Experiment for direct measurements of short-lived particle dipole moments at LHC

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Definitions (spin ½)

- Electric dipole moment (**EDM**): $\vec{\delta} = d\mu_B \frac{\vec{P}}{2}$
- Magnetic dipole moment (**MDM**): $\vec{\mu} = g\mu_B \frac{\vec{P}}{2}$

with

- μ_B: particle magneton
- d, g: adimensional factors
- $\vec{P}$: spin polarization vector

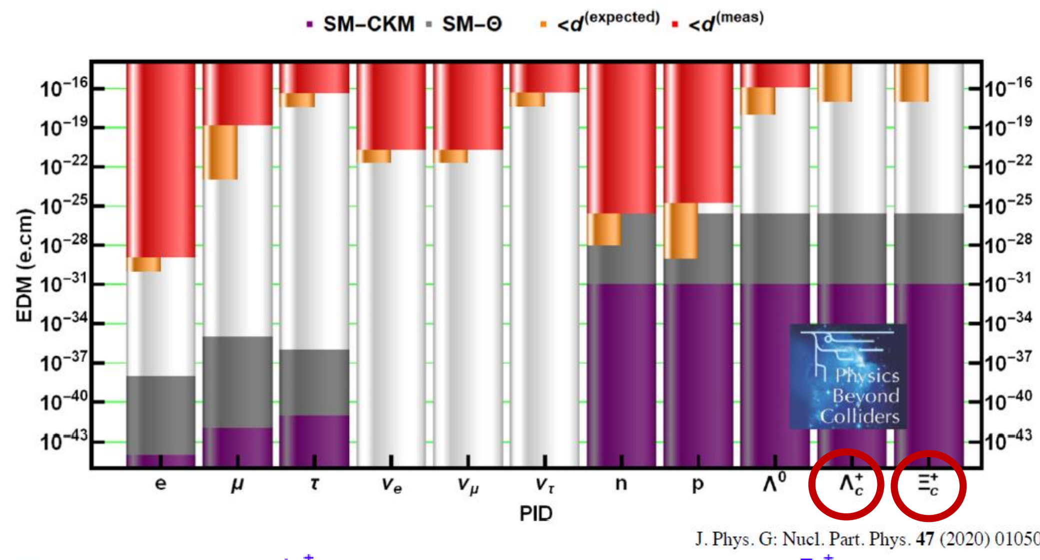
Physics motivation

EDM:

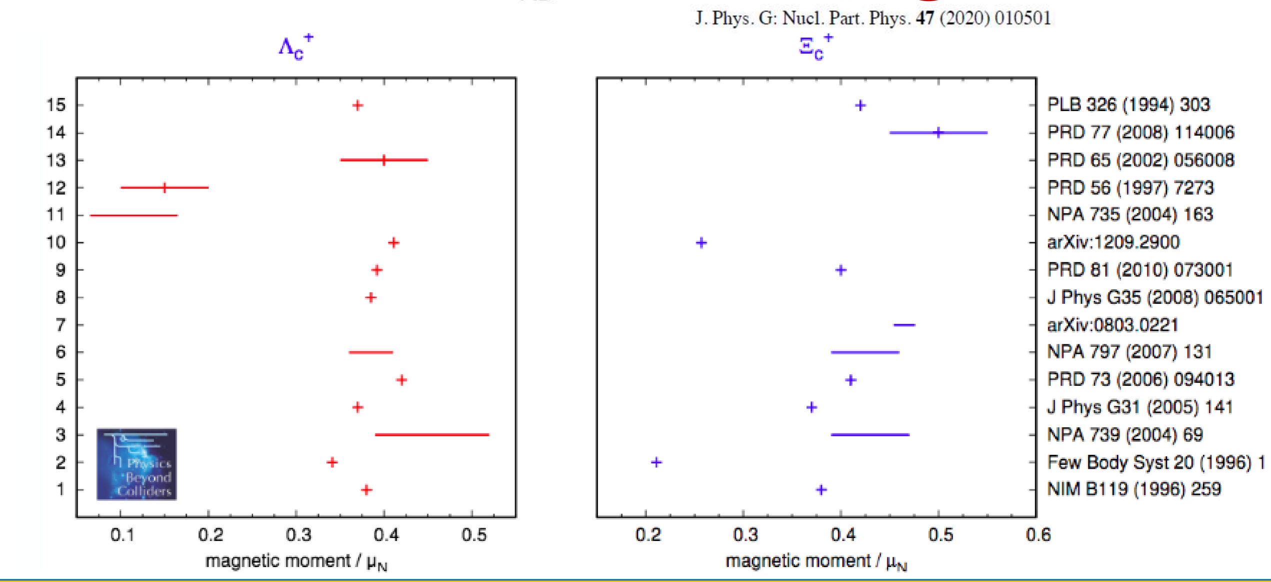
- of an elementary particle violates T and P symmetries → **CP violation** via CPT theorem, new CPV source for baryogenesis
- **flavour-diagonal** source of CPV → new physics **beyond the Standard Model**

MDM:

- probes **baryon substructure**
- particle and antiparticle MDM→ **CPT test**



No direct measurement for charm hadrons up to date [1, 2]



Experimental method

Spin precession in **bent crystals**

- Large electric field between crystal planes, effective B ≈ 500 T [3,4]

The **decay angular distribution** is sensitive to the polarization [5,6]:

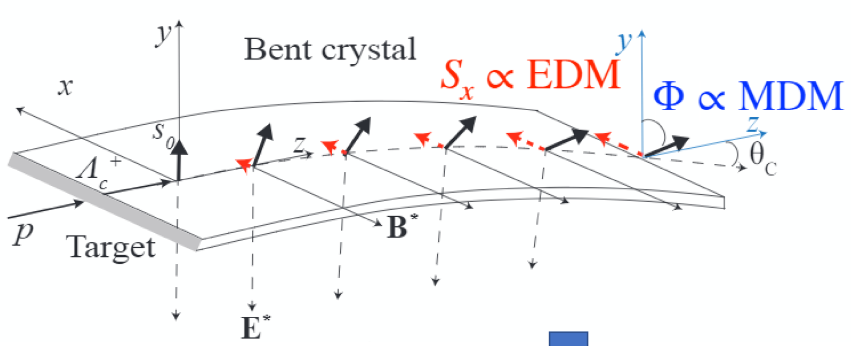
- Spin precession angle sensitive to MDM:

$$\Phi \approx \frac{g-2}{2}\gamma\theta_C,$$

with θ_C the bending angle

- X component of the spin vector after the precession sensitive to EDM:

$$s_x \approx s_0 \frac{d}{g-2}(\cos\Phi - 1)$$



1. Crystals + target

First crystal similar to those previously tested at LHC [8]

Second crystal tested [9], channeling efficiency >10% for 180 GeV/c pions (compatible with MC simulation). Different length and bending angles, Si and Ge material considered

W target of ≈ 2 cm thickness, taken into account number of particles at target exit and detector occupancy

Goniometer for target+crystal designed: accuracy on position ~ 20 µm, rotation angle ~ 20 µrad

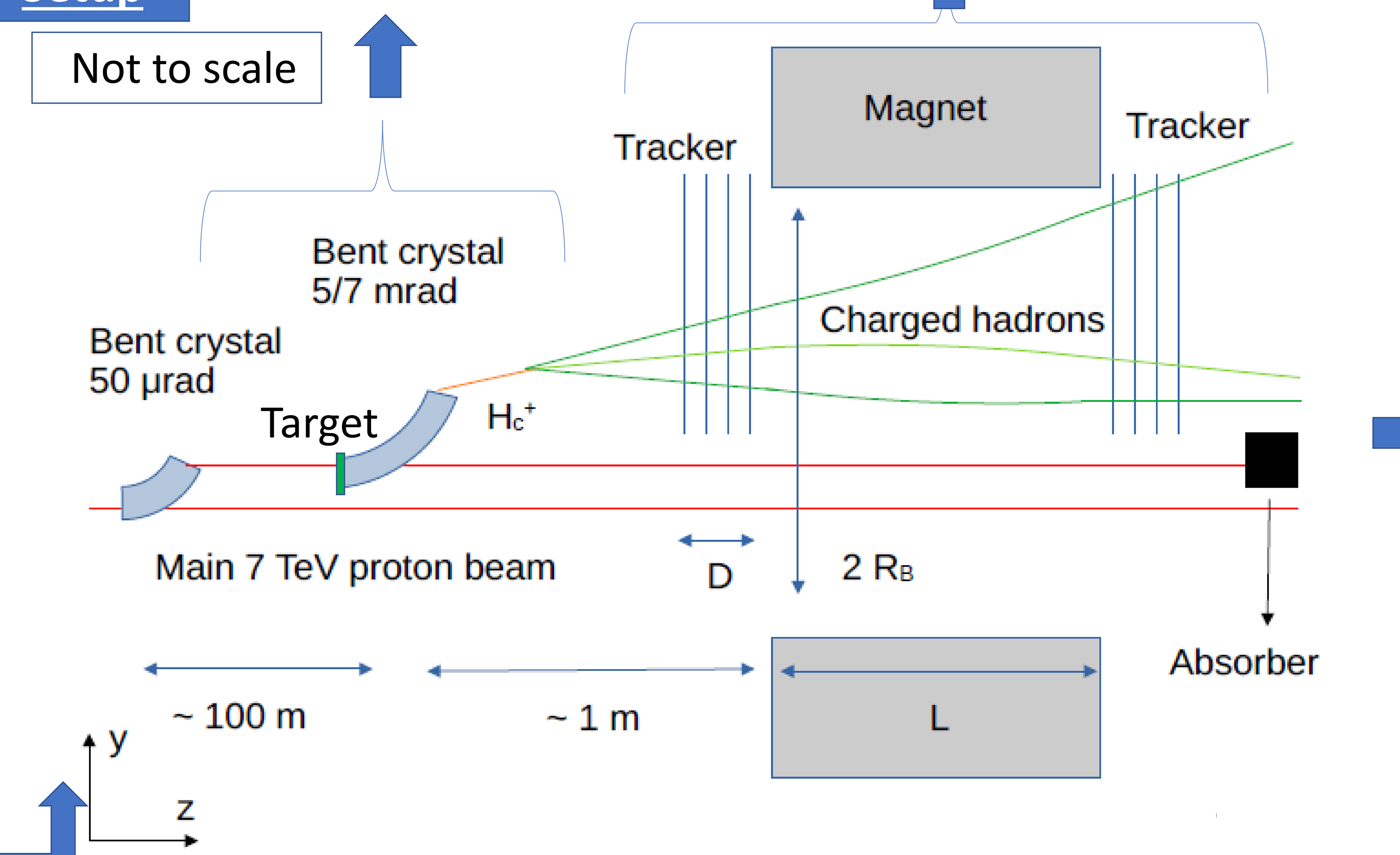
2. Spectrometer option under investigation

Magnet already available at IR3: MCBW, L = 1.7 m, B = 1.1 T

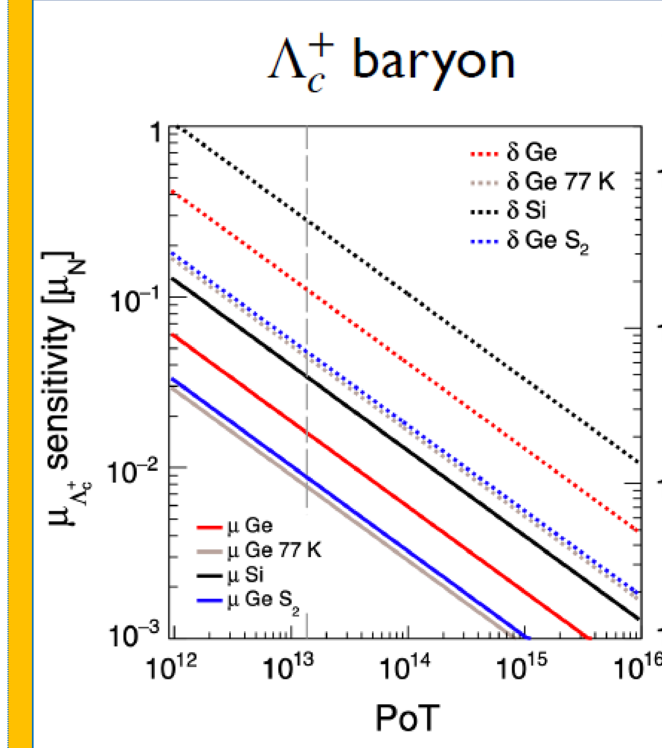
Provides acceptance > 80%

Silicon pixel sensors employed for **tracking**, need to optimize the number of layers and position

Setup



Sensitivity



Expected yields with IR3 test, 7 TeV proton beam, proton flux 10^6 p/s, baryons production spectrum from PYTHIA after channeling through 7 cm length, 7 mrad bent Ge crystal:

- $\mathcal{O}(1000)$ of **$D^+ \to K^-\pi^+\pi^+$** events recordable in 2 days of data-taking
- $\mathcal{O}(1000)$ of **$\Lambda_c^+ \to pK^-\pi^+$** ($\Xi_c^+ \to pK^-\pi^+$) events recordable in less than 2 months of data-taking

10^7 p/s possible with improved extraction technique

Proof-of-principle test at IR3 (LHC)

Goal: **demonstrate feasibility** of an experiment for heavy baryon EDM/MDM measurement

- **Channeling** of charm hadrons with significant yield
- **Reconstruction** with spectrometer based on available magnet
- **Background** characterization

→ several **LHC machine** studies needed

After the test, two possibilities:

i) **fixed-target** experiment at **LHCb**

ii) **dedicated** experiment at **LHC**

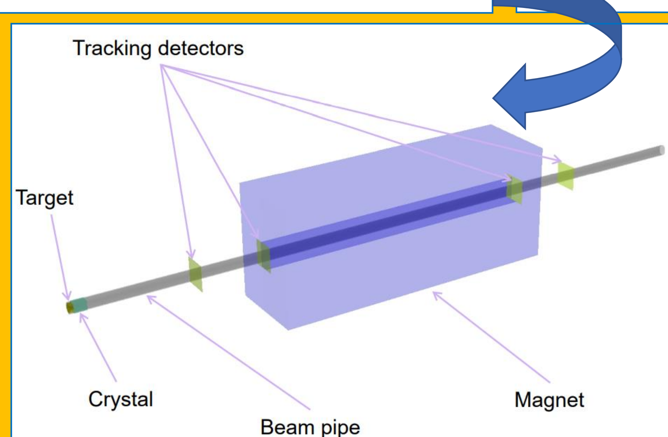
Current status

LHC machine studies ongoing:

- Performed LHC machine layout simulation [7]
- Successful layout test done at SPS. Test in LHC (IR3) possibly during Run3 or Run4
- Channeling of 6.5 TeV at LHC already demonstrated [8]

Decays considered:

- D^+, D_s^+, Λ_c^+ decaying to three charged hadrons
- Charm hadron decays separable exploiting invariant mass resolution, need σ_M < 50 MeV, possible optimizing tracking station length D



Ongoing study

Full simulation with DD4HEP (detector geometry) + GEANT4 to optimize the setup

References

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[5] F. J. Botella et al., Eur. Phys. J. **C** (2017) 77:181

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