MDI, synchrotron radiation simulations

LHeC beam dynamics meeting

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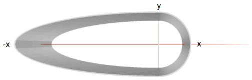
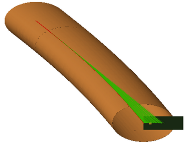
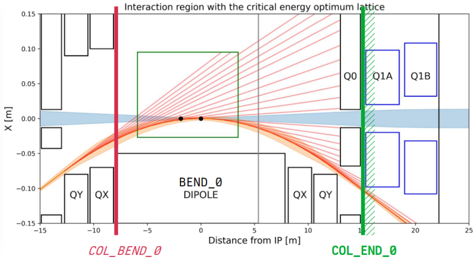
Introduction

Scope: study of the radiated power in all elements of the e/p beamlines

- Simulation tool: BDSIM, sampling at collimators, elliptical beamline (0.5×0.3 cm^2 apertures)
  - standard physics list, with addition of “synch_rad” EM processes
  - developed a circ-elliptic aperture for BDSIM, no difference observed in resulting distributions
  - lattice assumption: critical energy optimum
- in this study, only considering electron beamline (single 50 GeV e^- beam)
  - proton side QX/QY treated as upstream/downstream sector-bends



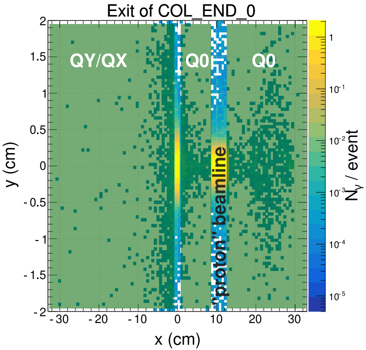


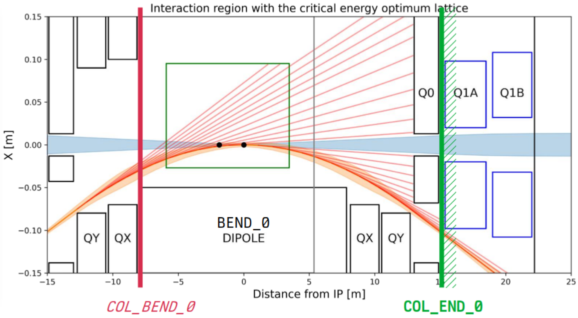


Name	Type	L (m)	Angle (mrad)	S Start(m)	S End (m)
uDRIFT50	Drift	0.5	0.0	0.0	0.5
uDRIFT_Q0	Drift	1.87198	0.0	0.5	2.37198
uDRIFT30_0	Drift	0.3	0.0	2.37198	2.67198
uBEND_QY	SBend	2.17713	2.072436	2.67198	4.8491
uDRIFT20	Drift	0.2	0.0	4.8491	5.0491
uBEND_QX	SBend	2.17713	2.072436	5.0491	7.22623
uDRIFT30_1	Drift	0.3	0.0	7.22623	7.52623/*7.50623*
COL_BEND_0	*R-Collimator*	*0.02*	*0.0*	*7.50623*	*7.52623*
BEND_0	SBend	15.70306	14.947956	7.52623	23.22929
dDRIFT30_0	Drift	0.3	0.0	23.22929	23.52929
dBEND_QX	SBend	2.17713	2.072436	23.52929	25.70642
dDRIFT20	Drift	0.2	0.0	25.70642	25.90642
dBEND_QY	SBend	2.17713	2.072436	25.90642	28.08354
dDRIFT30_1	Drift	0.3	0.0	28.08354	28.38354
dDRIFT_Q0	Drift	1.87198	0.0	28.38354	30.25552
dDRIFT50	Drift	0.495	0.0	30.25552	30.75052
COL_END_0	R-Collimator	0.005	0.0	30.75052	30.75552

$L^* = 15$ m beamline description

Synchrotron radiation at Q1A



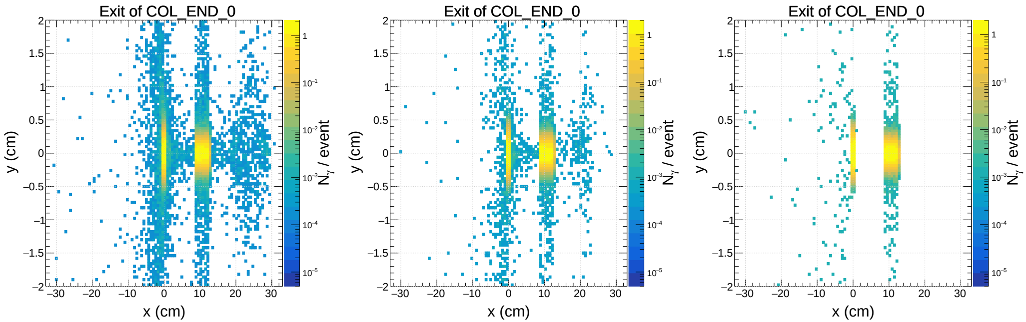


Flux of photons scored right before Q1A, and without collimator ; the $x = 0$ axis refers to the electron beamline coordinate system (i.e. red curve on rhs. figure)

Even without upstream collimator, “scraping” of the high-dispersed outliers already at the Q0 level

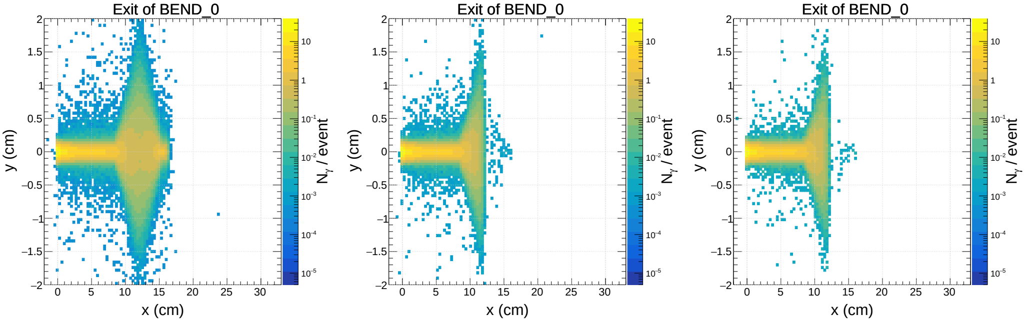
Introducing some shielding – at Q1A

Simulation of upstream shielding layer addition, tested a few thicknesses and materials



Left to right: without collimator, with a 4 cm upstream collimator after QX, with a 10 cm collimator at the same location.

Introducing some shielding – a bit upstream, at the detector area exit



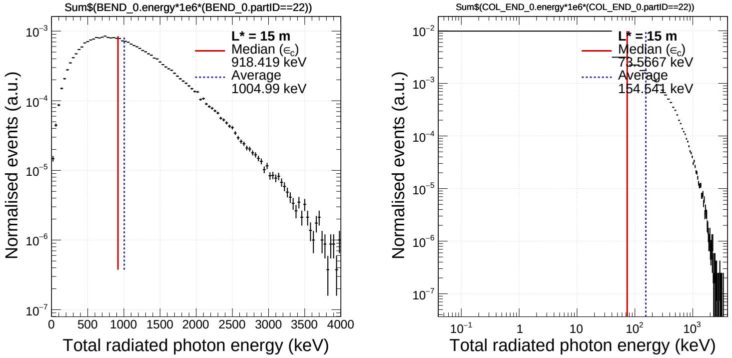
Left to right: without collimator, with a 4 cm upstream collimator after QX, with a 10 cm collimator at the same location.

Critical energy

From geometrical arguments, in a bending dipole

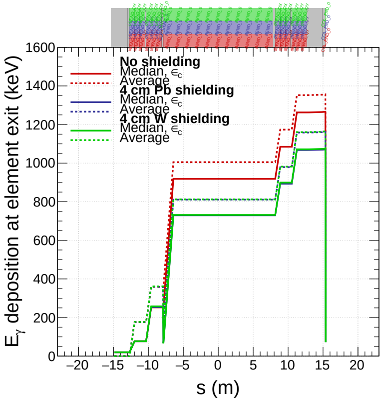
$$E_c = \frac{3c\gamma^3\hbar}{2R} = \frac{3c\gamma^3\hbar B}{2p}$$

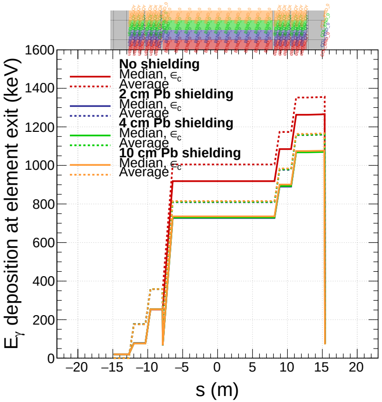
Here, computed as the median of the dN_γ/dE_γ flux distribution:



Photon energy distribution at the exit of two beamline elements: detector “BEND_0” area (left), and right upstream the proton Q1A (right)

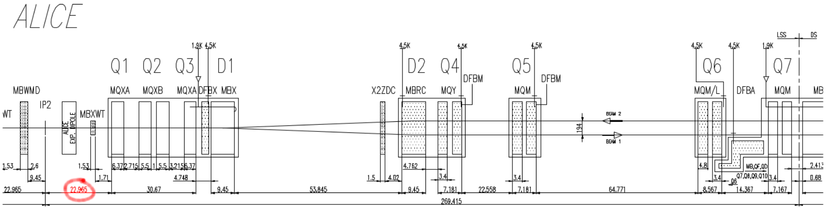
Photon critical energy at the exit of beamline elements





- no difference in critical energy along beamline elements with different assumptions on a shielding introduced upstream the interaction region
- ~flat 15% reduction of critical energy downstream the shielding

From L* = 15 m to 23 m



Source: LHC Design Report, matching section in IR2 – 10.5170/CERN-2004-003-V-1

Larger free drift (half-)length L^* $\longrightarrow$ increased space for experimental apparatuses + TAS/TCL/Qx

Requires a re-optimisation of the full beamline optics & Twiss parameters (K. André):

- **proton side**: no need for extra half-quadrupole
  - addition of two off-centered quadrupoles: Q0F and Q0D
  - increased space for dipole, same “crossing” angle at interaction point
- **electron side**: extra drift between detector dipole & Q1A, amended bending angle to maintain separation parameters

Operational parameters for 15 and 23 m

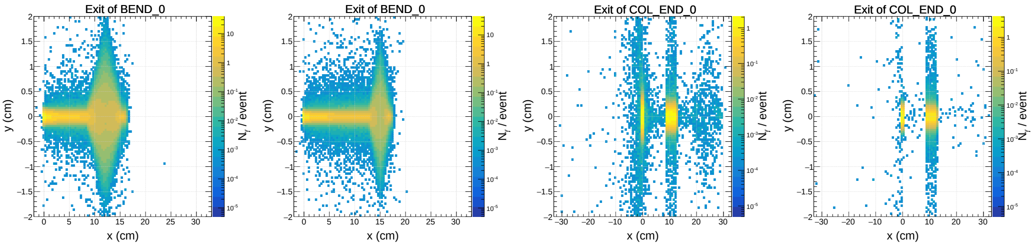
- Re-optimisation (K. André) of the beam & lattice parameters given the released geometrical constraints
  - P_{syn}/ε_c-based minimisation, further optimised for horizontal beam size

Parameter	L^* = 15 m	L^* = 23 m
initial drift	2.672 m	6.739 m
Q0F gradient	30.1337 T/m	29.0116 T/m
Q0F length	2.1771 m	1.8548 m
Q0F angle	2.0724 mrad	0.8347 mrad
Q0D gradient	-18.3684 T/m	-21.8747 T/m
Q0D length	2.1771 m	1.8548 m
Q0D angle	2.0724 mrad	0.8347 mrad
half IR length	7.8515 m	11.9512 m
half IR angle	5.378 mrad	=

Parameter	L^* = 15 m	L^* = 23 m
α_x	-0.0356	-0.0789
α_y	99.9485	6.2794
β_x	0.0905	0.4349
β_y	4881.1939	1699.5161
D_x	0.1337	0.0517
D'_x	0.0122	0.0030
D_y, D'_y	0	=
$\varepsilon_{x,y}$	5×10^{-10}	=
σ_E	0.28 MeV	=

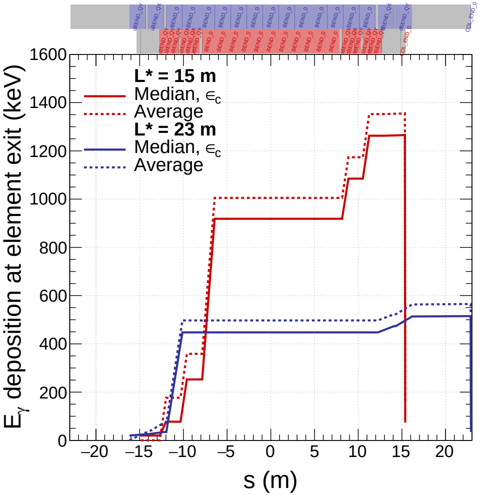
Lattice (left) and beam (right) operational parameters for the two free drift lengths scenarii

L^* and photon hits distributions outside IR/at Q1A



Number of photon hits scored as a function of the free-drift length, at the exit of the detector dipole, and at the Q1A entrance, for $L^* = 15$ m (odd) and 23 m (even).

Photon critical energy at the exit of beamline elements



- Factor 2 reduction observed in critical energy for all major beamline elements
- Moreover, integrated along the full arc:

$$E_c \sim \begin{cases} 272 \text{ keV for } L^* = 15 \text{ m} \\ 139 \text{ keV for } L^* = 23 \text{ m} \end{cases}$$

Summary and discussion

Towards a better understanding of the variables of interest…

Thanks a lot to Kevin for the derivation of beamline + optics parameters ; considering to re-run the minimisation algorithm under other geometrical assumptions on QX/QY?

Still have to re-run large samples production with circ-elliptic beam pipe

Spares