
(PLB 566,45)



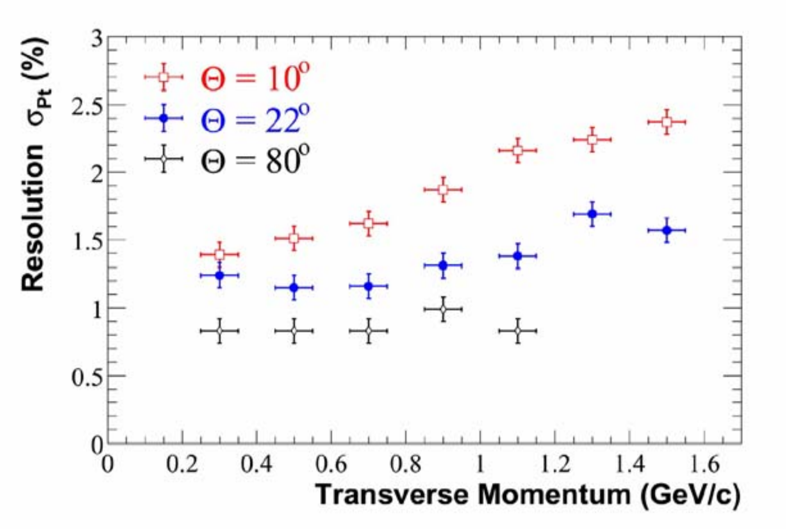


Summary

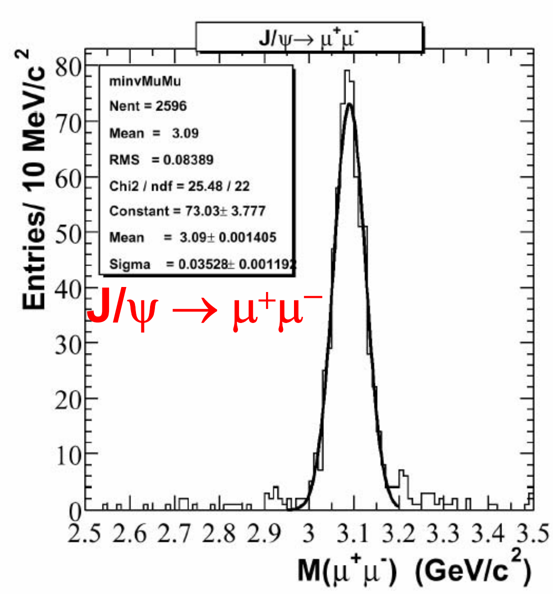
- High luminosity cooled p-bar from 1-15 GeV/c
- Wide physics program including
  - pbar-A reactions
- Panda collaboration forming

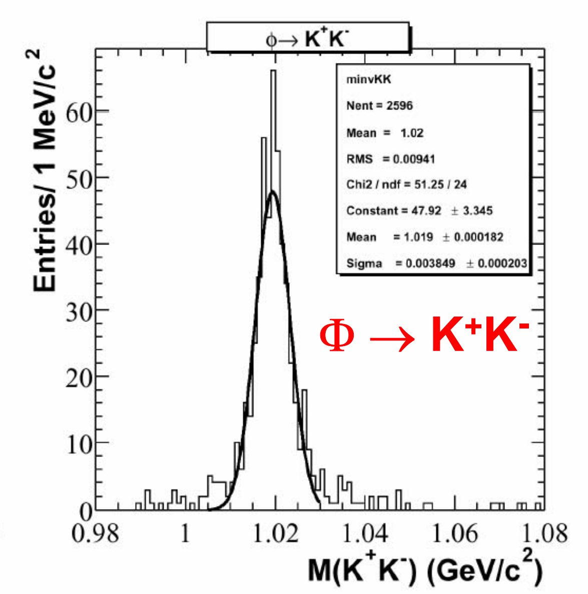
Tracking Resolution

Single track resolution



Invariant mass resolution





Example reaction:

$\bar{p}p \rightarrow J/\psi + \Phi$

($\sqrt{s}$ = 4.4 GeV/c^2)

$\sigma(J/\psi)$ = 35 MeV/c^2

$\sigma(\Phi)$ = 3.8 MeV/c^2