Parametric optimization of the hybrid source using channelling

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Outline

1. General aspect
2. Photons from channelling
3. Amorphous study
4. Summary & conclusions

General aspect (1/2)

- Needs of intense positron sources for the future linear colliders require the creation of a large amount of photons to be converted in a large number of e^-e^+ pairs (converter)
- But at the same time a particular attention to
  - The total energy deposited which needs to be below the fusion temperature
  - The Peak Energy Deposition Density (PEDD) which needs to be below 35 J/g (value based on the result of the SLC damaged target analysis)
- CLIC baseline for positron source:
  - Un-polarized : hybrid solution
  - Polarized : Compton scheme
- What is needed and requested for both sources ?

General aspect (2/2)

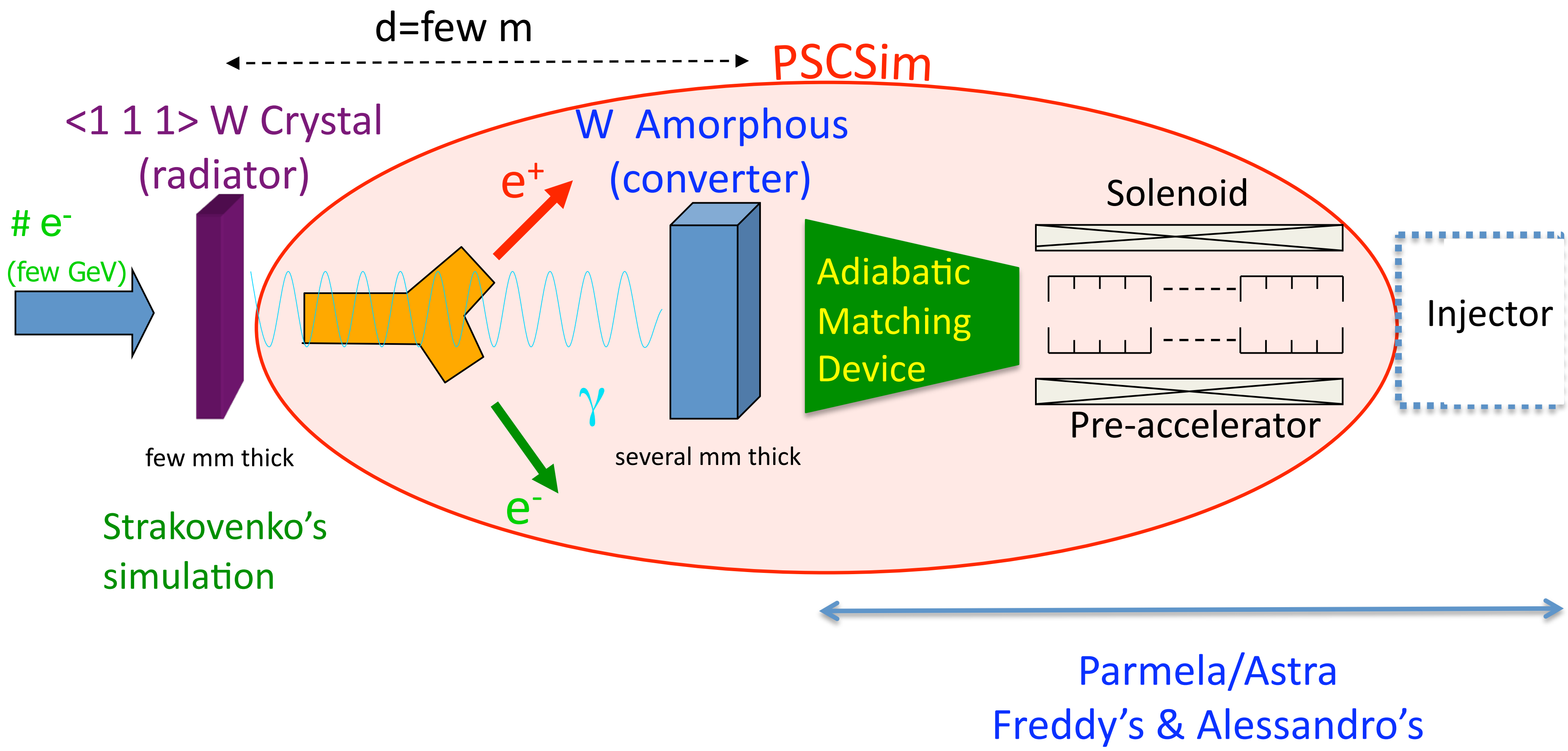
- Positron yield, energy deposition, polarization …
  with respect to : incident beam energy, target(s) thickness(es), #cavities …
- Positrons capture from the target up to pre-damping ring
  – AMD, accelerator, solenoid, bunch compressor …

PSCSim* : Positron Source & Capture Simulation
Geant4 based for target & AMD simulation
(recent progress : solenoid & acceleration up to 200 MeV)

Parmela & (Astra)
see Freddy & Alessandro talk's

*Very recent name, to avoid confusion with PPS-Sim from Desy -Zeuthen (A. Schälicke)

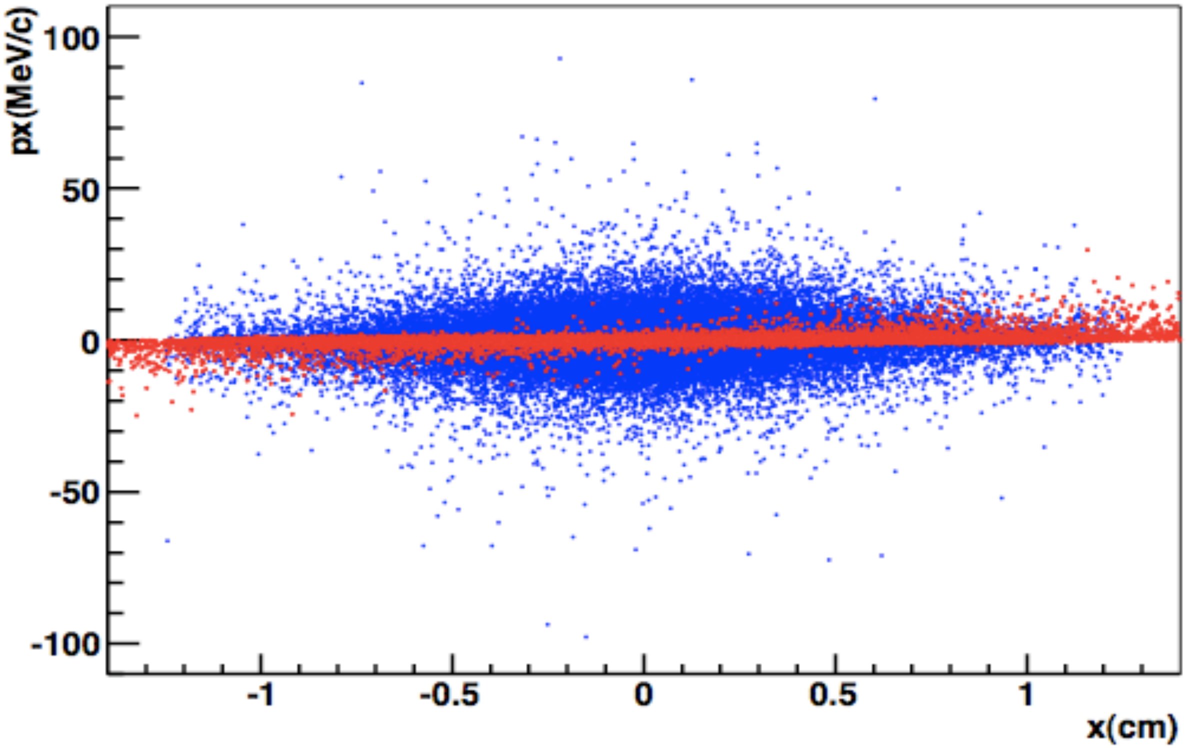
Simulations Overview



AMD effect on positron emittance

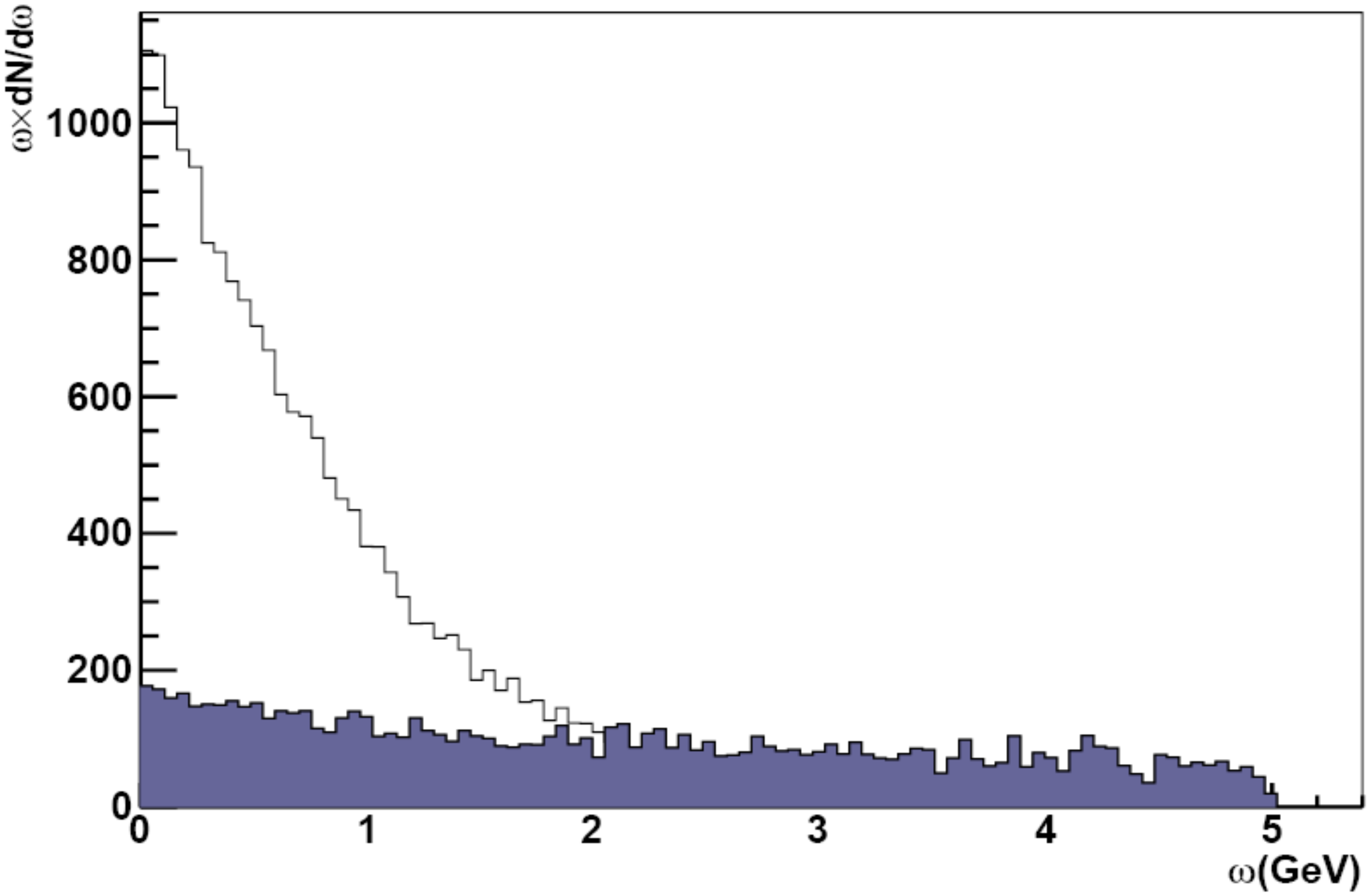
- After the amorphous
  - large angles & small dimensions

- After the Adiabatic Matching Device $$B = \frac{B_0}{1 + \alpha z}$$
  - small angles & large dimensions → easier to transport



Photons emitted in the crystal (1/2)

- At energies of some GeV the electron motion in the axial fields of an aligned crystal : photons + charged particles
  - Enhancement of photon production compared to pure Bremsstrahlung process

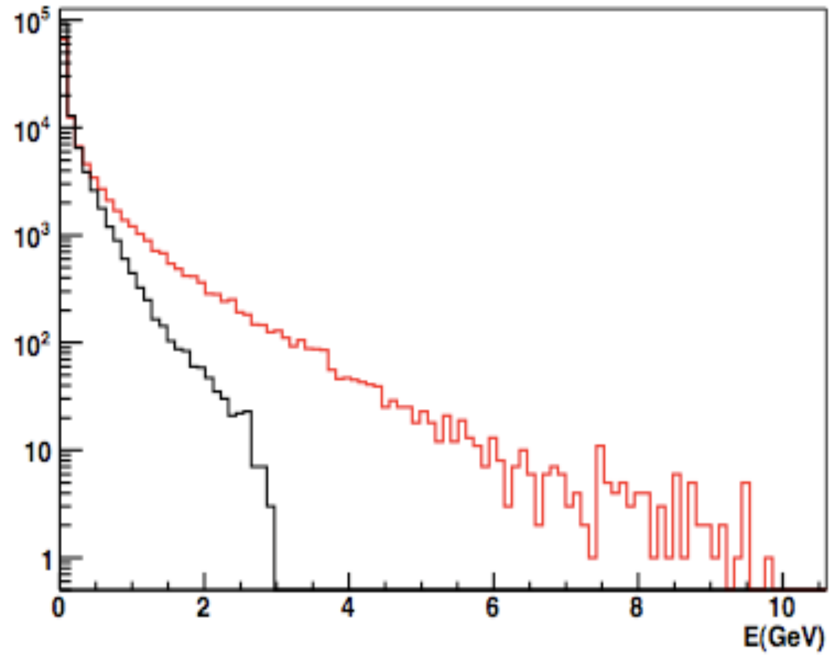


Comparison of photon spectra for crystal and amorphous target of 1.4 mm, incident electron energy 5GeV

Photons emitted in the crystal (2/2)

- At energies of some GeV the electron motion in the axial fields of an aligned crystal : photons + charged particles
- To ensure channelling radiation
  - T > U ~ 0.7 GeV for W & θ ~ normal incidence ($\theta < (2U/E)^{1/2}$)
  - Target crystal thickness optimized for the incident electrons energies
    - 1.0, 1.4, 1.5 and 1.6 mm for respectively 3, 4, 5 and 10 GeV (max 10 GeV for cost optimization and specially due to amorphous PEDD constrain)

E_{e^-}(GeV)	N_{e^-}	N_γ	$\bar{E}_\gamma$(MeV)
10	5×10^3	112098	304
5	6×10^3	119813	160
4	6.5×10^3	118312	136
3	8×10^3	125810	115



Photons emitted in the crystal (2/2)

- At energies of some GeV the electron motion in the axial fields of an aligned crystal : photons + charged particles
- To ensure channelling radiation
  - $T > U \sim 0.7$ GeV for W & $\theta \sim$ normal incidence
    (i.e $\theta <$ Thomas-Fermi radius/inter atomic distance)
  - Target crystal thickness optimized for the incident electrons energies
    - 1.0, 1.4, 1.5 and 1.6 mm for respectively 10, 5, 4 and 3 GeV
      (max 10 GeV for cost optimization and specially due to amorphous PEDD constrain)
- To limit the energy deposition the charged particles are bent after the crystal
  - The distance between crystal-amorphous is then used
    - Which distance must be taken ?

Before the results …

Goal of this study is to optimize:

- Amorphous thickness
- Distance between the crystal and the amorphous
- Different incident electron beam energy

For CLIC 3 TeV - 3.7×10^{9} positrons/bunch at the IP is requested -

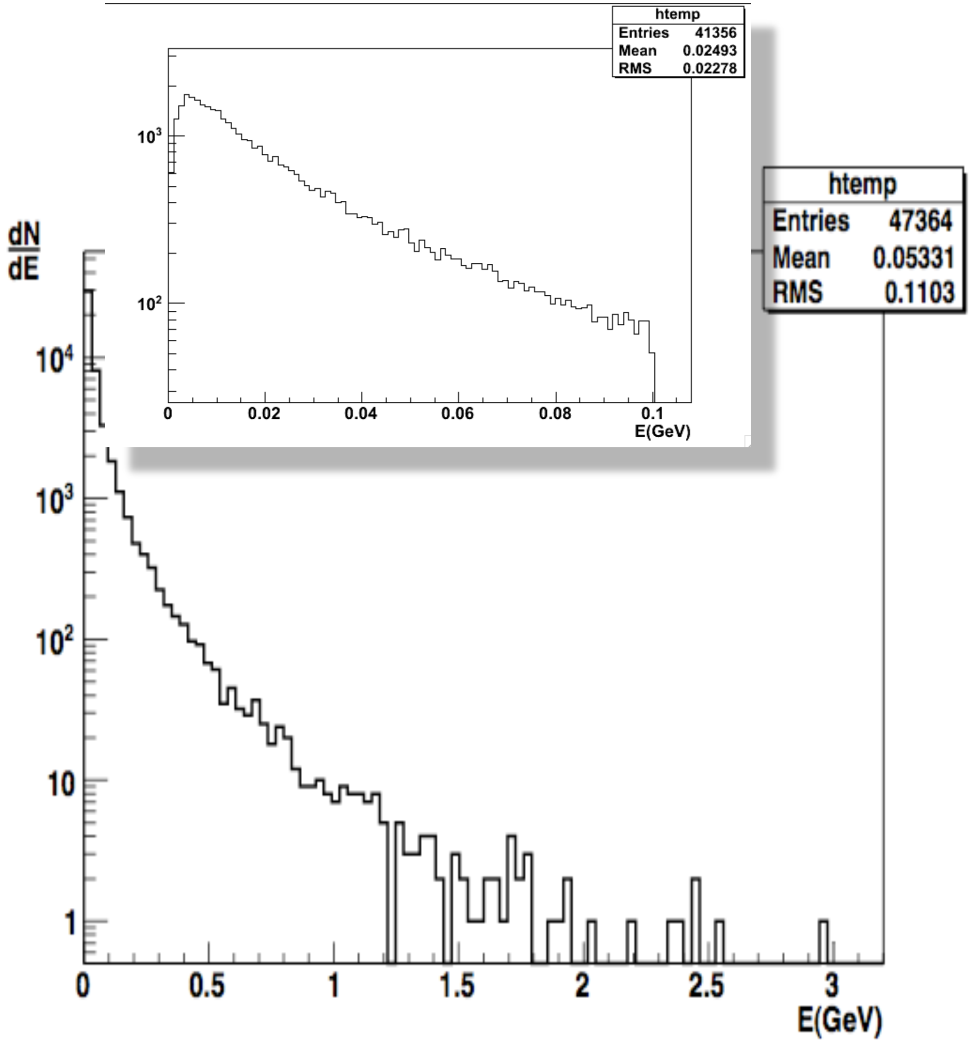
- Number of bunches per train : 312
- Repetition frequency : 50 Hz
- Number of electrons per bunch : 7.5×10^{9}
  (as a starting point, is this enough see Freddy's talk)
- Adiabatic Matching Device (AMD) : B0=6 T, L=50cm, α=22m^{-1}

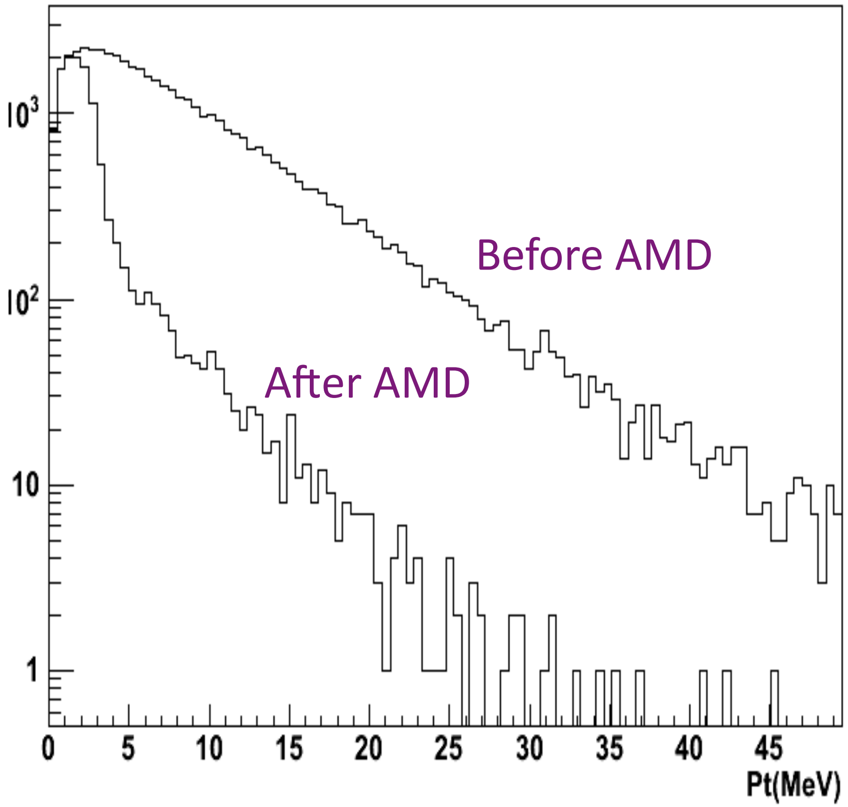
In the following the positron yield is defined as:

the number of positrons after the 50 cm of AMD within 2cm radius divided by the number of incident electron which impinged the crystal

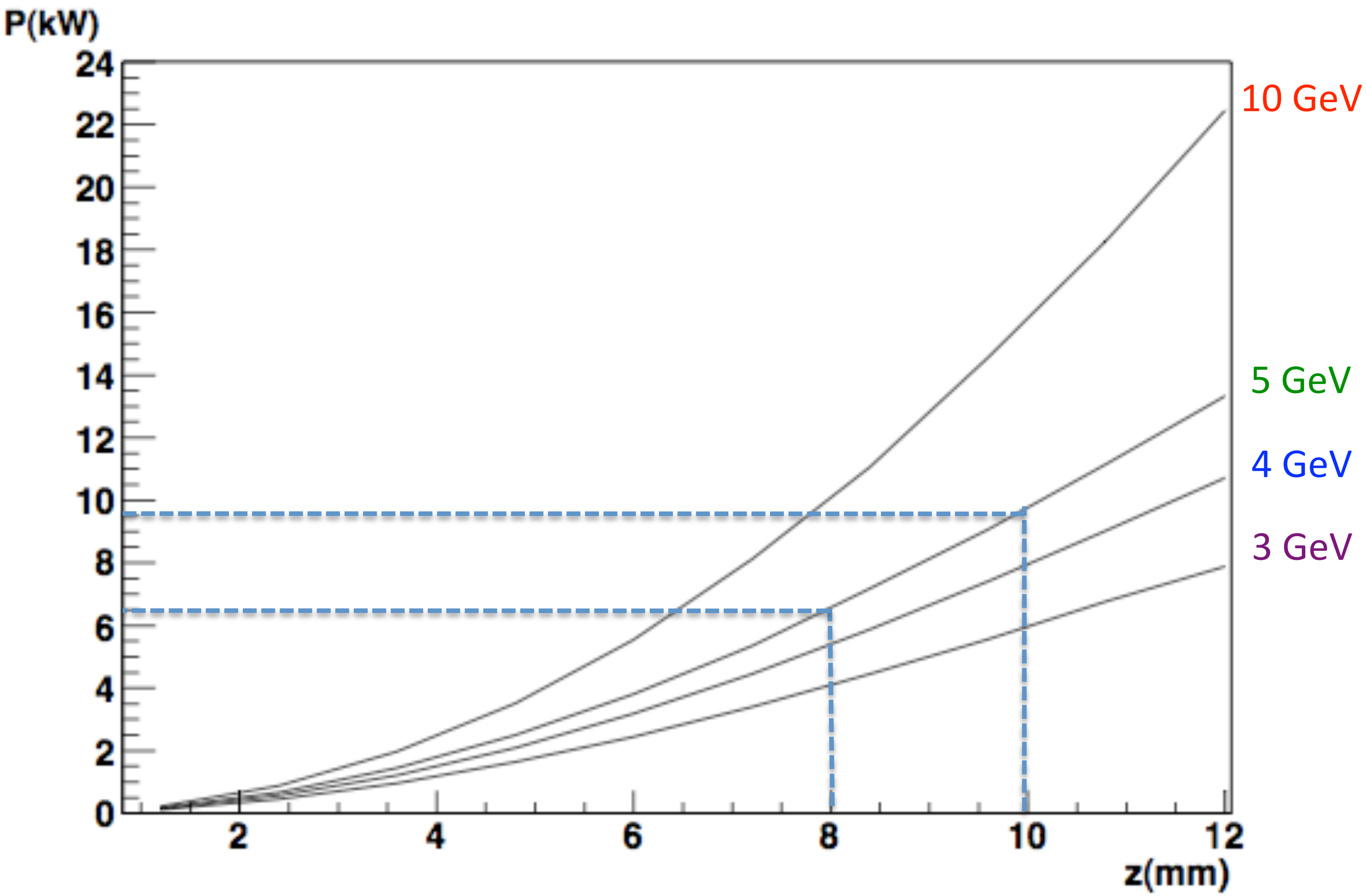
Positrons energy distribution

- 5 GeV incident e- energy, target thickness 10 mm
  - Positron mean energy 50 MeV 90% of positron are below 200 MeV
  - Mean Pt is peaked in the lower energy after the AMD



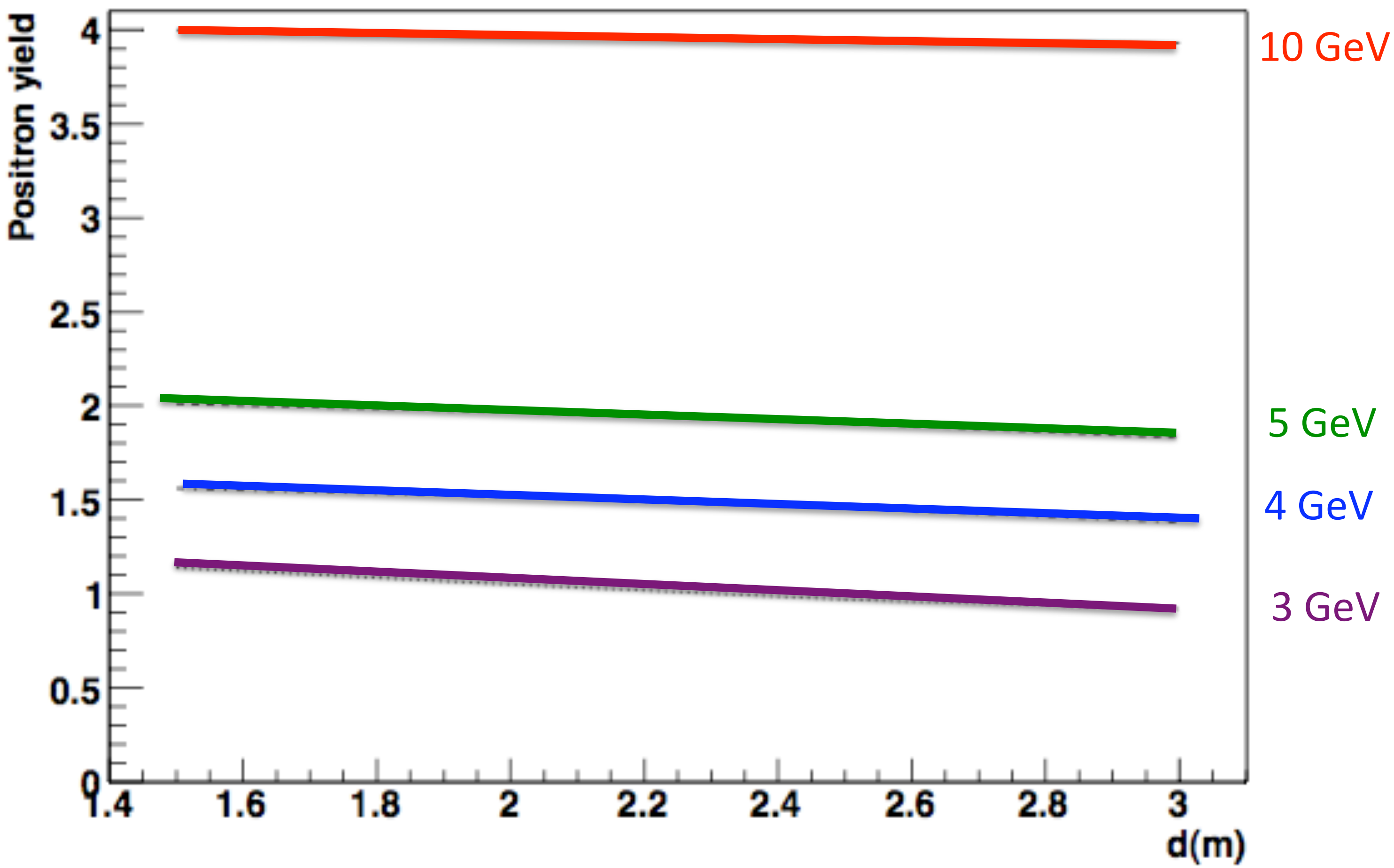


Power deposited versus target thickness



For example at 5GeV if we consider 8 mm and 10mm thickness, the water cooling system for 6 kW or 9.5 kW is not the same. This must be take into account

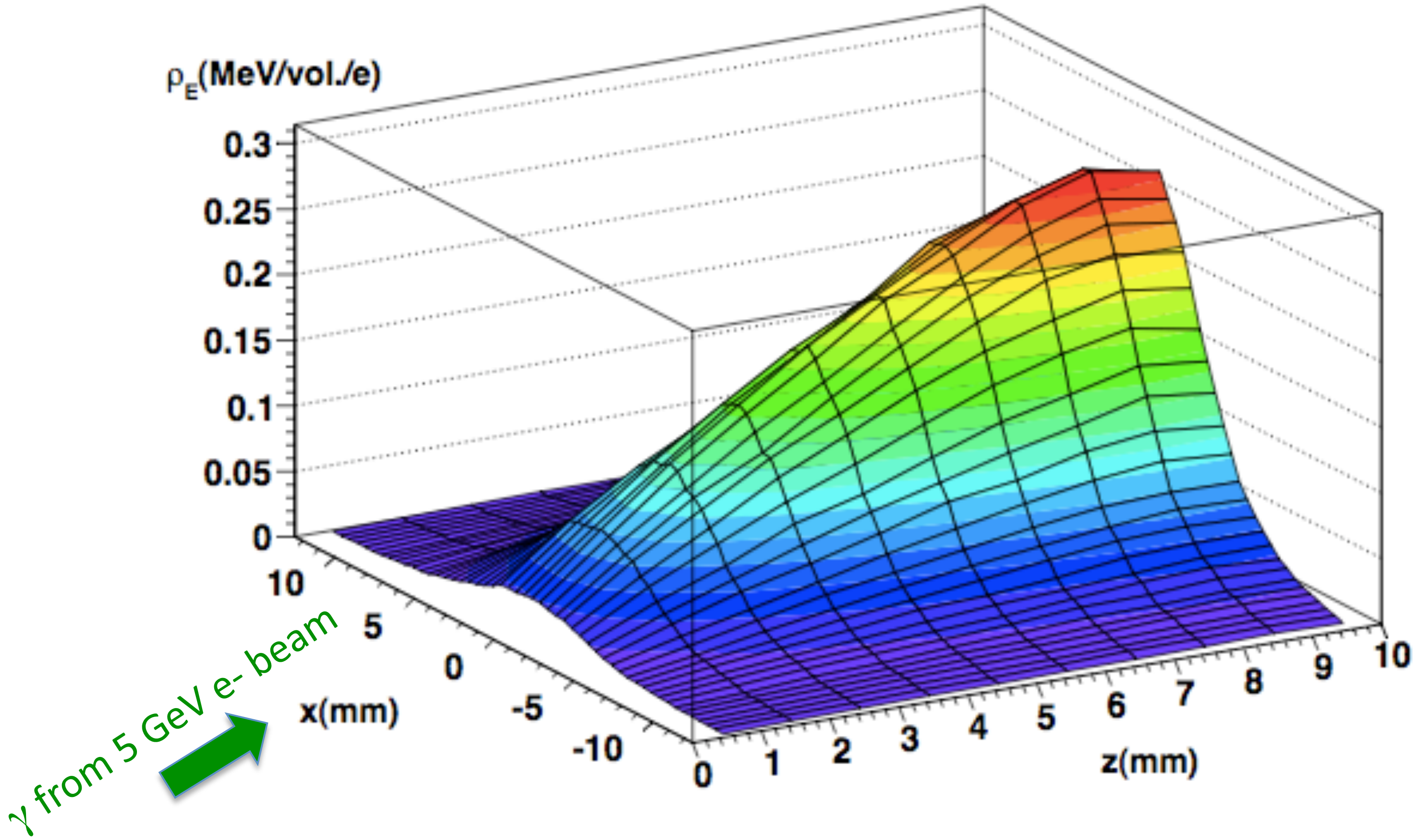
Positron Yield versus radiator-converter



The yield decrease very slowly as the d increase

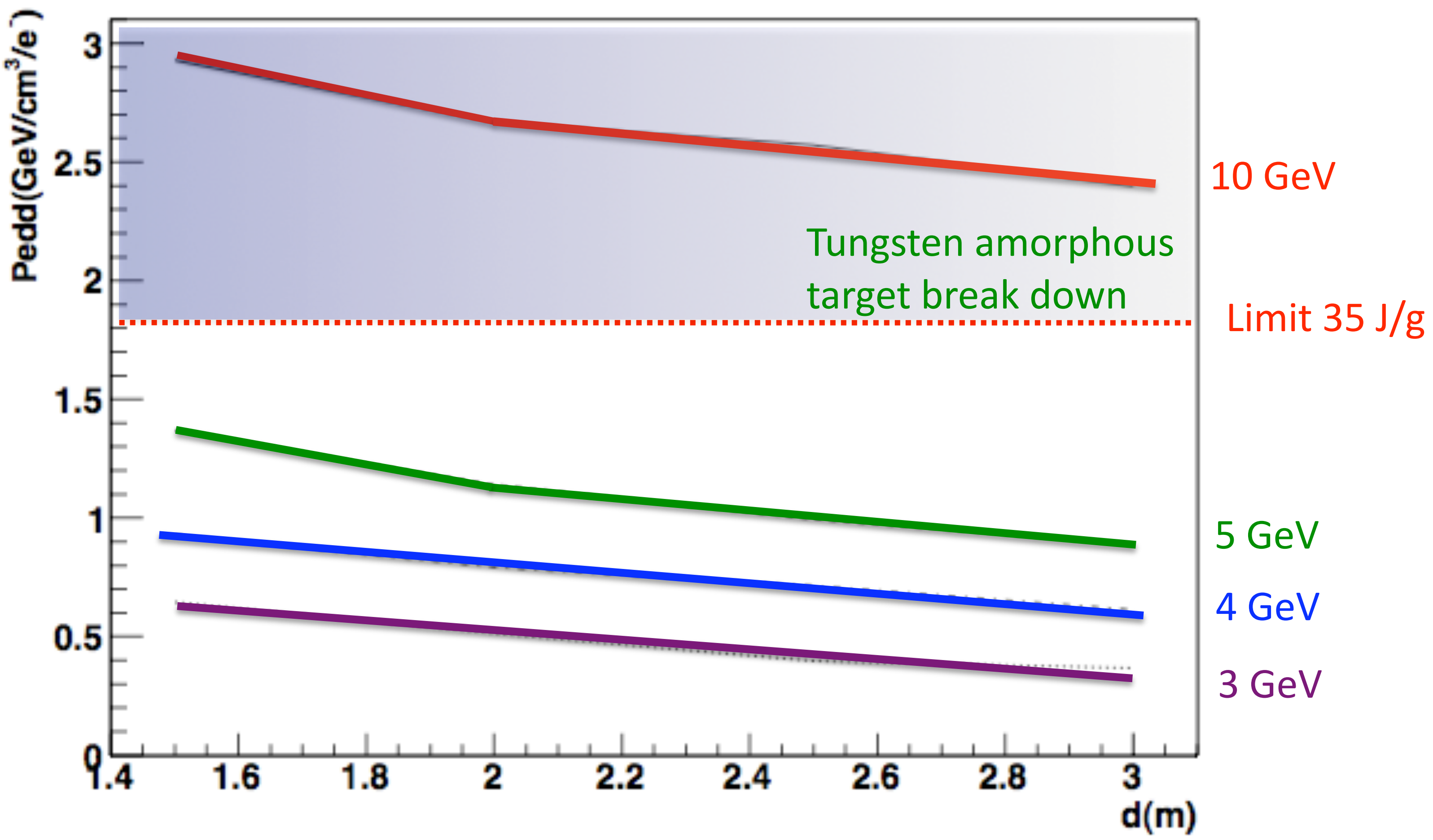
Energy deposition density in the Amorphous

- The Energy Deposition Density has been calculated dividing the amorphous target into small domains of $2.5\times10^{-4}cm^3$
- Maximum at the exit of the target (here thickness of 10mm)



PEDD versus distance radiator-converter

1 GeV/cm^3/e$^-$ = 19.42 J/g (for W)



The PEDD decrease as the d increase, faster than the yield

Systematic studies

e(cm)	d(m)	Yield	P(kW)	Pedd (GeV/cm^3/e$^-$)	Pedd(J/g/train)
0.6	1.5	1.05	2.60	0.47	9.13
0.6	2.0	0.98	2.45	0.37	7.20
0.6	2.5	0.92	2.30	0.33	6.41
0.6	3.0	0.87	2.20	0.28	5.44
0.8	1.5	1.10	4.30	0.57	11.07
0.8	2.0	1.04	4.10	0.45	8.74
0.8	2.5	0.97	3.90	0.37	7.20
0.8	3.0	0.90	3.60	0.37	7.20
1.0	1.5	1.14	6.30	0.65	12.62
1.0	2.0	1.05	5.95	0.52	10.10
1.0	2.5	0.97	5.60	0.40	7.77
1.0	3.0	0.92	5.25	0.37	7.20
1.2	1.5	1.12	8.40	0.65	12.62
1.2	2.0	1.04	7.90	0.53	10.30
1.2	2.5	0.96	7.45	0.45	8.74
1.2	3.0	0.90	7.05	0.37	7.20

Table 3: 3 GeV incident electron beam energy.

e(cm)	d(m)	Yield	P(kW)	Pedd (GeV/cm^3/e$^-$)	Pedd(J/g/train)
0.6	1.5	1.83	3.90	0.95	18.45
0.6	2.0	1.76	3.85	0.83	16.12
0.6	2.5	1.70	3.70	0.71	13.80
0.6	3.0	1.66	3.65	0.64	12.43
0.8	1.5	[illegible]	[illegible]	[illegible]	[illegible]
0.8	2.0	1.91	6.55	1.00	19.42
0.8	2.5	1.87	6.40	0.87	16.90
0.8	3.0	1.81	6.20	0.78	15.15
1.0	1.5	2.01	10.05	1.37	26.60
1.0	2.0	1.97	9.80	1.14	22.14
1.0	2.5	1.91	9.60	1.00	19.42
1.0	3.0	1.83	9.25	0.89	17.29
1.2	1.5	2.04	13.70	1.41	27.38
1.2	2.0	1.95	13.45	1.25	24.27
1.2	2.5	1.92	13.05	1.05	20.40
1.2	[illegible]	1.86	12.65	0.96	18.65

Table 5: 5 GeV incident electron beam energy.

e(cm)	d(m)	Yield	P(kW)	Pedd (GeV/cm^3/e$^-$)	Pedd(J/g/train)
0.6	1.5	1.44	3.30	0.72	14.00
0.6	2.0	1.38	3.20	0.65	12.62
0.6	2.5	1.29	3.05	0.50	9.71
0.6	3.0	1.27	2.95	0.48	9.32
0.8	1.5	1.54	5.55	0.80	15.54
0.8	2.0	1.49	5.40	0.74	14.37
0.8	2.5	1.41	5.20	0.60	11.65
0.8	3.0	1.36	5.00	0.54	10.49
1.0	1.5	1.56	8.20	0.93	18.06
1.0	2.0	1.52	8.00	0.80	15.54
1.0	2.5	1.46	7.70	0.71	13.80
1.0	3.0	1.38	7.30	0.61	11.85
1.2	1.5	1.56	11.15	1.02	19.81
1.2	2.0	1.50	10.80	0.87	16.90
1.2	2.5	1.45	10.35	0.79	15.34
[illegible]	3.0	1.39	10.00	0.64	12.43

Table 4: 4 GeV incident electron beam energy.

e(cm)	d(m)	Yield	P(kW)	Pedd (GeV/cm^3/e$^-$)	Pedd(J/g/train)
0.6	1.5	3.23	5.60	1.83	35.54
0.6	2.0	3.30	5.60	1.78	34.57
0.6	2.5	3.26	5.55	1.58	30.69
0.6	3.0	3.24	[illegible]	1.50	29.13
0.8	1.5	3.67	[illegible]	[illegible]	49.33
0.8	2.0	3.66	[illegible]	[illegible]	43.70
0.8	2.5	3.62	10.00	[illegible]	41.56
0.8	3.0	3.63	9.95	[illegible]	38.45
1.0	1.5	4.00	[illegible]	[illegible]	56.90
1.0	2.0	3.96	[illegible]	[illegible]	51.85
1.0	2.5	3.95	[illegible]	2.57	49.91
1.0	3.0	3.93	15.50	2.40	46.61
1.2	1.5	4.15	22.50	3.17	61.56
1.2	2.0	4.14	22.45	3.08	59.81
1.2	2.5	4.16	22.40	2.98	57.87
1.2	3.0	4.05	22.25	2.87	55.74

Table 6: 10 GeV incident electron beam energy.

Summary & Conclusions

Aiming to obtain high enough positron yield and a PEDD below the limit value of 35 J/g different parameters could be chosen

- 10 GeV target thickness below 0.6 cm but too closed of the limit value
- 3, 4 & 5 GeV different parameters can be taken

If we are looking at the optimisation of the produced yield and take into account a safety factor of 50% on the PEDD limit

1. an incident electron energy of 5 GeV
2. a distance radiator-converter of 2 – 3 meters
3. a converter thickness of 6 – 9 mm

(I have preference for 5 GeV , 8 mm and 2.5 m)

- Study of an hybrid positron source using channelling (CLIC Note XXX -published soon-)

Outlook

- Under study
  - target activation
  - target thermal cooling (Samcef field)
- Compton scheme
  - Iryna Chaikovska's PhD
  - Needed to upgrade our Geant4 simulation to be able to track polarization inside EOM field (A. Schälicke provide us the classes to implement)
- Starting
  - Work with Theory group of IPNL (Xavier Artru) for the hybrid source simulation
    - Fortran to C++ in goal of implemented in Geant4