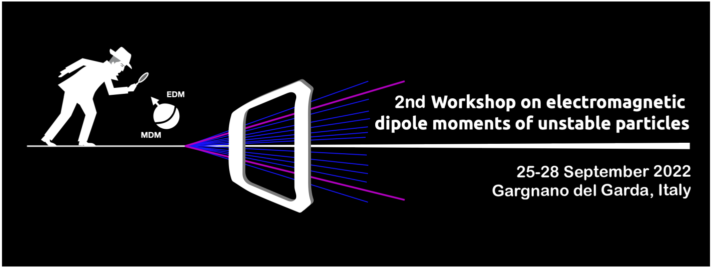
Summary of experimental aspect

Massimiliano Ferro-Luzzi, CERN



Meetings since last report (Jun 2021)

Tuesday, 27 September

09:00 → 11:00 LHC machine and engineering — Palazzo Feltrinelli, Aula Magna
Convener: Stefano Redaelli

- 09:00 **Layout and simulated Performance of a LHC Fixed-Target Test Stand** (30m)
  Speaker: Pascal Hermes (CERN)
  220927_EDM_MDM...
- 09:30 **Goniometer for precision positioning of bent crystals in the LHC** (30m)
  Speaker: Quentin Joel Demassieux
  2022_09_27_Talk.p...
- 10:00 **MD scenarios and operational considerations** (30m)
  Speaker: Daniele Mirarchi (CERN)
  GardaWokshop_DM...
- 10:30 **Non-uniformity of bent crystal curvature: impact on channeling efficiency and mitigation strategy (CANCELLED)** (1m)
  Speaker: Andrea Mazzolari (Istituto Nazionale di Fisica Nucleare)
- 10:31 **Round table discussion** (29m)

11:00 → 11:30 Coffee break (30m) — Palazzo Feltrinelli

11:30 → 13:00 IR3 proof-of-principle test — Palazzo Feltrinelli, Aula Magna
Convener: Pascal Hermes (CERN)

- 11:30 **Overview of the IR3 proof-of-principle test and beyond** (30m)
  Speaker: Elisabetta Spadaro Norella (Istituto Nazionale di Fisica Nucleare)
  Proof-of-Principle te... Proof-of-Principle te...
- 12:00 **Simulations and analysis framework for the IR3 test** (30m)
  Speaker: Han Miao (Institute of High Energy Physics)
  Milano_workshop.pdf
- 12:30 **Geant4 channeling model: current status and perspectives (CANCELLED)** (1m)
  Speaker: Alexei Sytov (Istituto Nazionale di Fisica Nucleare, Sezione di Ferrara; Korea Institute of Science and Technology Information)
- 12:31 **Charged particle tracking and event reconstruction for the IR3 test** (29m)
  Speaker: Jascha Grabowski
  Jascha_Grabowski_...

13:00 → 14:30 Lunch (1h 30m) — Palazzo Feltrin...

14:30 → 16:00 IR3 proof-of-principle test — Palazzo Feltrinelli, Aula Magna
Convener: Elisabetta Spadaro Norella (Istituto Nazionale di Fisica Nucleare)

- 14:30 **VELOpix/Timepix detectors, electronics and DAQ** (30m)
  Speaker: paula collins (cern)
  velo_brescia_2022_...
- 15:00 **Discussion on Letter of Intent** (1h)
  Speakers: All, Nicola Neri (University and INFN Milano)
  Neri_LoI_Gargnano...

16:00 → 16:30 Coffee break (30m) — Palazzo Feltrin...

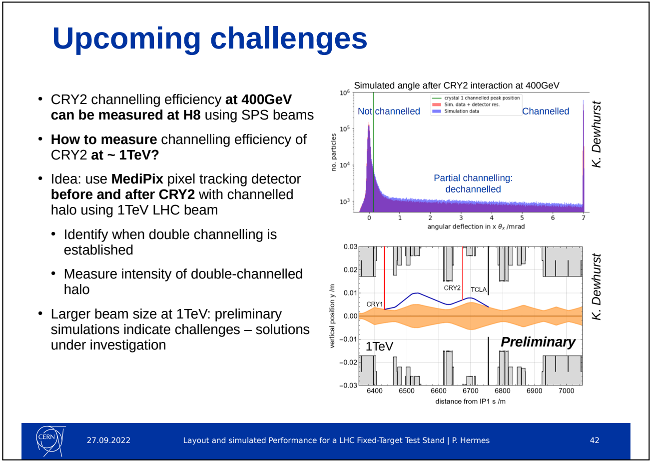
16:30 → 18:00 New ideas and future developments — Palazzo Feltrinelli, Aula Magna
Convener: Daniele Marangotto (Istituto Nazionale di Fisica Nucleare)

- 16:30 **Improved experimental layout with focusing crystals** (30m)
  Speaker: Joan Ruiz Vidal (IFIC-Valencia)
  RuizVidal_CrystalLe...
- 17:00 **Possibility of spin precession in high-field magnet** (30m)
  Speaker: Andrea Merli (Istituto Nazionale di Fisica Nucleare)
  Merli_high_field_ma...
- 17:30 **Developments in dipole magnet technology** (30m)
  Speaker: Massimo Sorbi (Istituto Nazionale di Fisica Nucleare)
  Developments in di...

20:00 → 21:00 Dinner (1h) — Palazzo Feltrin...

Session 5: LHC machine and engineering

SIMULATIONS



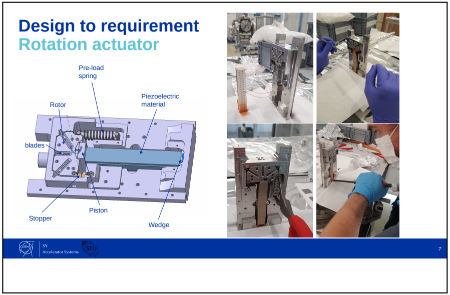
There is a continuous effort on LHC machine simulations

A concrete location has been identified in IR3 and studied.

Brand new (preliminary) simulation results shown for 1 TeV 2-crystal test

Session 5: LHC machine and engineering

ENGINEERING

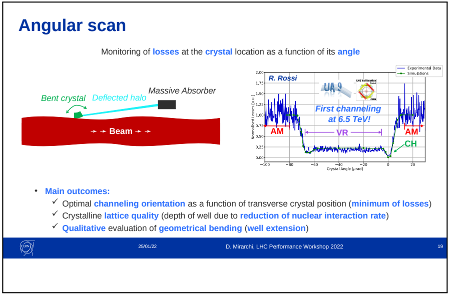


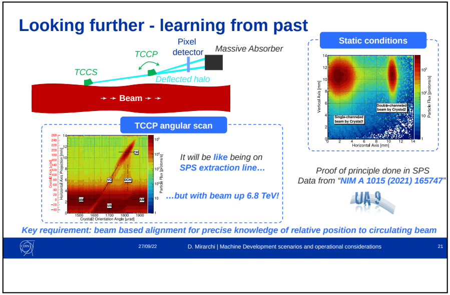
High level of expertise essential for mechanics of crystal
Current (ion) LHC design not compatible with HL-LHC operation (impedance!)
A new design is coming up

My humble opinion: IR3 test stand will be unique → make it "easy" to change crystal!

Session 5: LHC machine and engineering

OPERATION





A lot of preparatory work to make a successful Machine Development test

Many different steps and methods to characterize the crystals in the LHC

$\Rightarrow$ My advice: start drafting an MD program proposal now

Session 6: IR3 proof-of-principle test

DETECTOR SIMULATIONS

Acceptance and invariant-mass resolution

by Giorgia Tonani, Federico Zangari

Spectrometer acceptance

B_x field, for different magnet aperture, bending angle and Si/Ge

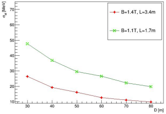
	Si 7 mrad	$R_B = 2\,\mathrm{cm}$	$R_B = 2.5\,\mathrm{cm}$	$R_B = 3\,\mathrm{cm}$	$R_B = 4\,\mathrm{cm}$
MBW	$B = 1.4\,\mathrm{T}$, $L = 3.4\,\mathrm{m}$	0%	0%	0%	14%
MBCW	$B = 1.1\,\mathrm{T}$, $L = 1.7\,\mathrm{m}$	0%	18%	81%	97%

Ge 5 mrad	$R_B = 2\,\mathrm{cm}$	$R_B = 2.5\,\mathrm{cm}$	$R_B = 3\,\mathrm{cm}$	$R_B = 4\,\mathrm{cm}$
$B = 1.4\,\mathrm{T}$, $L = 3.4\,\mathrm{m}$	0%	0%	16%	74%
$B = 1.1\,\mathrm{T}$, $L = 1.7\,\mathrm{m}$	38%	89%	96%	99%

MBCW with good acceptance for $R_{B,x} > 3$ cm

Invariant mass resolution vs tracker length

Invariant mass uncertainty from tracks Si 7mrad



$\sigma_M < 50$ MeV for tracker length D > 40 cm

- MCBW magnet can be considered as a valuable solution
- Si 7mrad, best Cry2 configuration for invariant mass resolution

Rate of Background events

by Federico Zangari

$\text{Rate} = N_{\text{hits}}/cm^2/s$

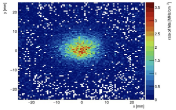
Scaled by the fraction of interacting protons:

Proton flux; Probability of interaction pW

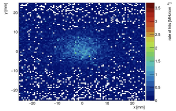
$$\Phi = 10^6 \text{p/s} \left(1 - e^{-\frac{x_W}{\lambda_{I,W}}}\right)$$

x_W = target length, $\lambda_{I,W}$ = nuclear interaction length

Tracker **before** magnet



Tracker **after** magnet



Major simulation effort already done in the last few years ("LHCb")

Recently started developments for detailed IR3 studies

$\Rightarrow$ Define detector for PoP and for future Expt

DETECTOR SIMULATIONS

Geometry

- Simulation is configured by `xml` files
- Geometry (according to Elisabetta Spadaro Norella):
  - Target: W, 2 cm long
  - Crystal2: Si, 7 cm long, 7 mrad
  - Beam pipe: Cu OFE, elliptical form
  - MCBW Magnet: Fe, at 1 m from crystal
    - ✓ B=1.1 T, L=1.7 m
    - ✓ Bore: $R_B(x,y) = (2.6, 7.2)$ cm
  - Tracker stations: 2 blocks of 4 trackers before and after magnet
    - ✓ Si, 300 μm thick, 15 × 15 cm^2
    - ✓ Tracker block length=40 cm
  - (Transition radiation detector (TRD))

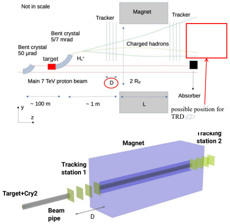


Fig. 2 Upper: A schematic picture of IR3 test; Lower: Geometry in simulation

Channeling process

by Chiara Maccani

- Example in Geant4 has been reproduced in DD4hep
  - Crystal characteristics:
    - ✓ Dimension: 1.0 mm × 70.0 mm × 1.94 mm
    - ✓ Bending radius: 38.416 m
  - Gun:
    - ✓ 400 GeV protons
    - ✓ 100 events

Channeling works correctly in DD4hep

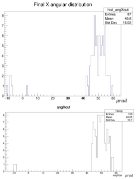


Fig. 5 The distribution of escaping angles. The upper picture is simulated by DD4hep and the lower is from Geant4

13

Framework chosen (DD4hep) and first simple setup implemented

G4 channeling routine activated/tested in DD4hep

DETECTOR SIMULATIONS

Two candidates for track reconstruction framework

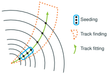
GenFit

- developed for Belle2, focussed purely on the track fitting itself
- tracking geometry by hand or from TGeo
- track propagation and fitting
- no seed finding implementation
- no vertexing

but the devil is in the details!
°requires dd4hep description to have endcap-barrel-endcap structure of general purpose detectors
† assumes cylindrical setup
††not looked into yet

Acts

- developed from ATLAS tracking, providing high-level reconstruction modules "usable in any tracking detector"
- different options to implement tracking geometry (by hand, from TGeo or via DD4hep)°
- track propagation and fitting
- seed finding †
- vertexing ††

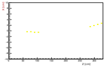


Jascha Grabowski, Sebastian Neubert   Track Reconstruction IR3   22-09-27   6

GenFit First Test

- implement track fitting of truthmatched events (can skip seed-finding step)
- use minimum bias events from full IR3 detector simulation
- build from Miao's IR3 test analysis framework
- implement very basic tracking geometry and ignore material effects

first fits are working!
but still a lot of things to do



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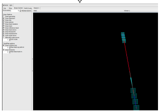


Jascha Grabowski, Sebastian Neubert   Track Reconstruction IR3   22-09-27   7

Exploring ways to get reconstruction tools in the DD4hep IR3sim
Comment: re-use of some of LHCb packages ?

Session 7: IR3 proof-of-principle test

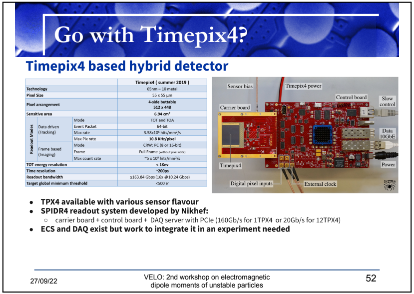
ACTUAL DETECTORS

IR3 PoP: VeloPix or Timepix4 ?

Which readout ?

LHCb-like, Spidr-like, "LHCpix"-like ? ...

Cooling/vacuum: PoP $\neq$ future Expt



Go with Timepix4?

Timepix4 based hybrid detector

			Timepix4 (summer 2019)
Technology			65nm – 10 metal
Pixel Size			55 x 55 µm
Pixel arrangement			4-side buttable 512 x 448
Sensitive area			6.94 cm²
Readout Modes	Data driven (Tracking)	Mode	TOT and TOA
		Event Packet	64-bit
		Max rate	3.58x10⁶ hits/mm²/s
		Max Pix rate	10.8 KHz/pixel
	Frame based (Imaging)	Mode	CRW: PC (8 or 16-bit)
		Frame	Full Frame (without pixel addr)
		Max count rate	~5 x 10⁹ hits/mm²/s
TOT energy resolution			< 1Kev
Time resolution			~200ps
Readout bandwidth			≤163.84 Gbps (16x @10.24 Gbps)
Target global minimum threshold			<500 e⁻

- **TPX4 available with various sensor flavour**
- **SPIDR4 readout system developed by Nikhef:**
  - carrier board + control board + DAQ server with PCIe (160Gb/s for 1TPX4 or 20Gb/s for 12TPX4)
- **ECS and DAQ exist but work to integrate it in an experiment needed**

27/09/22 VELO: 2nd workshop on electromagnetic dipole moments of unstable particles 52

Session 7: IR3 proof-of-principle test

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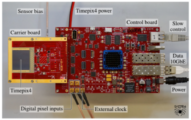

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27/09/22 VELO: 2nd workshop on electromagnetic dipole moments of unstable particles 52

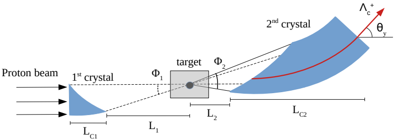
Thank you!

27/09/22 VELO: 2nd workshop on electromagnetic dipole moments of unstable particles 54

CRYSTAL LENSES

Double-lens scheme **(qualitative)**

V.M. Biryukov, JRV, arXiV:2110.00845



Double-lens scheme:

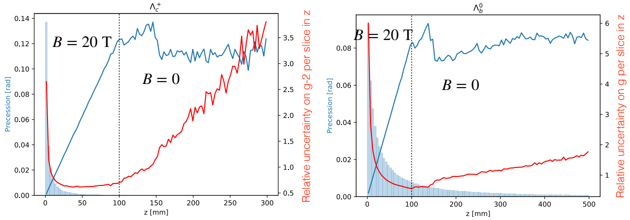
- Additional crystal focusing protons onto the target
- More Λ_c^+ produced at the focal point, or passing through it

Potentially a large gain in stats ($\sim \times 15$)
To be further studied

PRECESSION IN HIGH-FIELD MAGNET

Typical decay length for Λ_c^+ and Λ_b^0

- Charm baryons decay length ~ 10 mm < b-baryons decay length ~ 70 mm



SELDOM Possibility of spin precession in high-field magnet - Andrea Merli 11

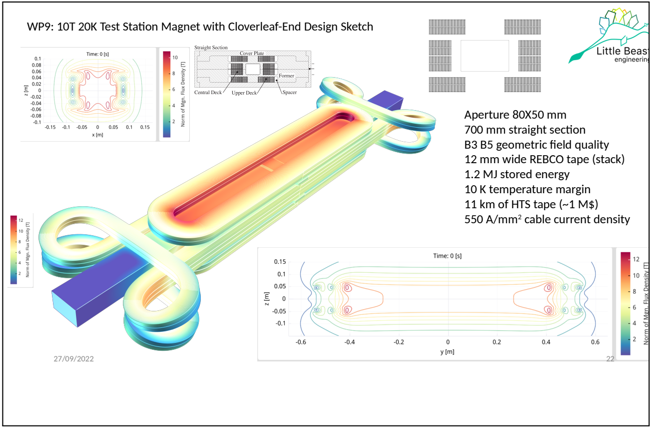
Potentially can do more types of particles than with crystal precession

More stats but less precession, and different angular distributions

To be further studied

Session 8: New ideas and future developments

HIGH-FIELD MAGNETS



The way to 20 T is being paved...

Non-insulated HTS cables

Timescale $\sim$ 10 years

Session 7: IR3 proof-of-principle test

THE WAY FORWARD (as shown by Nicola Neri)

Timeline

- Possible timeline for the experimental proposals in LHCb or for a dedicated experiment

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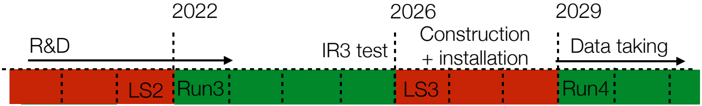

The normal way for LHC experiments: (my addition)

- **Letter of Intent**
- **Technical Proposal**
- **(Technical Design Report)** not seen for FASER/SND