Spectroscopy with Antiprotons

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CERN

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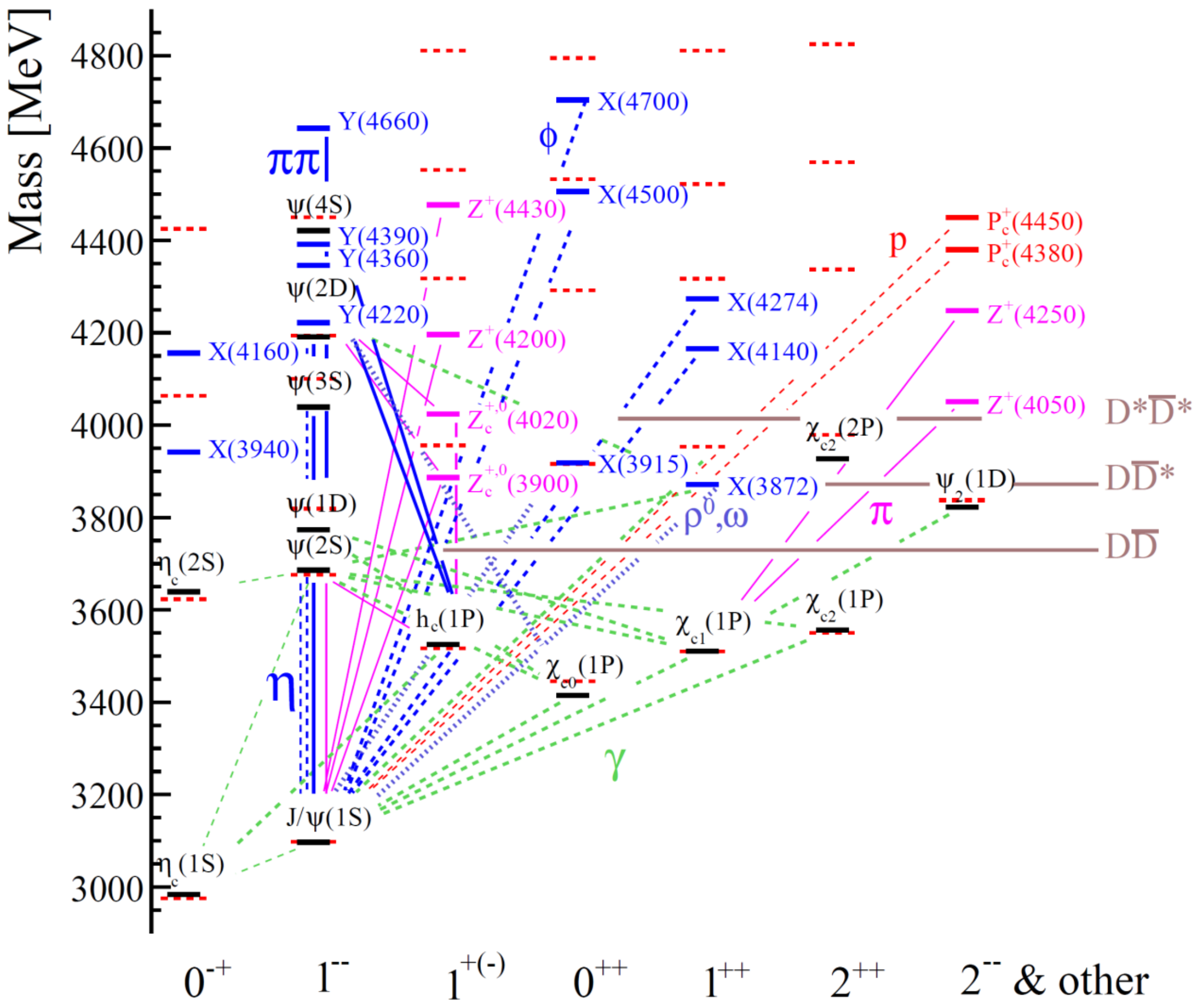
Charmonium Spectrum



Quark model:

- SU(3)$_{flavor}$:

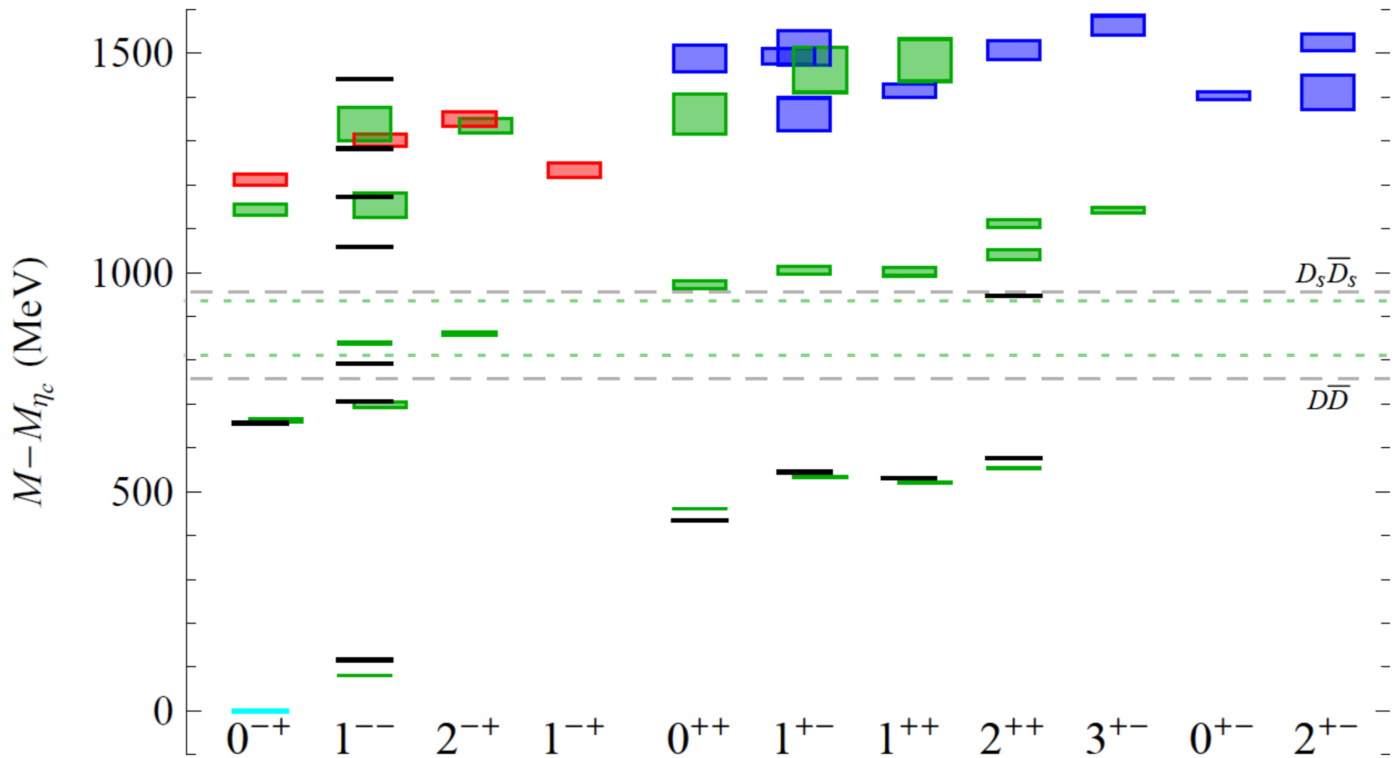
$$q \otimes \overline{q}' = 3 \otimes \overline{3} = 8 \oplus 1$$

- color singlets

- Many new (narrow) states discovered in recent years
- Assignment not clear
- Some definitively not charmonium-like

[S. Olsen et al., Rev. Mod. Phys. 90, 015003 (2018)]

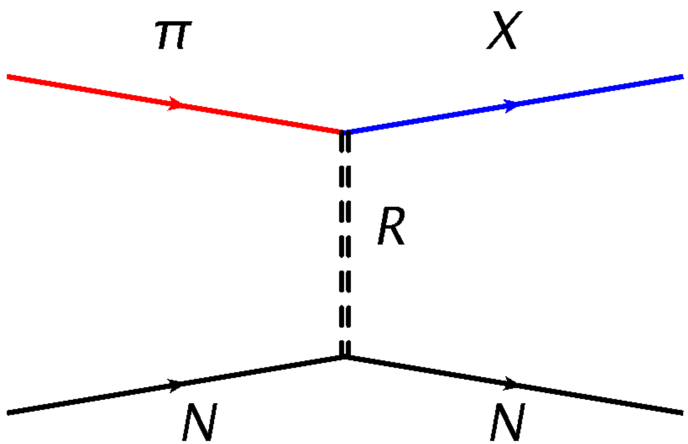
Lattice QCD

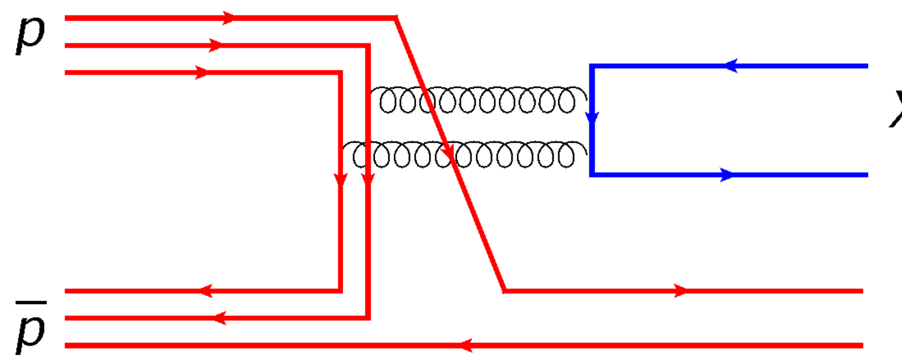


- Unphysical pion mass: 400 MeV
- No decays
- May still be used as guidance, e.g. pattern for Hybrids

[Hadron Spectrum Coll., L. Liu et al., JHEP 07, 126 (2012)]

Production Mechanisms





Diffraction

E852, VES, COMPASS

- light mesons
- exotic states: multi-quark, hybrids

Antiproton annihilation

E760, E835, Crystal Barrel (PANDA)

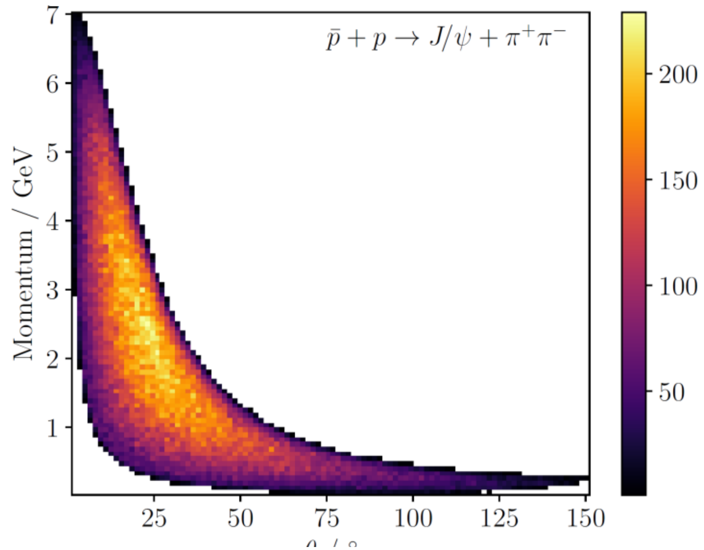
- charmed mesons, high-spin states
- exotic states: multi-quark, hybrids, glueballs
- production cross sections

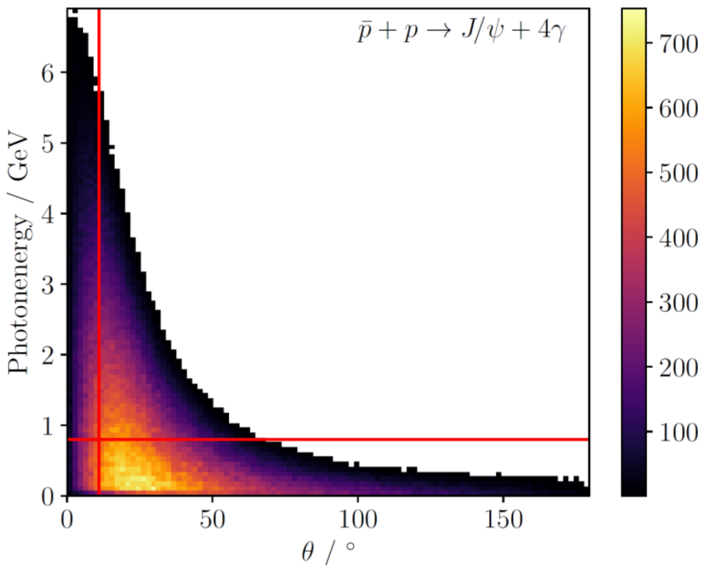
Monte Carlo Simulations

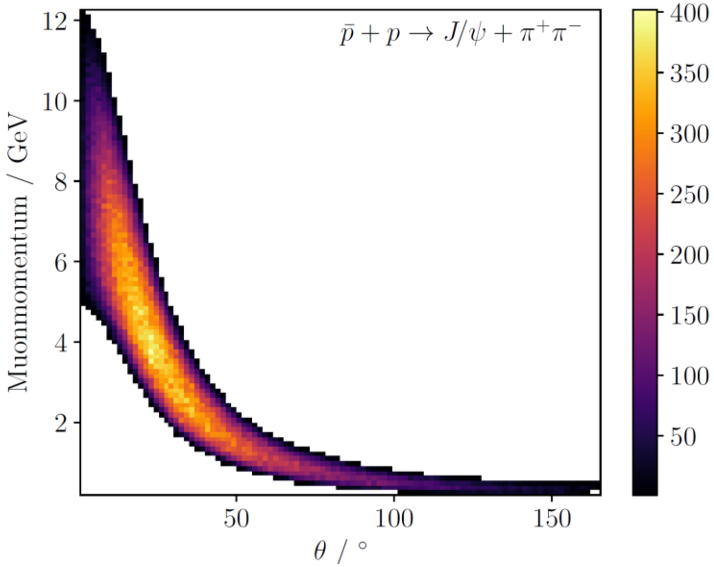
1. $p\bar{p} \to \pi^- Z_c^+(4430)$, with $Z_c^+ \to \pi^+ J/\psi$,
2. $p\bar{p} \to \pi^0 Z_c^0(4430)$, with $Z_c^0 \to \pi^0 J/\psi$,
3. $p\bar{p} \to \eta h(4300)$, with $h \to \pi^0 \pi^0 J/\psi$ (fictitious $c\bar{c}$ hybrid at 4.3 GeV) and $\eta \to \gamma\gamma$,

- beam momentum: 12 GeV/c
- $J/\psi \to \mu^+\mu^-$

Monte Carlo Simulations







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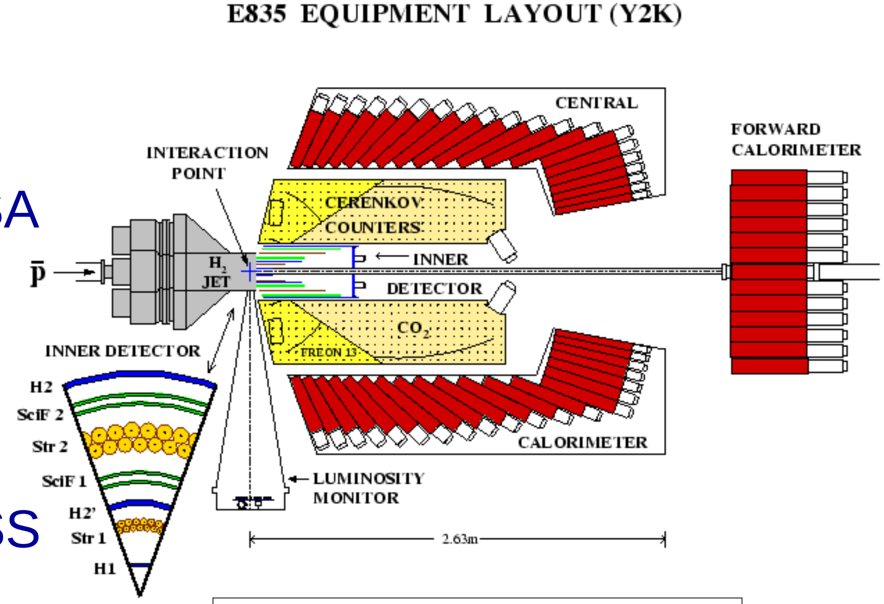
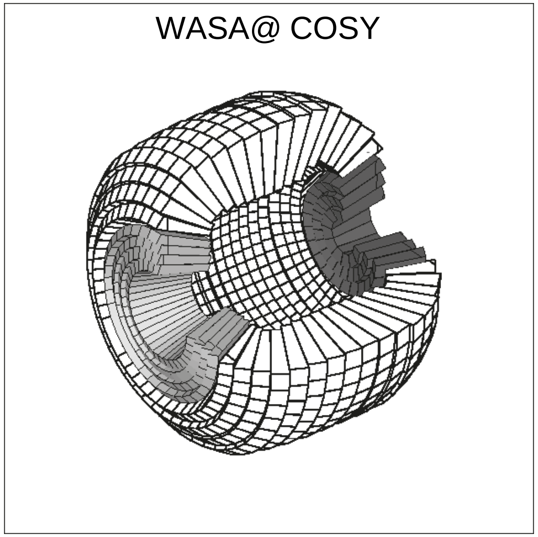
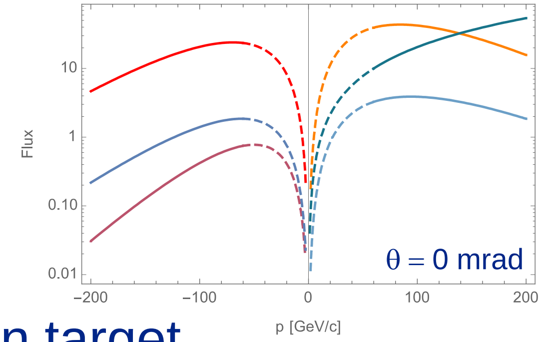
Setup

- Target spectrometer a la E835, WASA
  - charged-particle tracking
  - identification of particles
  - electromagnetic calorimeter
- Forward spectrometer a la COMPASS
  - ECAL0
- Trigger:
  - dimuons
  - dielectrons





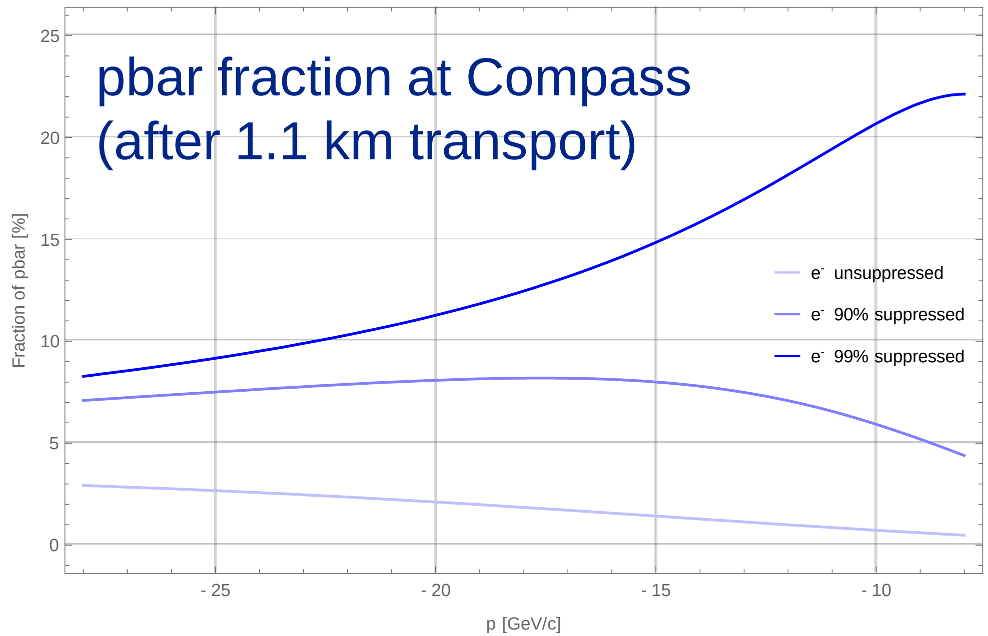
Antiproton Beams

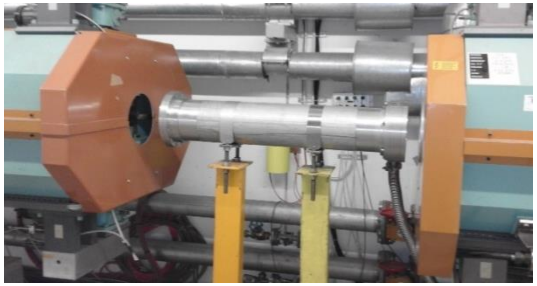


- Production of Antiprotons not an issue
  - Atherton parameterisation for 20 GeV/c: 0.41 pbar / int.proton / GeV / steradian
  - Solid angle $\pi \cdot 10^{-5}$
  - Assume target efficiency of 40% and 10^{13} ppp on target
  - Assume 2 GeV/c momentum bite
  - Particle flux: $0.4 \cdot 10^{13} \cdot 0.41 \cdot \pi \cdot 10^{-5} \cdot 2$ pbar = **10^8 pbar per pulse** (half for 12 GeV/c beam)
- Note: e^- needs to be well filtered by including a lead degrader
- For RP limit of 10^8 on total flux, maximum antiproton flux limited mainly by purity, hence upper limit of
  - **1.8 10^7 pbar per pulse for 12 GeV/c**
  - **1.1 10^7 pbar per pulse for 20 GeV/c**

Antiproton Beams

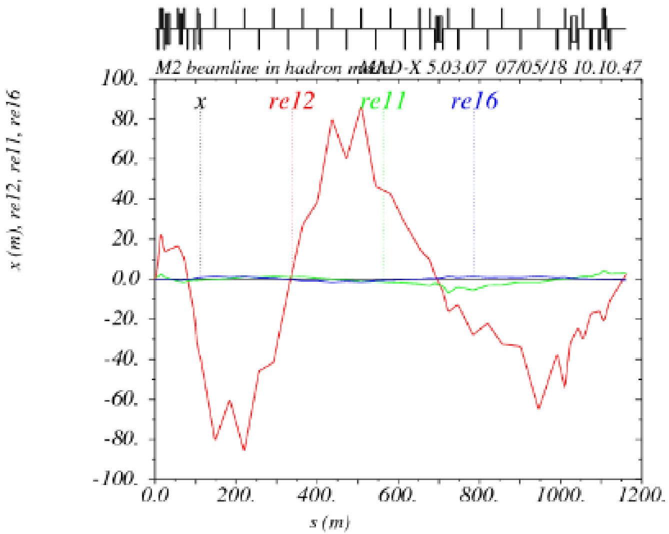
- M2 mainly optimised for muon beams (e.g. rather flat tunnel, scrapers)
- Expected transmission losses: Vacuum not complete, 80 m missing
- Initial cost estimate for vacuum pipes: 90-110 kCHF
- Replace Collimator 5 by XCHV (vacuum)
- Remove absorbers in Bend 4, install vacuum pipe
- Time for installation: Order of a few weeks

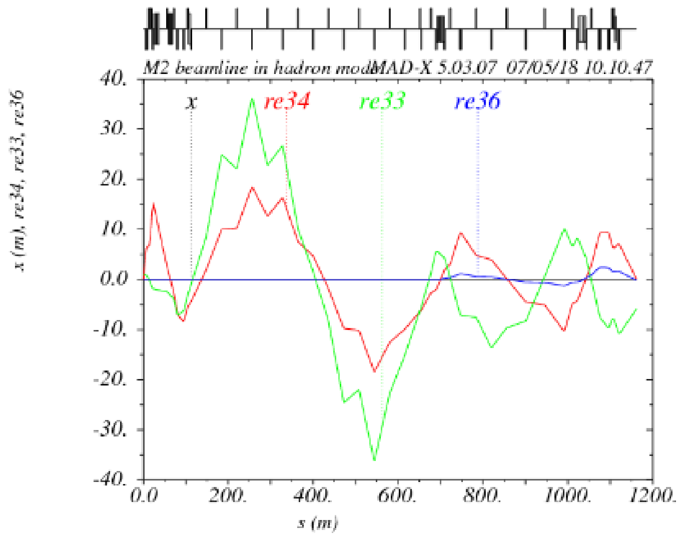




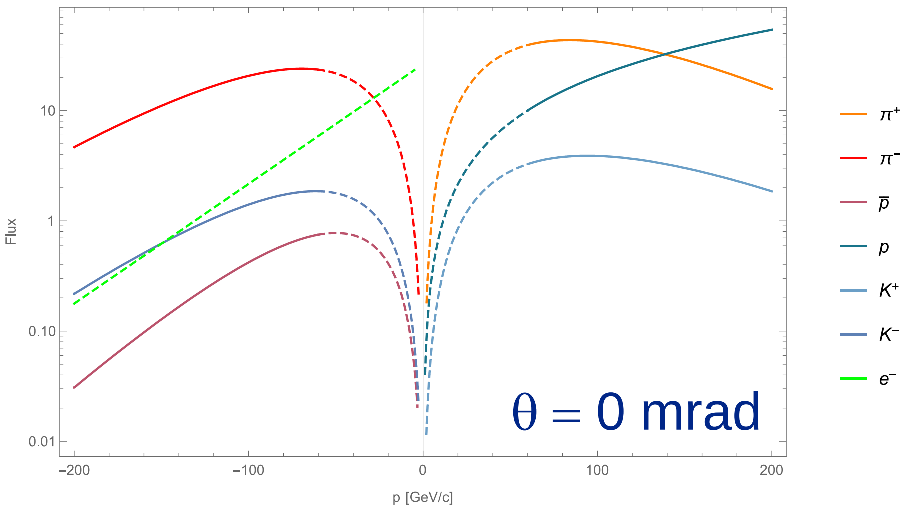
Antiproton Beams

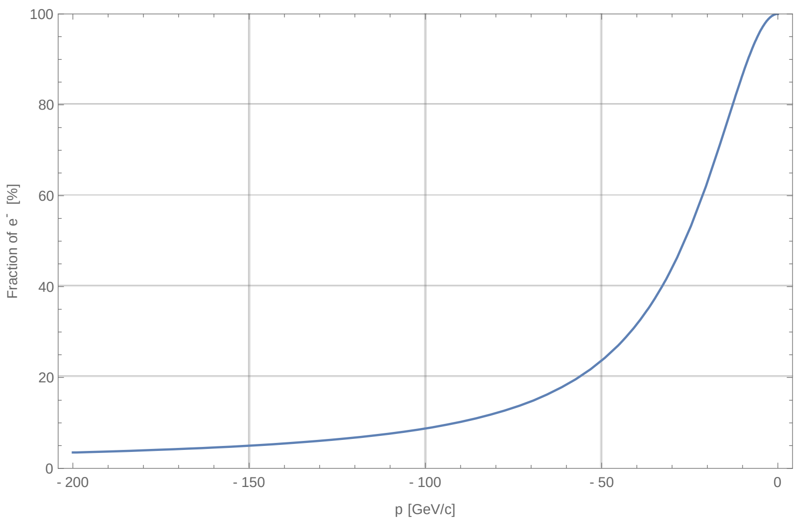
- Further optimisation of beam PID: Either dedicated CEDAR with new optical system and radiator gas for low momenta (cost to be studied) or new threshold Cherenkov with large area photo detector (e.g. ThickGEM or LAPPD-like), study to be launched end of this year
- New optics, try improve parallelism at CEDARs and try to enlarge acceptance by changing frontend optics (e.g. DDFF-D to FDDFFD)





Thank you!





Monte Carlo for e^- production:

- Process $\pi^o = (\pi^+ + \pi^-)/2$, $\pi^o \rightarrow \gamma\gamma$
- $x=E_e/E_\gamma$ with $f(x)=x^2+(1-x)^2+2x(1-x)/3$

Extrapolation from CERN West Area experience:

- e^- about 8% of beam at -120 GeV/c ($\theta = 0$ mrad)

Possible reduction:

- Thin Pb sheet in strong focus (degrader)
- Drawback: might affect parallelism at CEDARs (Beam PID)