Update on crystal channeling simulations

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Sixtrack crystal routine

- Routine developed for **crystal collimation** studies, then integrated in SixTrack (multi-turn simulations)
- Our Monte-Carlo routine based on **analytical and empirical models**
- **Models built, tuned and benchmarked using experimental using** data taken on the H8 extraction line
- **Further benchmarking and prediction** made using experimental data taken on the **SPS and LHC**
  Verify extrapolation to higher energies!
- **Comparisons w.r.t. experimental data** performed in the energy range **from 180 GeV (pions in H8) up to 6.5 TeV (protons at LHC top energy)**
- Routine optimized for the description of planar channeling of positive particles and for $R>3R_c$

Coherent interactions implemented:

- ✓ Planar channeling
- ✓ Dechanneling
- ✓ Volume reflection
- ✓ Volume capture
- ✓ Transition regions

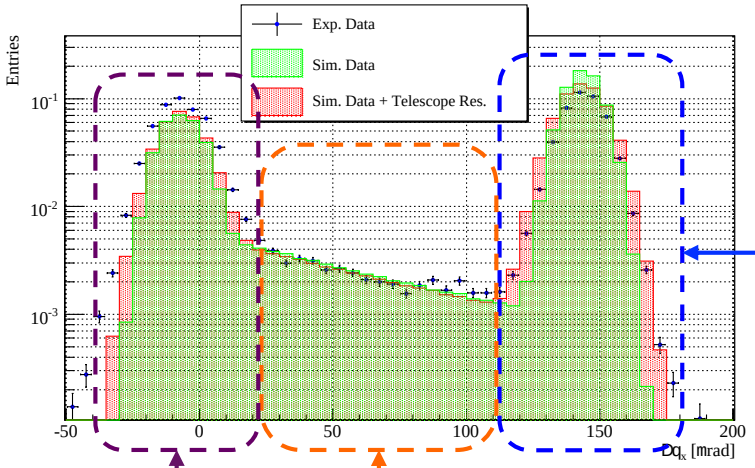
Amorphous interaction treated with scattering routine used for standard LHC collimators, interactions implemented:

- ✓ Energy loss by ionization
- ✓ Multiple coulomb scattering
- ✓ Deep inelastic scattering
- ✓ p-p & p-n & p-N elastic scattering
- ✓ Single diffractive events
- ✓ Rutherford scattering

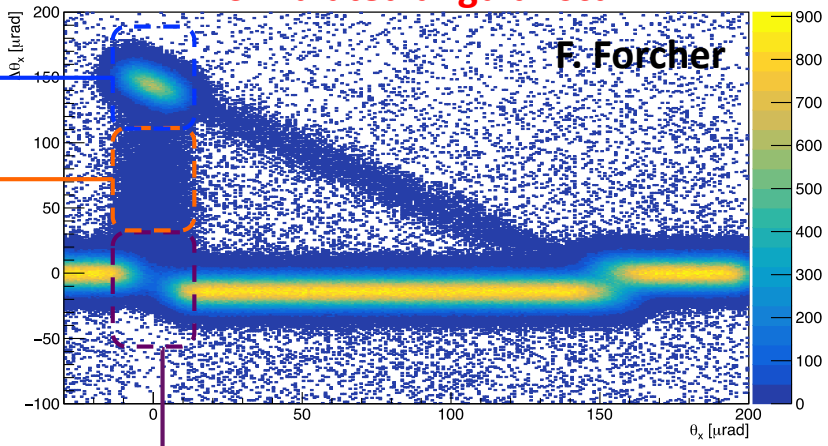
Point-like interactions probability evaluated also for channeled particles with the Sixtrack scattering routine, using cross sections rescaled to average nuclear density between crystalline planes

Crystal routine benchmark

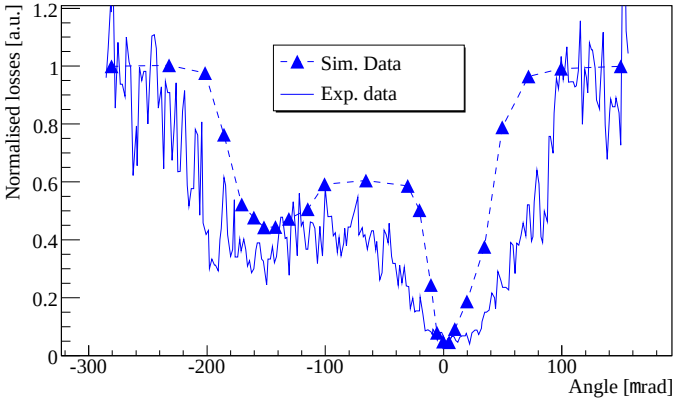
Examples of benchmark using H8 Data using 400 GeV/c proton beams:



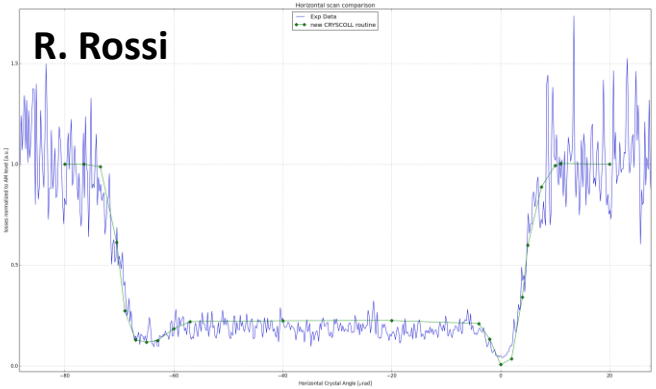
Simulated angular scan



Angular scan at the SPS (270 GeV/c proton beams)

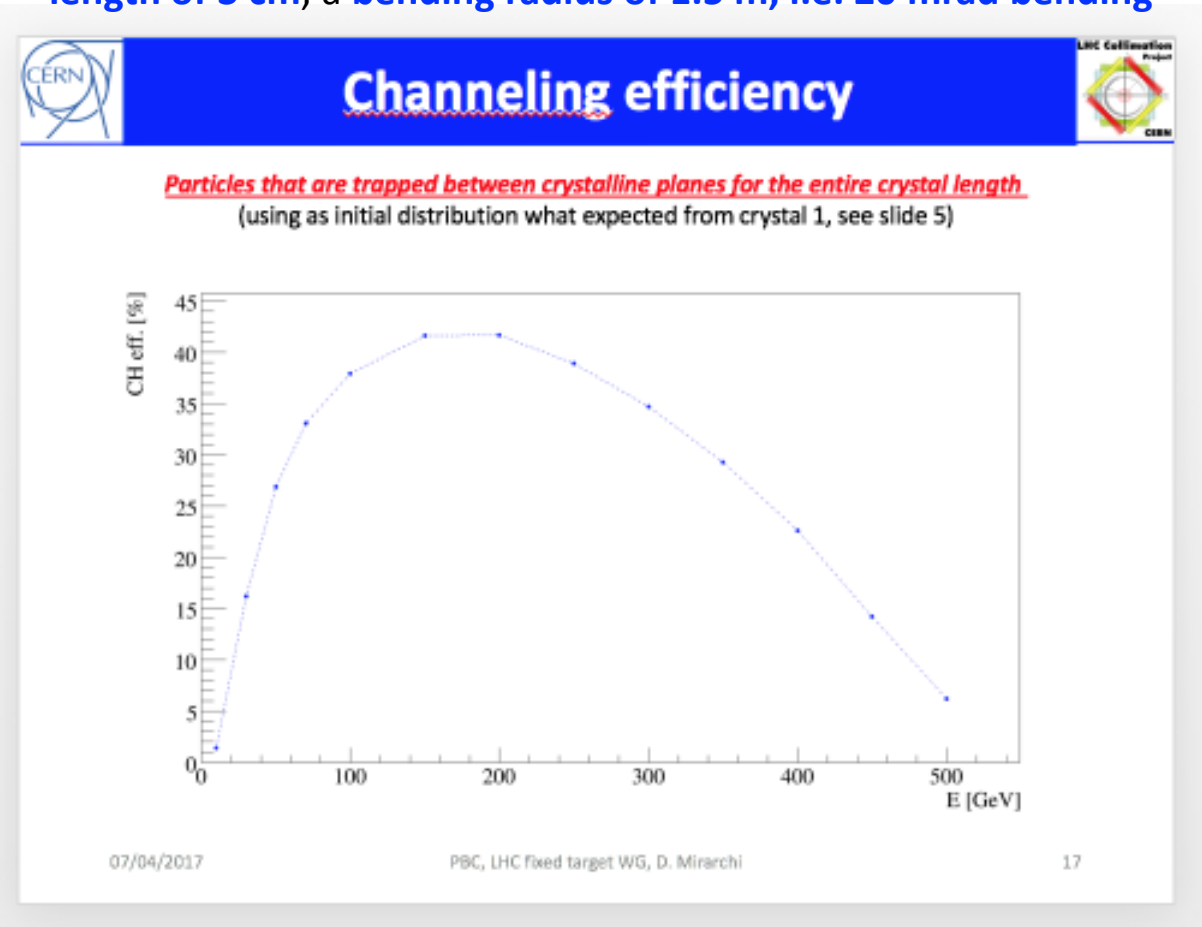


Angular scan at the LHC (6.5 TeV/c proton beams)



Recap from last presentation

Simulated channeling efficiency for a crystal with:
length of 3 cm, a **bending radius of 1.5 m, i.e. 20 mrad bending**

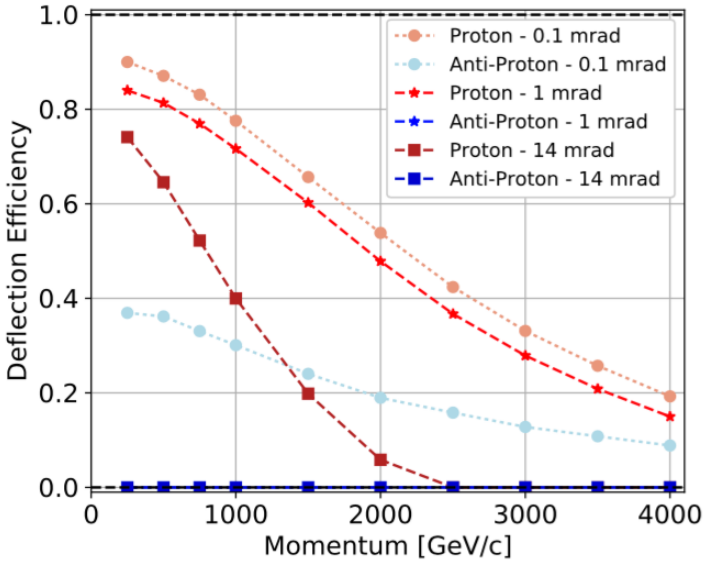


Strong dependence on beam energy: crucial to know spectrum of particles produced in the target in order to ***optimize crystal parameters*** *and to find the best compromise with losses generated around the LHC*

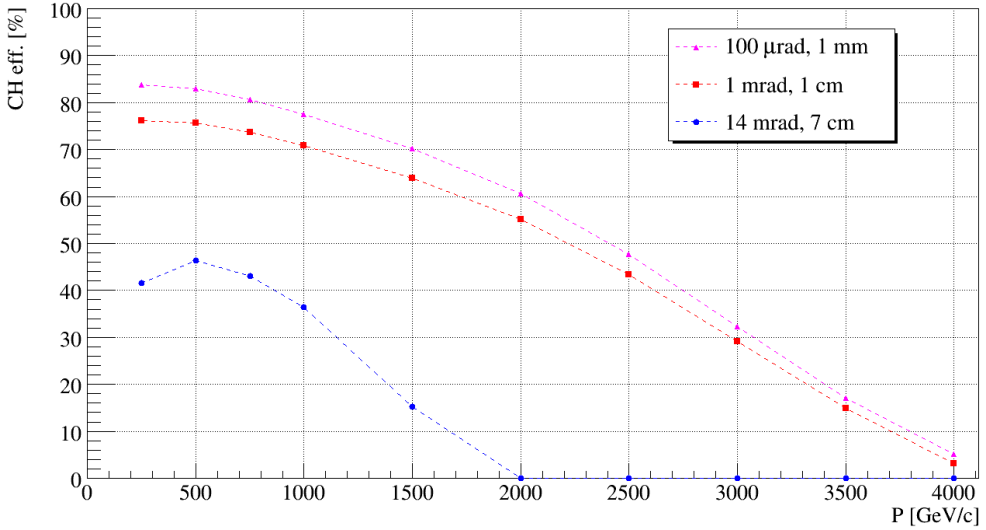
Comparisons w.r.t. estimation by Neri et al.

- Follow up of action: Comparisons against simulations in: Eur. Phys.J. C77 (2017) no.12, 828

N. Neri et al.



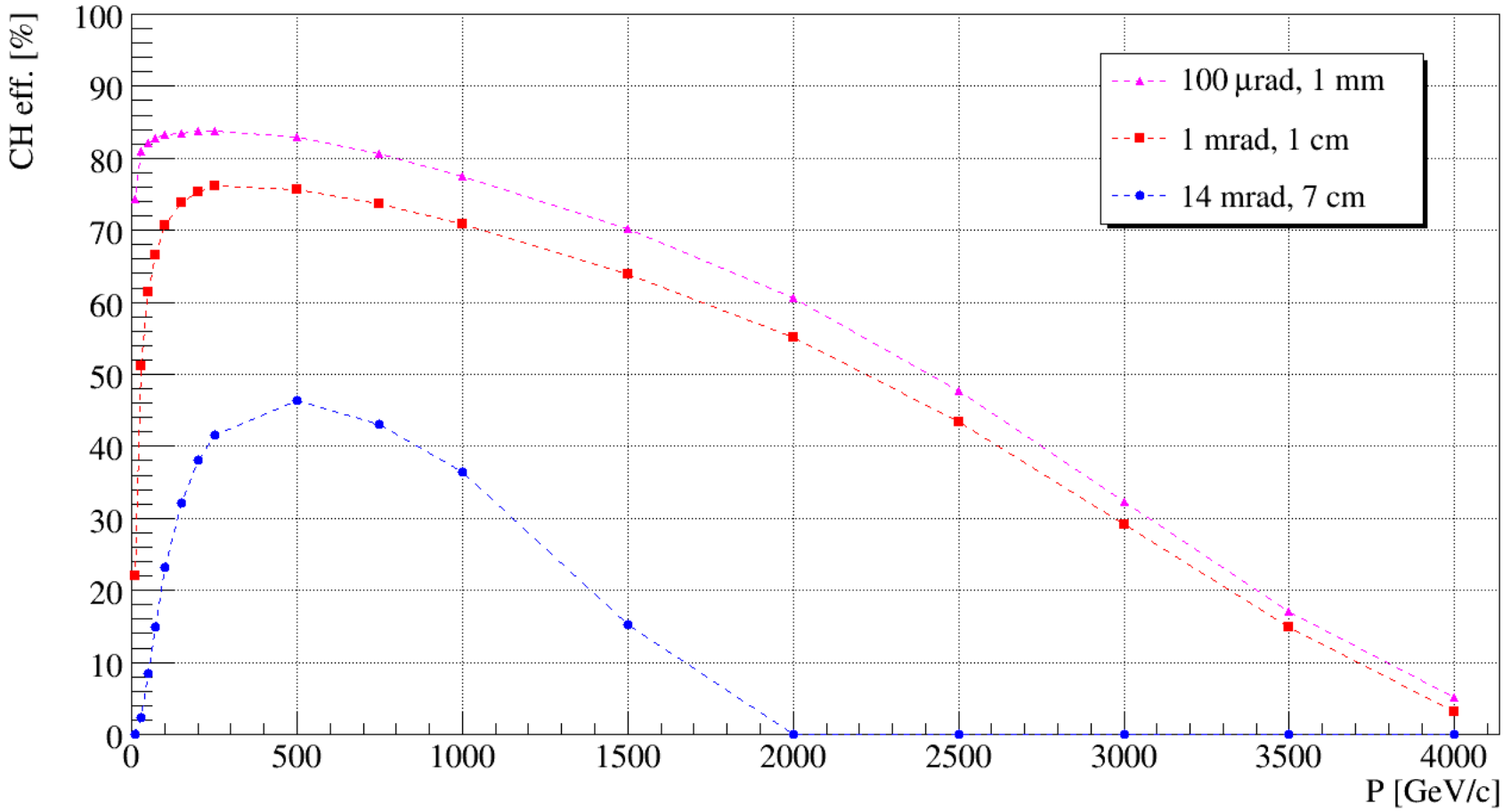
SixTrack simulations (only protons):



- **Qualitative good agreement between the other two crystal cases** (within ~10%)
- **Significant discrepancies for a 7cm-long crystal with 14 mrad bending,** in particular below 1 TeV

Extension to lower energies

Simulations carried out for the same crystals end extended to lower energies



- **May be useful to follow-up from N. Neri et al. side in order to understand why they don't see reduction of efficiency for low energies at fixed crystal parameters?**

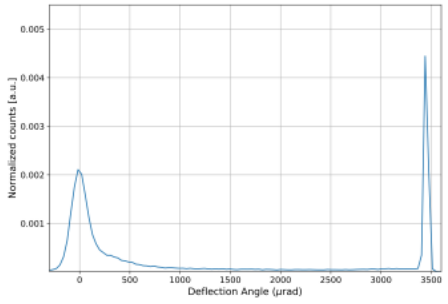
Preliminary comparisons for large bending

- **Recent measurements carried last year in H8 by the UA9 Collaboration**
  - Crystal length: **79.7±0.2 mm**
  - Crystal bending: ~ **3.5mrad**

- *Preliminary analysis results:*

LONG CRYSTAL «PL10» - OCTOBER 2017 – 180 GEV/C PIONS

Angular Cut on Incoming Angle	Mean Deflection Angle (μ)	Efficiency (μ±3σ)
7.5	3453 ± 2 μrad	22 ± 2 %
15	3454 ± 2 μrad	20 ± 2 %



Channeling Angle Variation With Vertical Position	5 ± 2 urad/mm
Torsion	< 2 urad/mm

E. Bagli

- Simulated efficiency using SixTrack: ~ **37.4 %** (angular cut ~15.2 urad = 1 θ_c).
  We understand that the crystal is "to be optimized" (uniformity of curvature, torsion) so there is hope to improve .

Conclusions

- **Crystal routine in SixTrack thoroughly benchmarked at H8, SPS and LHC**
  in the energy range from 180 GeV/c to 6.5 TeV/c

- **Comparisons w.r.t.** simulations reported in the paper **Eur.Phys.J. C77 (2017) no.12, 828** show:
  - ✓ Qualitatively **good agreement for crystals at small/medium bending** (efficiency within ~10%)
  - ✓ **Significant discrepancy for crystals with large bending angle and energy below 1 TeV**
    (~70% (Neri *et al*) vs ~40% channeling efficiency at ~250GeV/c at 14mrad)

- Benchmark of our routine against experimental results to be improved for long crystals:
  - ✓ Preliminary results by UA9 indicate a crystal performance to be improved