Apologia

- I am comfortable with counting up to 2.
  Hence, I have spent the last 20 years with **mesons**.
- Counting 3 is too much for me.
  Hence, I know little about **baryons**.
- About Cascades I know even less.
  Only what is in the PDG:
  - 12 Cascades are listed with $M = 1315\!-\sim 2500$ MeV.
    Only 7 have 4 or 3 stars.
    Only 4 have J^π determined.
  - 4 or 3 star ones have widths ≤ 50 MeV.
  - Most were formed with kaon beams.
  - Most were studied in $\Lambda\pi$ and ΛK decays.

  End of my knowledge of Cascades.
- So let me move on to GSI, which is what Ben Nefkens asked me to talk about.

Cascading down to
GSI
Gesellschaft für SchwerIonenforschung

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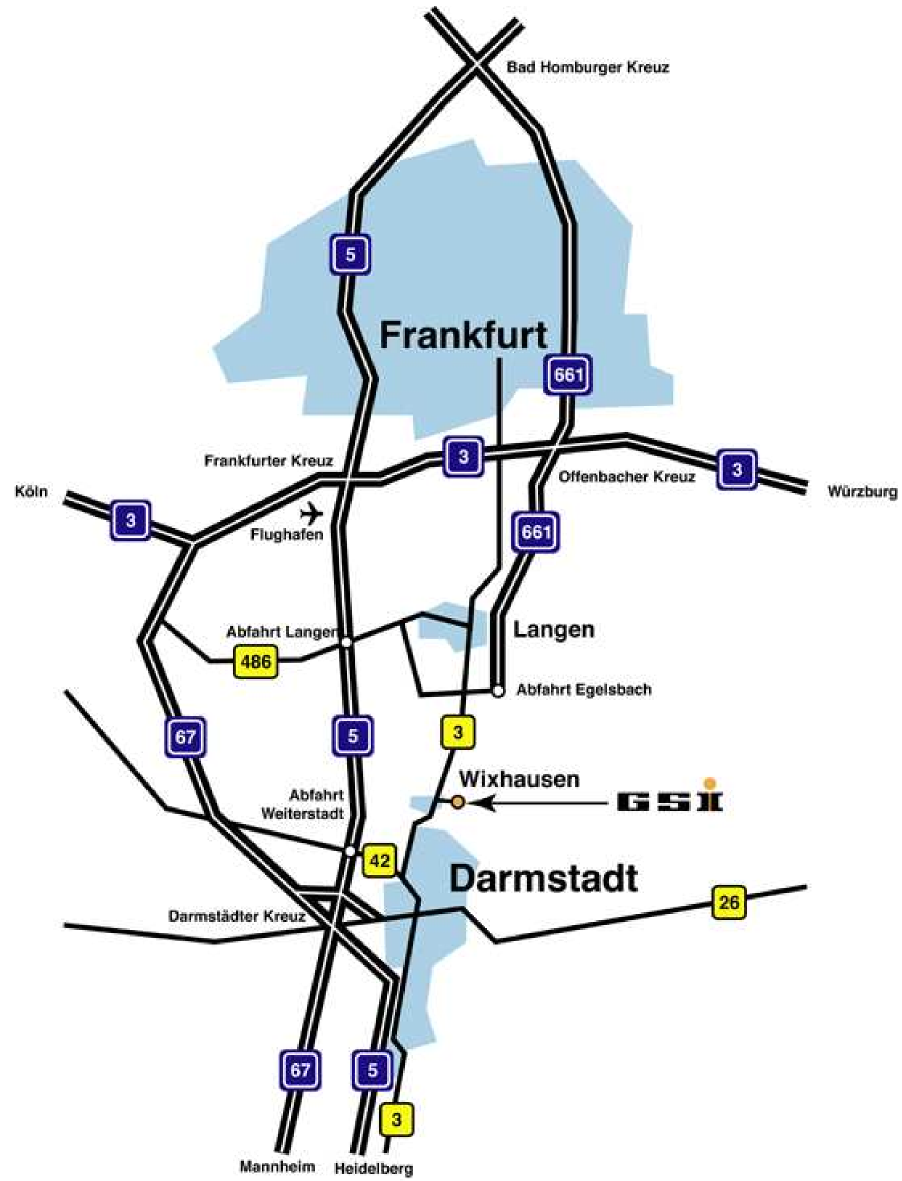

Bad Homburger Kreuz
5
Frankfurt
661
Frankfurter Kreuz
3
Offenbacher Kreuz
Köln
Würzburg
Flughafen
661
Abfahrt Langen
486
Langen
Abfahrt Egelsbach
67
5
3
Wixhausen
Abfahrt
Weiterstadt
42
Darmstadt
26
Darmstädter Kreuz
67
5
3
Mannheim
Heidelberg

The Past and Present GSI

- Founded in 1969 to do heavy–ion research.
- Consists of 3 major accelerator complexes
  - UNILAC (< 15 MeV$/c$)
  - SIS – Schwerionen Synchrotron (1–2 GeV$/u$)
  - ESR – Experimental Storage Ring (< 0.8 GeV$/u$)
- Staff of 850, including 300 scientists and engineers

Research Programs

- Nuclear and Atomic Physics
  - famous for superheavy element discoveries
- Plasma Physics
- Materials Research
- Biophysics and Cancer Therapy

The Future GSI (FAIR)

Facility for Antiproton and Ion Research

- Approved by German Govt. on Feb 6, 2003, for

Infrastructure	226 million euros
Accelerator	265 million euros
Experiments, Detectors	185 million euros
TOTAL	675 million euros = $\sim$ \$800 million

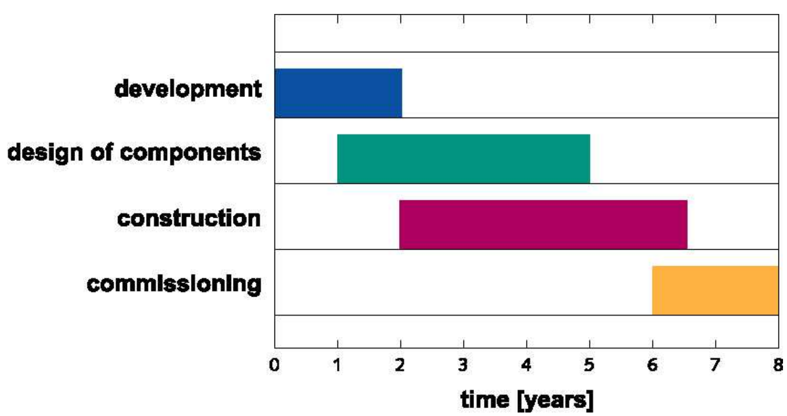
- Physics Program
  - Nuclear Structure (radioactive beams)
  - Nuclear Matter (heavy ion physics)
  - Plasma Physics (astrophysics)
  - Atomic Physics (QED of strong fields)
  - ANTIPROTON PHYSICS
    (340 physicists from 47 institutes and 16 countries)
    * GeV region (PANDA)
    * Low energy region (FLAIR)

FAIR: Users, Costs and Schedules

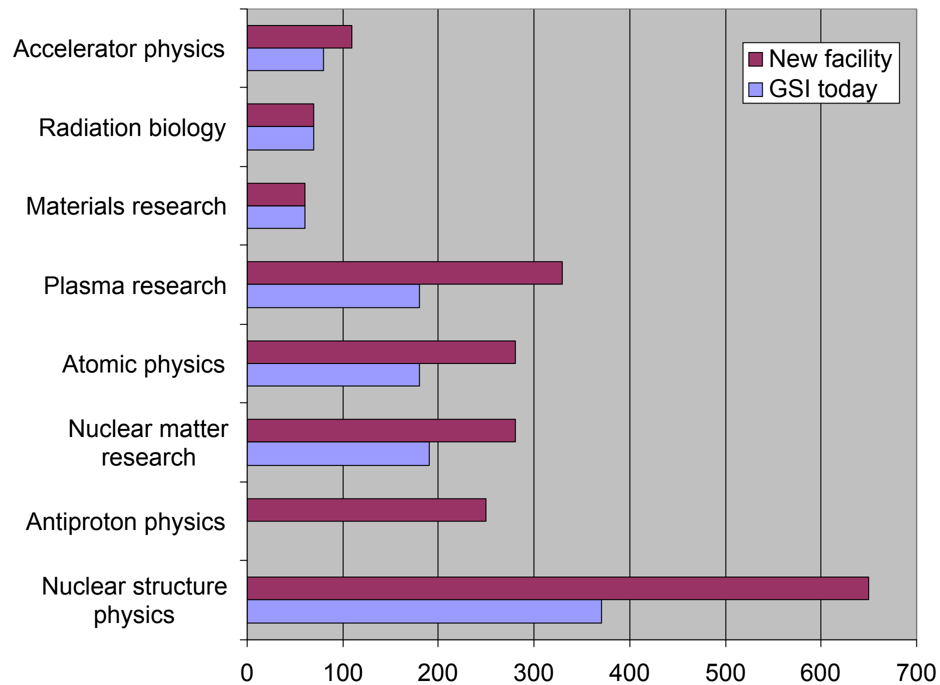
COSTS

Building and infrastructure:	225 Mio. €
Accelerator:	265 Mio. €
Experimental stations / detectors:	185 Mio. €
Total:	675 Mio. €

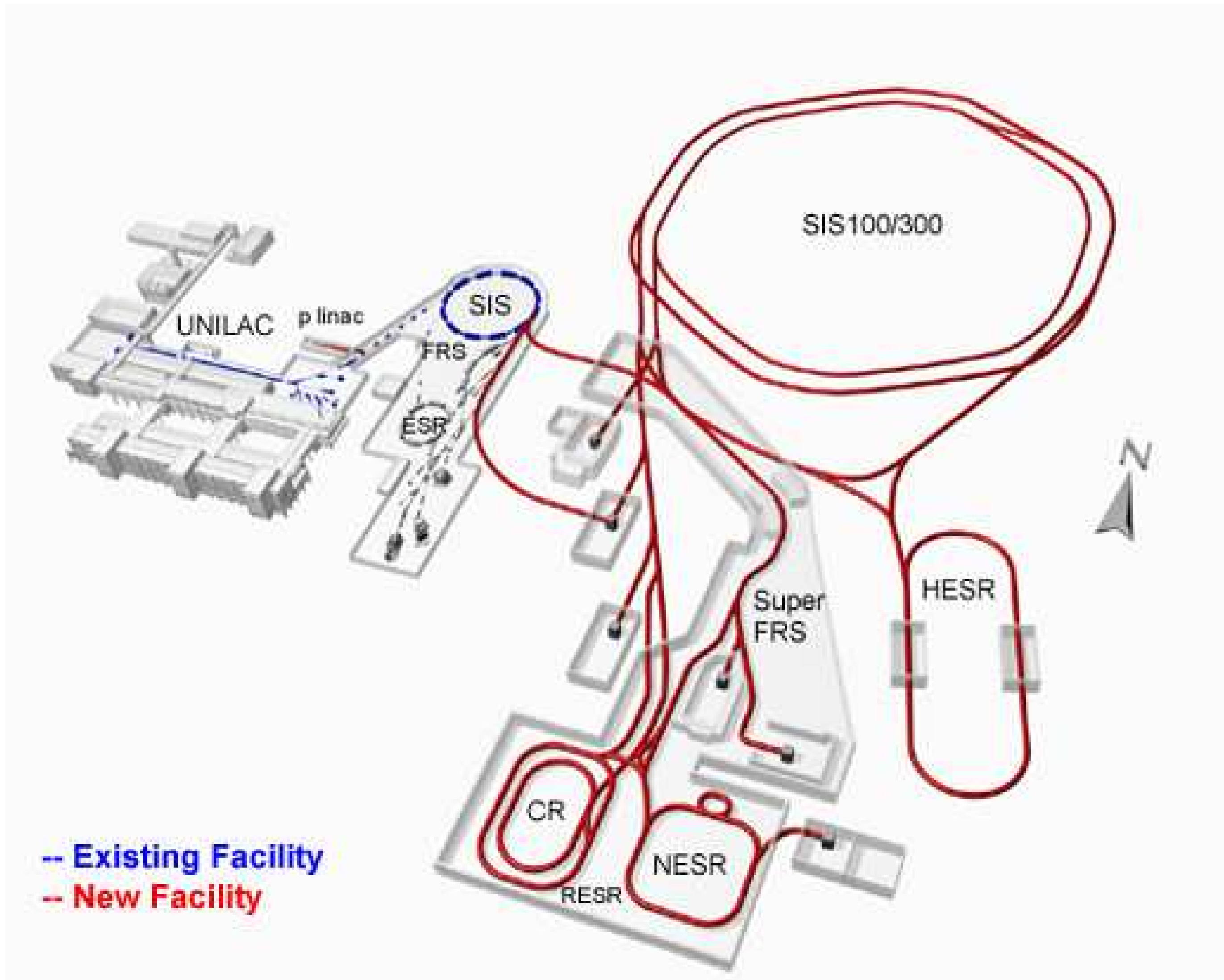
SCHEDULE



Users interest




Panda


SIS100/300
UNILAC
p linac
SIS
FRS
ESR
N
HESR
Super
FRS
CR
NESR
RESR
-- Existing Facility
-- New Facility

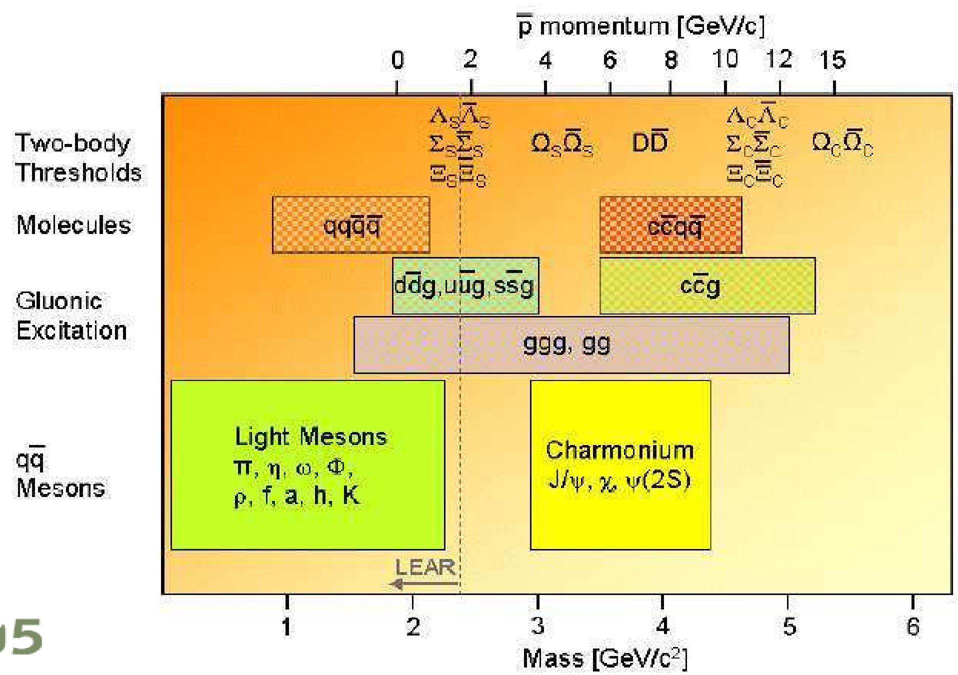
PANDA

PANDA is an experiment that will use a very high intensity $\bar{p}$ beam with momentum from 1.5 GeV/c up to 15 GeV/c on a fixed proton target : $\sqrt{s}$ from 2.25 up to 5.47 GeV

It will continue and extend the successful physics program initiated at facilities like LEAR at CERN and FERMILAB

Physics topics covered in PANDA

- Charmonium
- Exotics : hybrids, glueballs and other exotics
- Mesons in nuclear matter
- Charmonium absorption in nuclear matter
- Hypernuclear physics
- Open charm factory : CP violation, and D physics
- Crossed-channel Compton scattering and related exclusive processes
- Electromagnetic form factors of the proton in the time-like region



The PANDA experiment site within FAIR

High Intensity Mode:

Luminosity $2x10^{32}$ $cm^{-2}s^{-1}$ ($2x10^{7}$Hz)

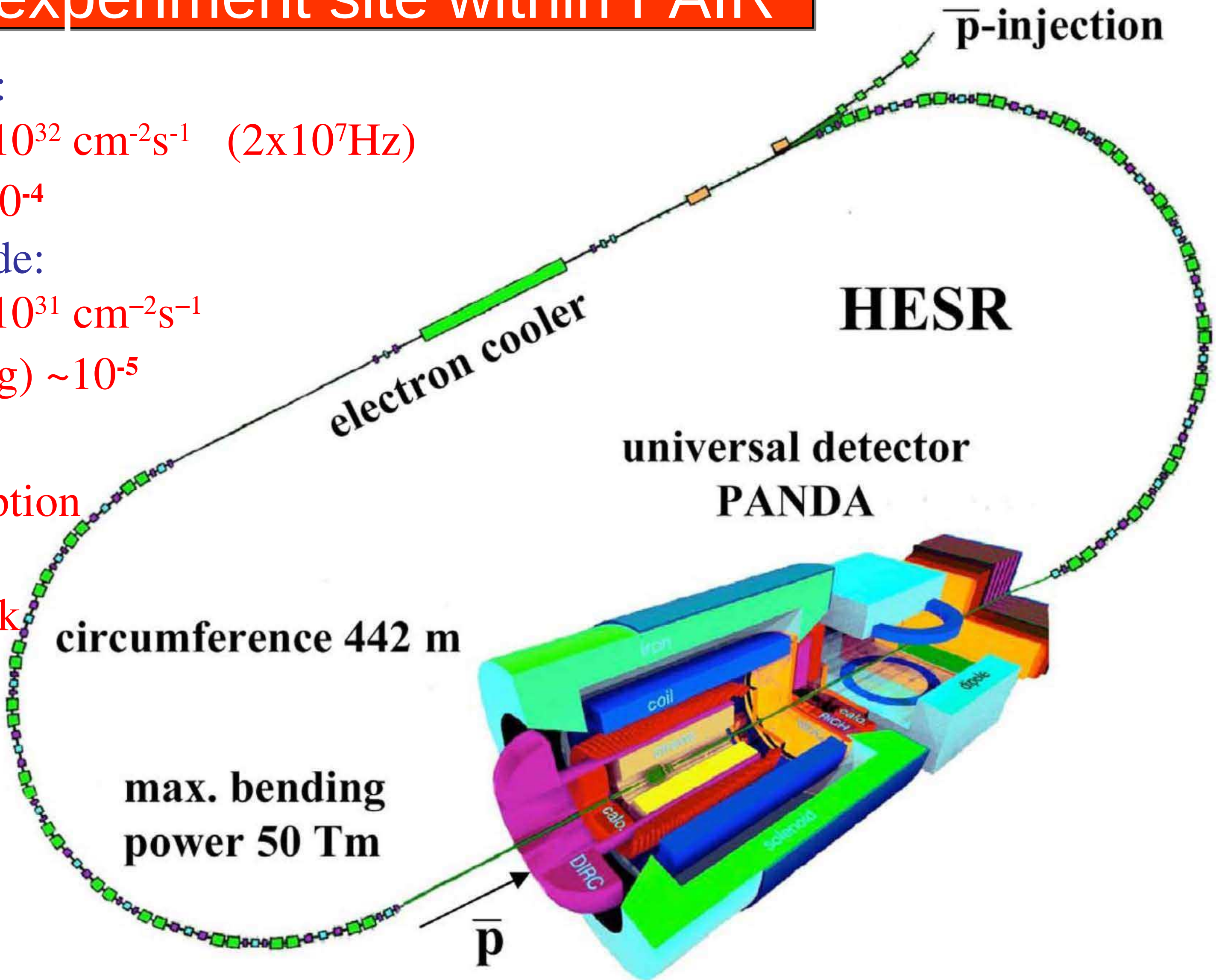
$\delta p/p$ (st. cooling) ~10^{-4}

High Resolution Mode:

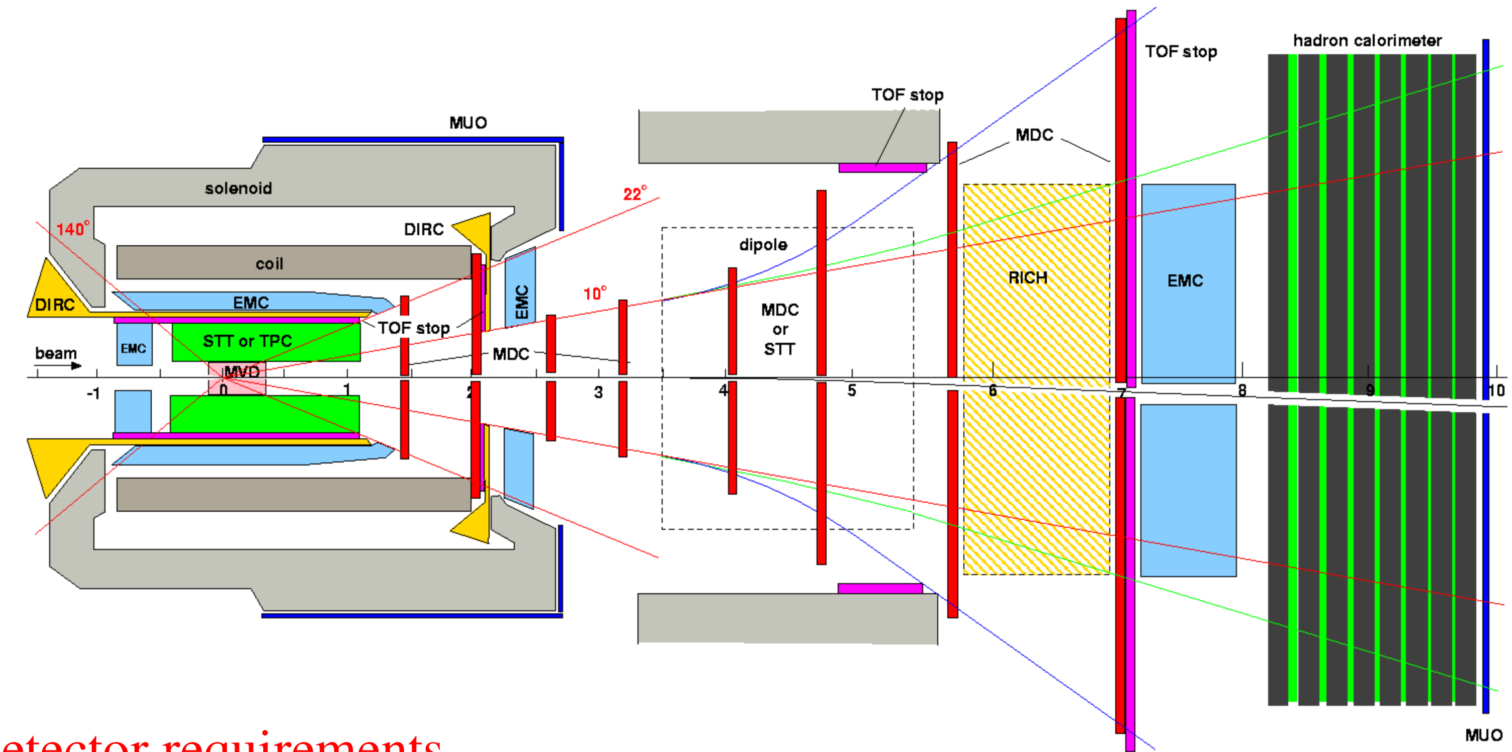
Luminosity $2x10^{31}$ $cm^{-2}s^{-1}$

$\delta p/p$ (electron cooling) ~10^{-5}

For a detailed description of the **FAIR** facility project at GSI see talk by K. Peters on Monday morning plenary session



The PANDA detector

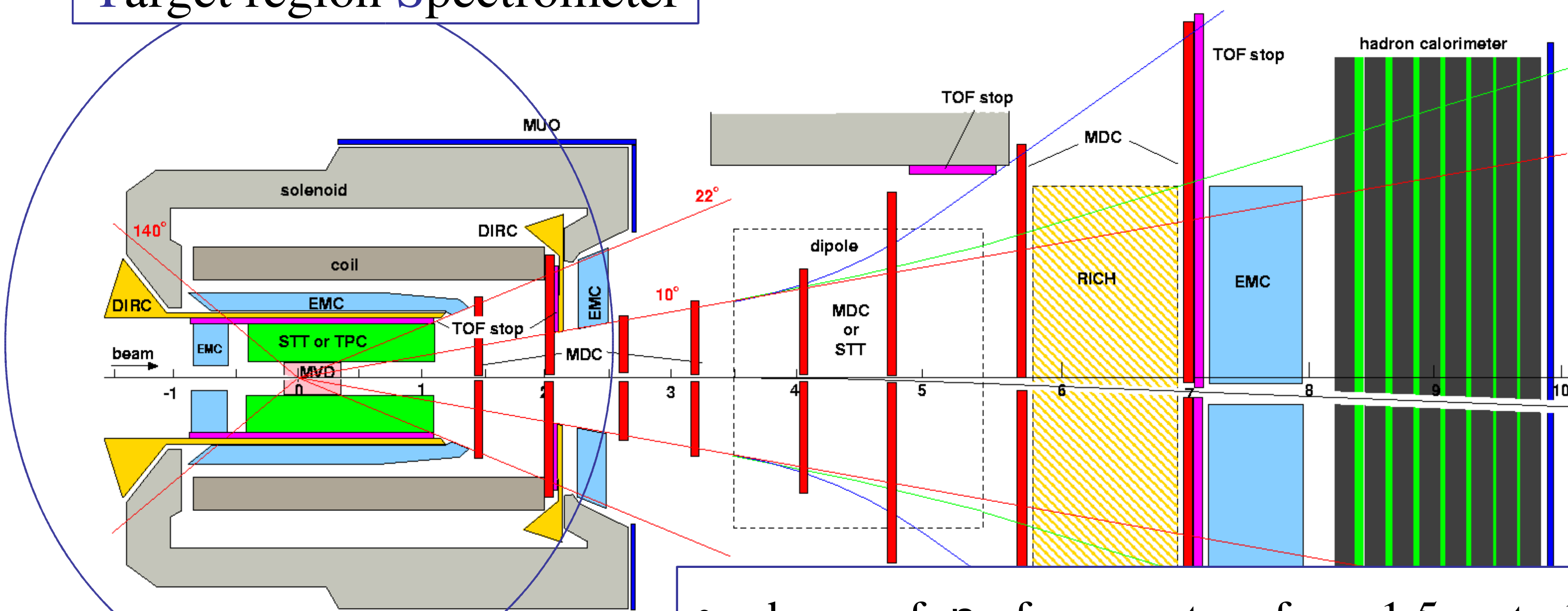


Detector requirements

- full angular acceptance and angular resolution for charged particles and γ, π^0
- particle identification (π, K , e, μ) in the range up to ~ 8 GeV/c
- high momentum resolution in a wide energy range
- high rate capabilities, especially in interaction point region and forward detector : expected interaction rate ~ 10^7

The PANDA detector

Target region Spectrometer



also wire targets or foil targets for nuclear target physics

carbon target interleaved with silicon detector for hypernuclear physics

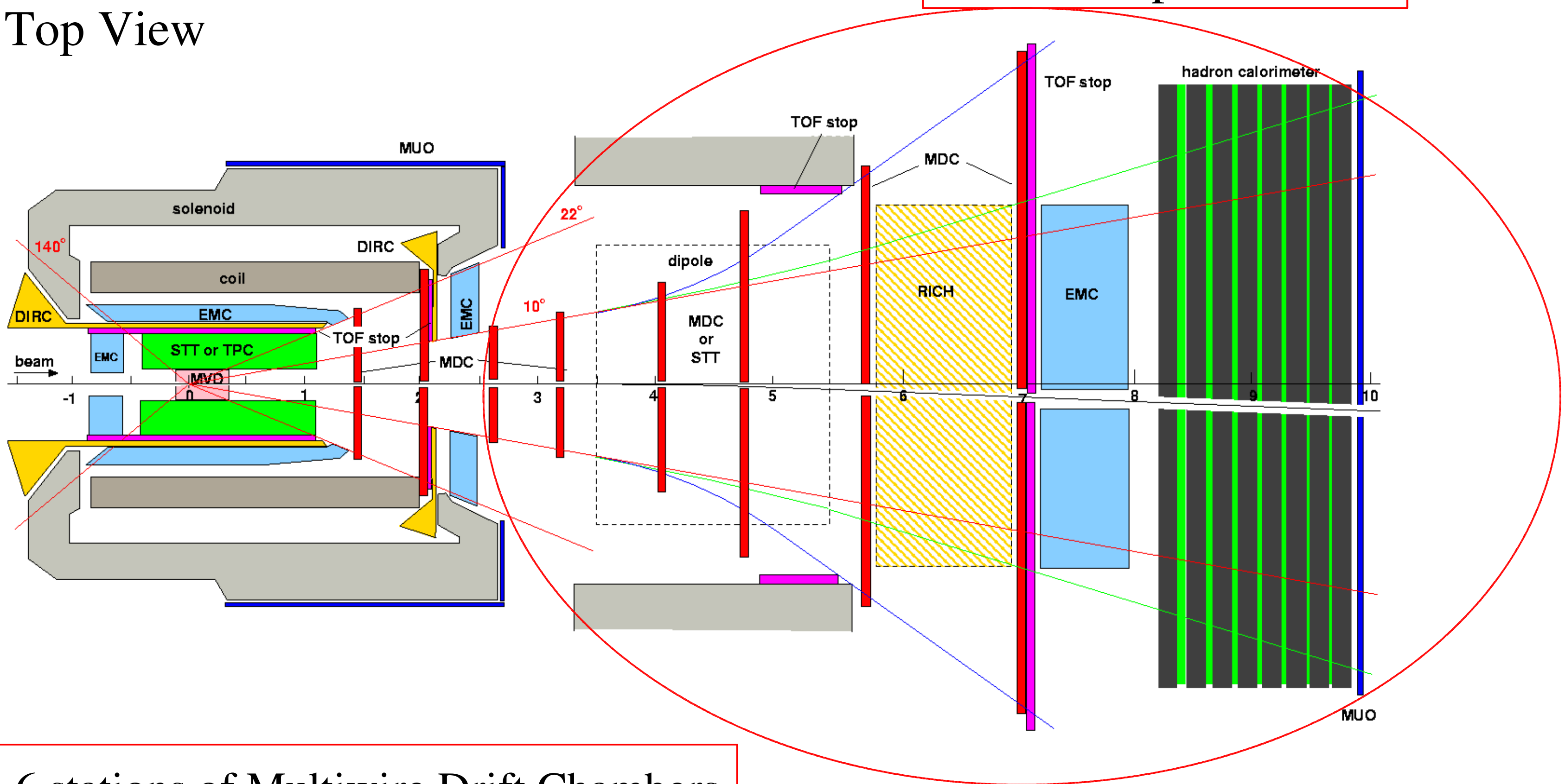
- beam of p of momentum from 1.5 up to 15 GeV/c
- proton pellet target (or gas jet target)
- Micro Vertex Detector
- Inner Time of Flight detector (still under discussion)
- Tracking detector : Straw Tubes Tracker or TPC
- DIRC
- Electromagnetic Calorimeter
- 2 Tesla solenoid
- scintillation muon counters
- 2 stations of Multiwire Drift Chambers

HADRON05

The PANDA detector

Top View

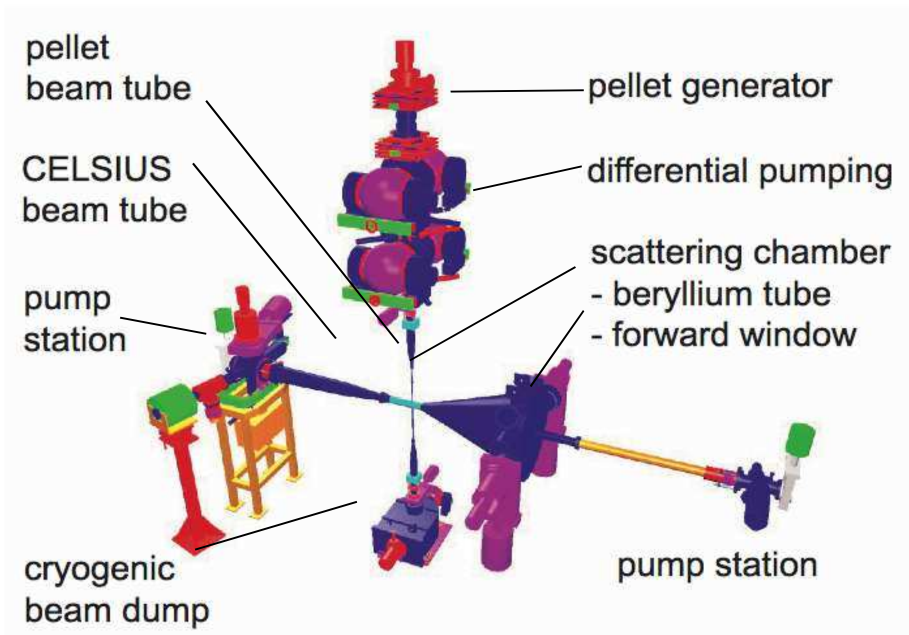
Forward Spectrometer

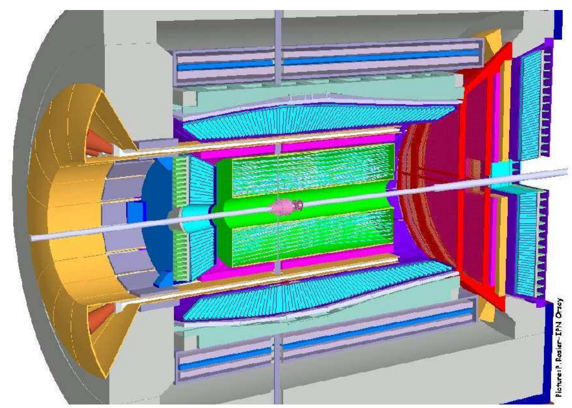


- 6 stations of Multiwire Drift Chambers
- analysing dipole : 2 Tesla·meter
- Forward DIRC and RICH
- Forward Electromagnetic Calorimeters
- Time of Flight counters
- Hadron Calorimeter

The pellet target

- To achieve design luminosity required effective target thickness of 3.8×10^{15} atoms/cm^2
- Frozen droplets of hydrogen (pallets) successfully operating at CELSIUS/WASA facility very close now to requirements (2.8×10^{15} atoms/cm^2), still working to reach goal
- pellet beam pipe 6 mm diameter

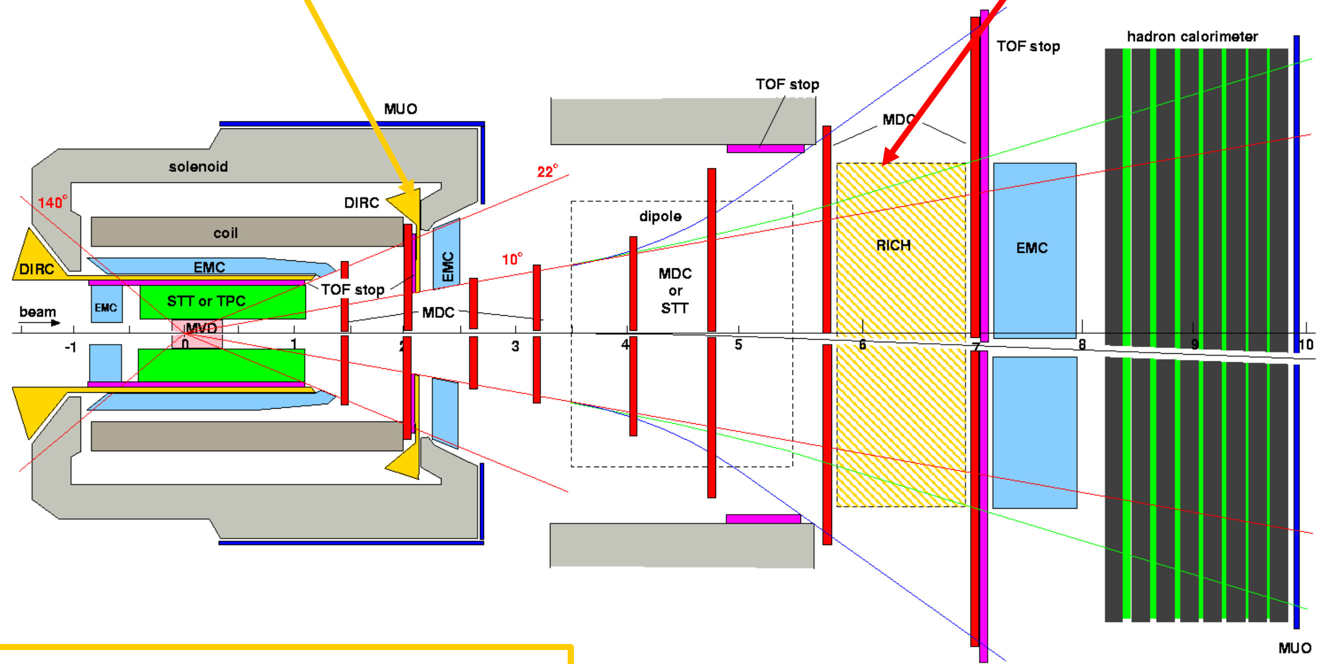




Charged particle identification for angles < 22° : the forward Dirc and the Rich

forward Dirc : fused silica disk (or proximity imaging RICH)
angle coverage between 10° and 22°

RICH, located downstream of dipole
angle coverage < 10°



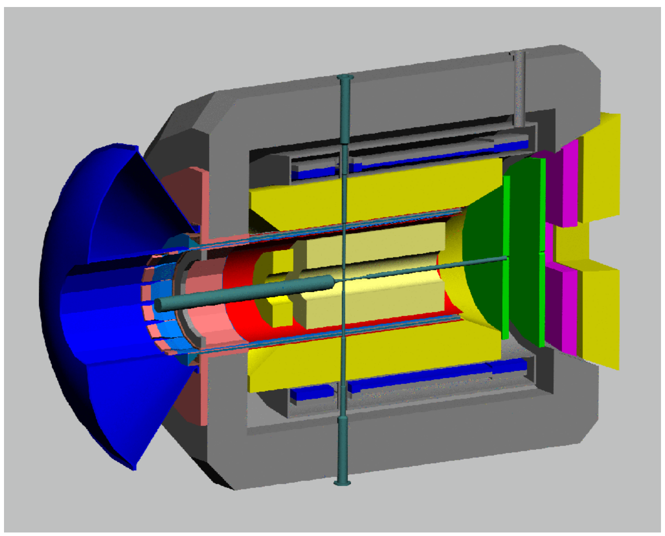
Forward DIRC present design ideas :
fused silica (n= 1.47)
read out by 2304 pixels 10mm x 5° +
864 pixels 10mm x 10°
lower momentum π/K separation ~ 1 GeV/c
upper momentum π/K separation :
10 GeV/c at θ =0 , 5 GeV/c at θ = 25°

RICH present design ideas :
3rd generation aerogel, hydrophobic, > 80% transmittance
and no Hermes 'meniscus' difect
read out : new type of multipixel hybrid photocatode
GaAsP photocatode (60% q.e. in 300-700 nm range)
multipixel avalanche diode, 64 pixels 2mm x 2mm,
with < 100 ps time resolution in 1.5 T field

Charged particle identification : dE/dx, ToF

dE/dx measurements to separate π/K/p typically below 800 MeV/c
If TPC will be implemented, it will be ideal device but also Straw Tubes since working in proportional mode and the MicroVertex Detecor pixels can measure dE/dx

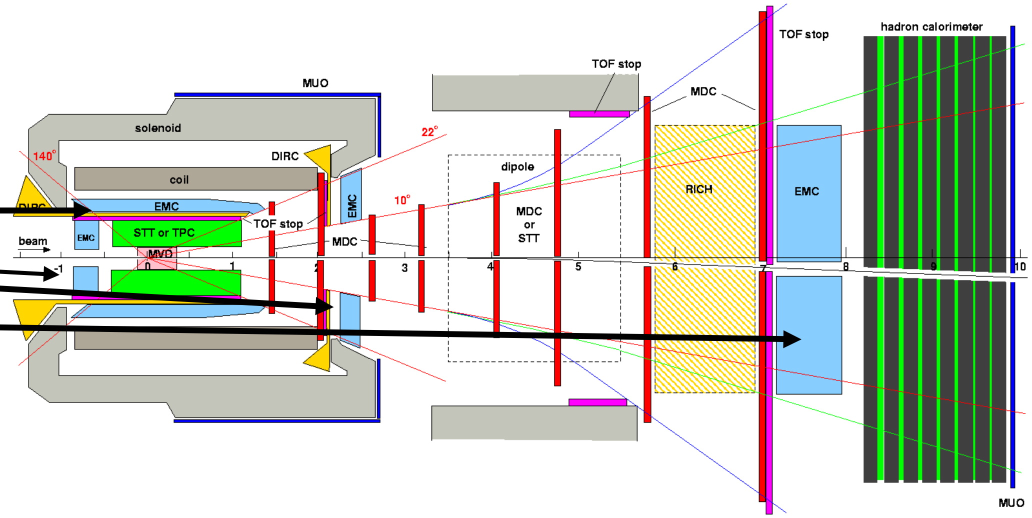
Time of Flight in the Target Region



A cylindrical Time of Flight scintillation counter is placed around the DIRC
96 strips of fast scintillator like BC404 : decay constant 1.8 ns
thickness 0.5 cm
mechanically mounted together with DIRC
phototubes : channel plate photomultipliers, can work up to 2.2 Tesla field
π/K separation at 3 σ level up to 430 MeV/c at θ = 90° and up to 760 MeV/c at θ = 22°

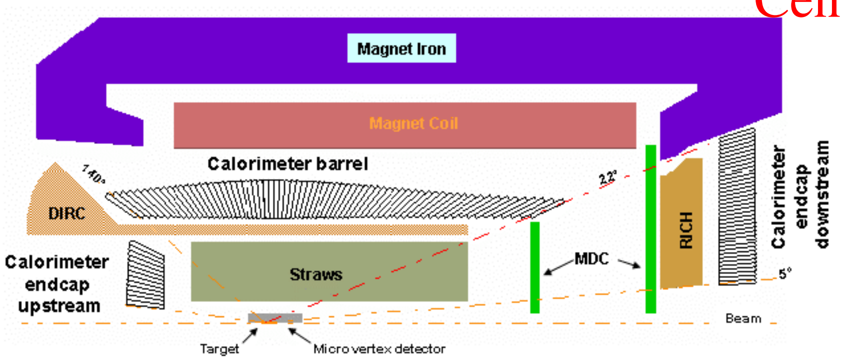
The PANDA detector : the EM calorimeters

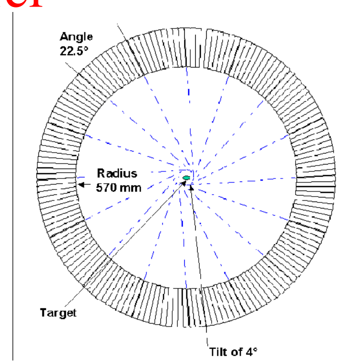
EM calorimeter located
in three positions :
central barrel
end caps
forward



Required fast, high resolution, radiation hard scintillator for γ between 20 MeV - 4 GeV
Presently favored solution : $PbWO_4$ (PWO) crystals 2×2 cm² × 22 X_0 read out by APD's used for the presence of strong magnetic field. Expected resolutions of < 2%/√E + 1%

Central Barrel





Barrel : 2.5 m long, 0.54 m radius, 11360 crystals
upstream end cap : 0.34 m radius,
816 crystals, segmentation in 16 slices

downstream end cap : 1 m radius,
6864 crystals

Charm Quark Spectroscopy

- Charmonium
  - Precision spectroscopy of charmonium ($c\bar{c}$) spin–singlets, $\eta_c(1^1S_0)$, $\eta_c'(2^1S_0)$, $h_c(1^1P_1)$, which were only recently discovered at CLEO
  - High resolution spectroscopy above $D\overline{D}$ threshold, at 3.73 GeV. Identify narrow radial excitations and higher charmonia.
  - Spectroscopy of open charm ($c\bar{u}$, $\bar{c}d$, $\bar{c}s + c\bar{s}$)
- Glueballs and Hybrids

Advantages:

- Expect 1.5 fb^{-1} luminosity/yr (FNAL$\times 10$)
- $\Delta p/p \approx 10^{-5}$ (FNAL/10)
- Charged particle identification (FNAL – none)
- Hermeticity $> 90\%$ (FNAL – $< 50\%$)

Cascades

- The only mention of cascades in the present program is in relation to hypernuclear physics
- The main goal is to study $\Lambda\Lambda$ hypernuclei (only 6 known)

$$\begin{aligned} p\bar{p} &\rightarrow \Xi^-\overline{\Xi}^+ \\ \Xi^- + {}^{A}Z &\rightarrow {}^{A+1}_{\Lambda\Lambda}(Z-1)^* \rightarrow {}^{A+1}_{\Lambda\Lambda}(Z-1) + \gamma \rightarrow {}^{A+1}(Z+1) + \pi^+\pi^- \end{aligned}$$

Anticascade is used as tag. γ's detected with high resolution Ge detector, and $\pi^+\pi^-$ in main detector.

$$\begin{aligned} \sigma(p\bar{p} \rightarrow \Xi^-\overline{\Xi}^+) &= 2\ \mu\text{b at } \sim 3\ \text{GeV}/c \\ \sigma(\bar{p}A \rightarrow \Xi^-\overline{\Xi}^+) &= A^{2/3}\sigma(p\bar{p} \rightarrow \Xi^-\overline{\Xi}^+) \end{aligned}$$

using ${}^{12}C$ wire target expect $\sim 700\ \Xi^-\overline{\Xi}^+/$sec.

- Can certainly do cascade spectroscopy, all the way to $\Xi(2500)$. $\Lambda\overline{K}$, $\Lambda\pi$, $\Sigma\overline{K}$, $\Sigma\pi$ decays can be measured with precision.
- Need enthusiasts to put it on the map for 2014.