REPORT FROM CHANNELING WORKSHOP (ERICE 2008)

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- This workshop, held every 2 years, was at that time housed in the center "Ettore Majorana" of Erice in Sicily.
- The talks and posters presented in this workshop are concerning generally radiation problems in periodic structures or fields; channeling in crystals is a typical case.
- I shall give a very short presentation of the meeting and the last results concerning the hybrid target

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- (1) THE WORKSHOP
- **The contributions on radiations were concerning:**
- *** Crystal effects: channeling radiation, coherent bremsstrahlung, ordinary bremsstrahlung (never absent). Our contribution on the positron source using channeling was the only one, in this workshop, for this application.**
- **A particular emphasis has been put on the particle collimation using bent crystals{ planar channeling for positive (and negative) particles, volume reflection }. Up to now, most of the experiments concerned positive particles. Negative particles have shorter dechanneling lengths but this inconvenient becomes less important at high energies.**

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- * **Synchrotron radiation:** some presentation on FEL projects like SPARC (Roma) have been given. One very interesting idea is concerning the **crystal undulators** {crystals which have been deformed, giving them an **undulation**} In this device having periodically bent crystallographic planes, the particles (+, easier) move along nearly sinusoidal trajectories and could radiate X rays, for instance. The advantage of such devices, with respect to the ordinary magnetic undulators is that the strong crystal fields are steering the particles more efficiently.
- Works are in development in Russia, Ukraine, Germany,..

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- *** Compton interaction: laser-Compton scattering using moderate energy electron accelerators (tens of MeV) and Nd:YaG lasers with possibility of second and fourth harmonics are under study for X ray production with applications in biology and medecine.**

- *** Transition radiation: backward transition radiation from an oblique foil is a known method for beam diagnostics. Using a stack of thin foils regularly spaced provides X rays; that is a good method for an X-ray source. It could also be used for particle detection.**

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- * Diffraction radiation: diffraction of the electron beam Coulomb field on an edge, a slit or a hole provides a good method for diagnostics. This non invasive method is quite attractive and used in beam diagnostics for emittance measurements. The radiation features are close to those of the transition radiation. Measurements are made, for instance, at DESY on the FLASH linac to measure the transverse emittance using optical wavelengths and the bunch length using the coherent radiation spectrum.
- A set of slits regularly spaced can also provide X-rays (with high energy beam)

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- * Smith-Purcell radiation: A grating with regularly spaced edges can provide optical or X-ray radiation depending on the beam energy and the grating geometry.
- Beam diagnostics are interesting application. The possibilty of getting an X-ray source (with 20-30 MeV electron beam) is very attractive.
- * Parametric X Ray (PXR) this radiation can be understood as the diffraction at Bragg angle of the electron Coulomb field on the crystal planes. As for the other radiations and depending on the beam energy and crystal characteristics applications for beam diagnostics and X-ray source are underway in many places.

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- OTHER ITEMS
- **Different subjects not really related to the topics of the workshop were presented:**
- *** Nuclear waste treatment**
- *** X rays transmission using capillary tubes (invented by Kumakhov, the physicist who discovered the channeling radiation)**

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- **(2) Hybrid source**

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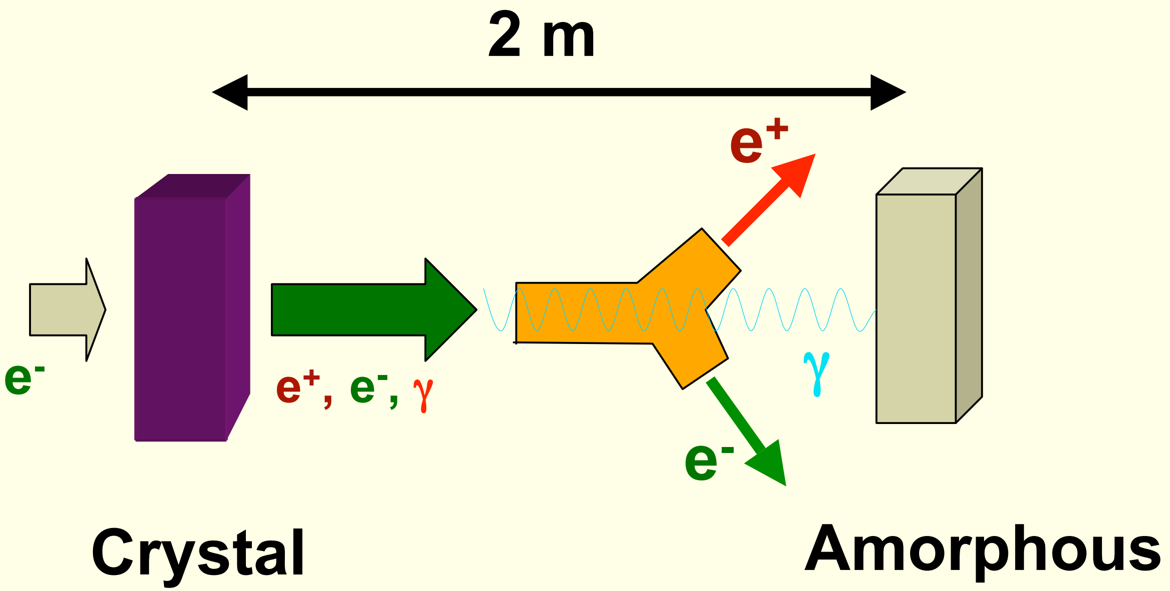
- THE HYBRID TARGET



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- * THE CRYSTAL : Photons generated by electrons in channeling conditions and above barrier.
- * The crystal, axially oriented, may be W, Si, Ge, C(d)…
- In our case, we choose W in <111> orientation
- * THE AMORPHOUS CONVERTER: it is made of W
- * THE DISTANCE RADIATOR-CONVERTER: it is of some meters; here it is 2 meters. It allows the use of sweeping magnet in between. Another possibility is to select also charged particles coming from the radiator (e+, e-) with energy larger than Etreshold to increase the yield e+/e-
- * IMPINGING ENERGY: E- = 5 to 10 GeV; the incident electron beam can be provided by an ERL (Energy Recovery Linac)

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- SIMULATIONS
- Incident beam: the electron beam energy is of 5 GeV (CLIC) or 10 GeV (ILC) and transverse rms radii of 1 and 2.5 mm have been considered
- Targets: W Crystal: thickness: 1.4 mm (CLIC) & 1 mm (ILC)
- Amorphous W target, 10 mm thick (CLIC) & 8mm thick (ILC)
- Capture system: an Adiabatic Matching Device with a magnetic field decreasing from 7 Teslas to 0.5 Teslas on 21 cms. Iris aperture is ~20mm radius (L-Band, 1.5 GHz). Accelerating field is 25 MV/m peak value.
- Outputs: Simulations have been carried out corresponding to the general scheme. The accepted yield e+/e- and the Peak Energy Deposition Density (PEDD) have been determined. The number of positrons accepted at the target (transverse and longitudinal acceptances) as the PEDD have been calculated for the 2 cases described hereafter.

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- **SIMULATIONS RESULTS**
- **Two cases have been considered:**
- *** Only the photons are impinging on the amorphous target**
- **All the charged particles coming out from the crystal are swept off. The e+ exiting from the amorphous converter are coming from showers generated by the photons due to channeling radiation, coherent bremsstrahlung, ordinary bremsstrahlung in the crystal.**
- *** The photons and some of the charged particles generated in the crystal are impinging on the amorphous converter**
- **The shower providing the positrons in the amorphous converter is generated by the photons and electrons (positrons) above an energy threshold determined by the magnetic field in the sweeping magnet and the collimation.**

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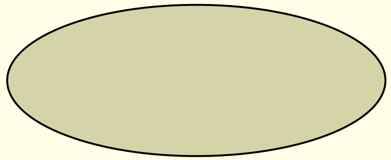
- **ACCEPTANCE CONDITIONS**
- **The accepted e+ are contained in the transverse phase space defined by the acceptance ellipse at the target:**
- **$[r/0.53]^2 + [p_T/11]^2 = 1$; r is in cm and p_T in MeV/c**
- 
- **The longitudinal momentum p_L is taken between 1.3 MeV/c (debunching) and 17.3 MeV/c (adiabatic condition)**
- **The longitudinal and transverse momenta satisfy the relation:**
- **$p_T < 0.1875$ MeV/c + $0.625\, p_L$; this relation corresponds to a maximum positron angle of emission of ~32 degrees which put a limit on the debunching (in an L-Band accelerator) with the focusing fields considered.**

See CLIC note 465

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- SIMULATION RESULTS FOR γ GENERATED SHOWER (CLIC)

- **ACCEPTED POSITRON YIELD**
- *** For an incident e- beam with s = 2.5 mm => h = 1.28 e+/e-**
- **PEDD**
- **Assuming an incident e- pulse of 2.34 1012 e-, we have :**

	CRYSTAL		AMORPHOUS	
	PEDD/e- (GeV/cm3/e-)	PEDD/total J/g	PEDD/e- (GeV/cm3/e-)	PEDD/total J/g
s=1mm	2	38	2.5	48.5
s=2.5mm	0.35	6.8	0.8	15.5

- **An entirely amorphous target, 9 mm thick, with the same incident e- beam would have provided the same accepted yield and a PEDD of 150 J/g (s=1mm) or 40 J/g (s=2.5 mm). This shows the advantages of an hybrid scheme leading to a unique target with a PEDD < 35 J/g using an e- beam with s= 2.5 mm. The average power deposited in the target is < 4 kW.**

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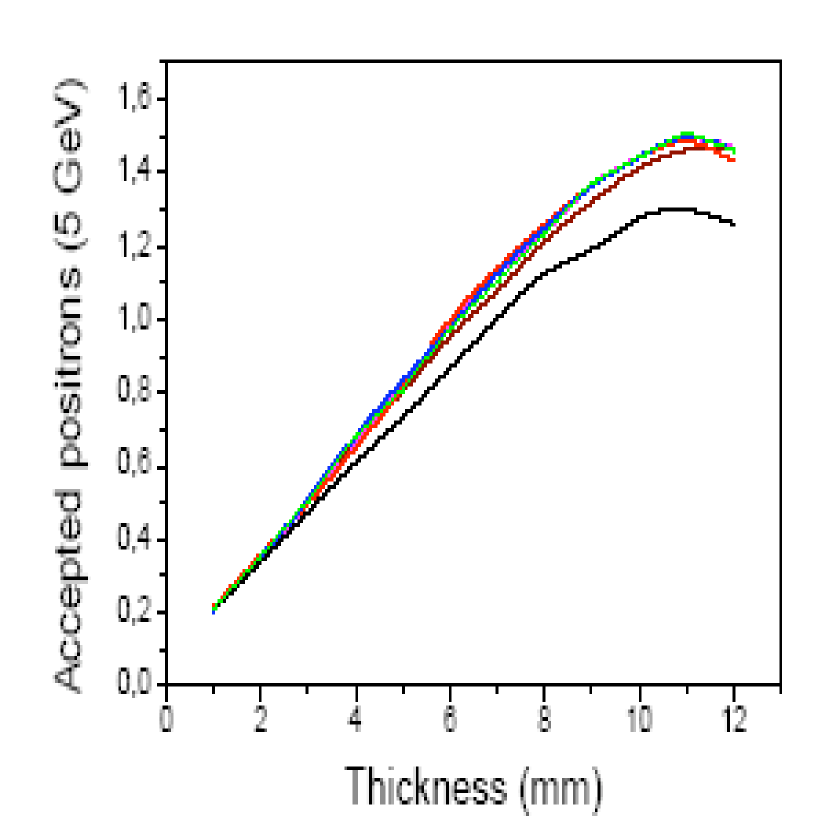
- **THE CASE OF CLIC**
- **POSITRON SOURCE GENERATED BY γ AND e-, e+ COMING FROM THE CRYSTAL: comparison for the accepted yields (threshold energies are between 50 and 900 MeV)**
- **For 10 mm amorphous target, the yields are:**
- *** 1.28 (only γ)**
- *** 1.44 (e-, e+, γ)**



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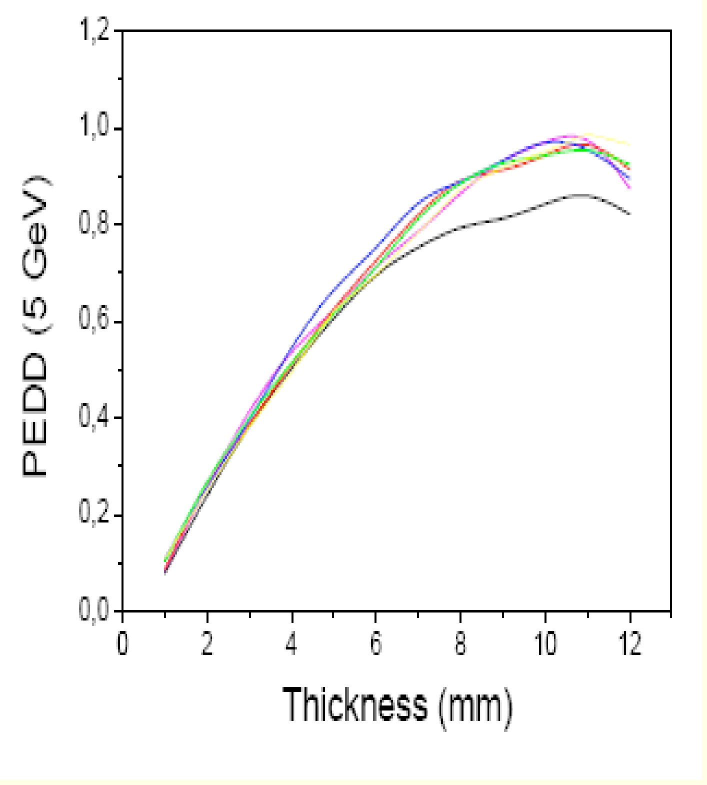
- THE CASE OF CLIC: PEDD
- On the figure the PEDD is given
- in GeV/cm3/e-
- The PEDD is growing from
- 0.80 GeV/cm3/e- to a mean
- value of 0.96 GeV/cm3/e- when
- sending photons, e- and e+
- emitted at the crystal on a
- 10 mm thick amorphous target
- That brings the PEDD per CLIC
- Pulse to less than 18 J/g, well
- below the 35J/g limit. Threshold
- Energies are: 50 →900 MeV



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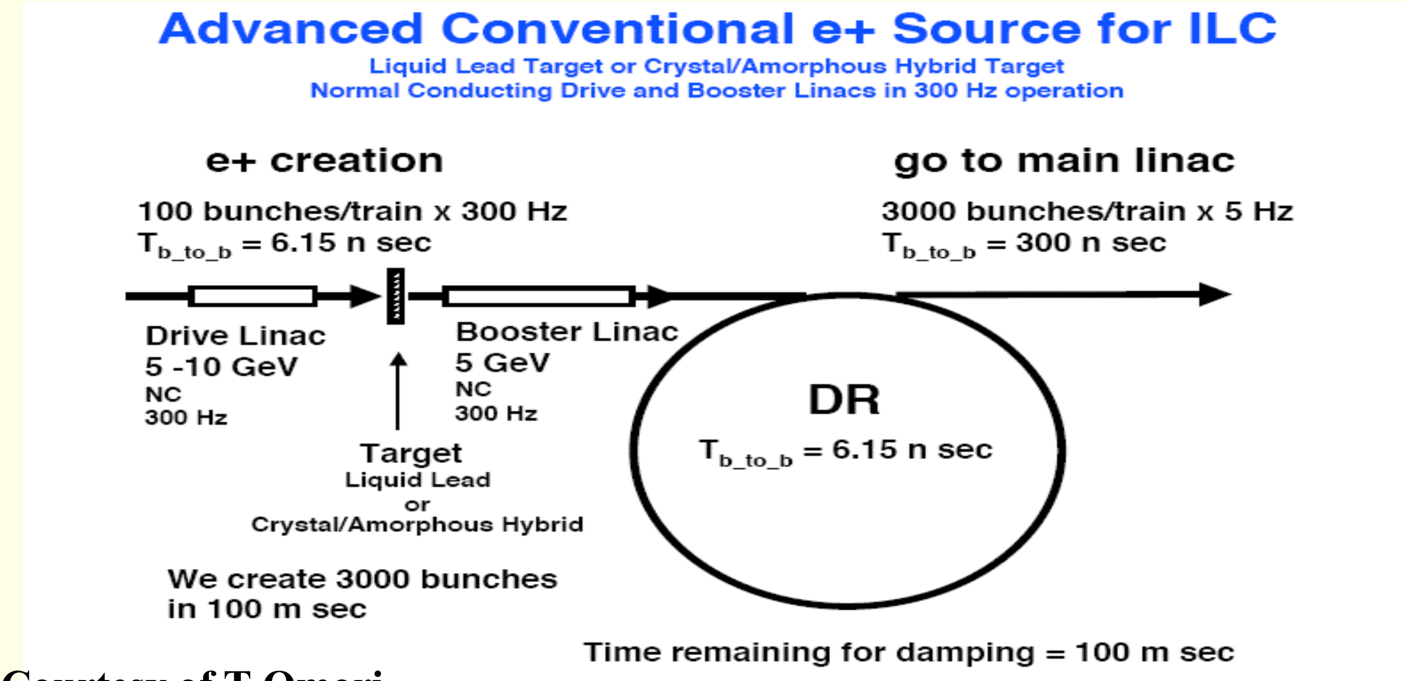
- THE ILC CASE
- Due to very intense pulses, the hybrid option for ILC need a preliminary transformation of the incident beam on the targets to preclude immediate destruction



Courtesy of T.Omori

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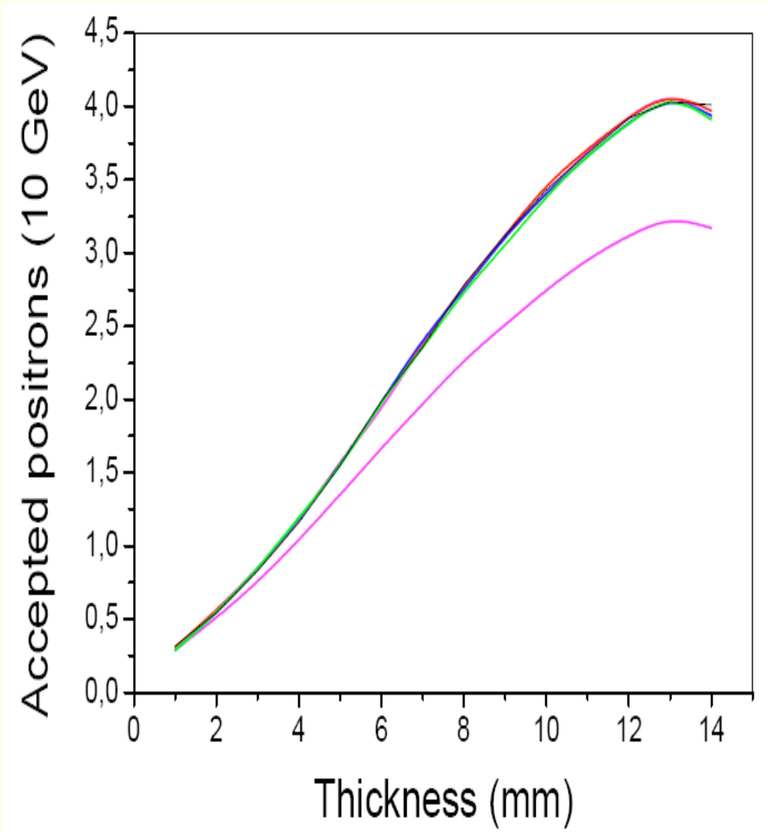
- **POSITRON SOURCE GENERATED BY γ AND e-, e+ COMING FROMTHE CRYSTAL: COMPARISON FOR THE ACCEPTED YIELDS (ILC)**

- **For 1 mm thick crystal (W) and**
- **8 mm thick amorphous target**
- **and incident energy of 10 GeV**
- **and an e- beam with σ=2.5mm**
- **The yields are:**
- **- 2.25 e+/e- (only g)**
- **- 2.75 e+/e- (g, e-, e+)**
- **The threshold energies are**
- **between 50 and 900 MeV**



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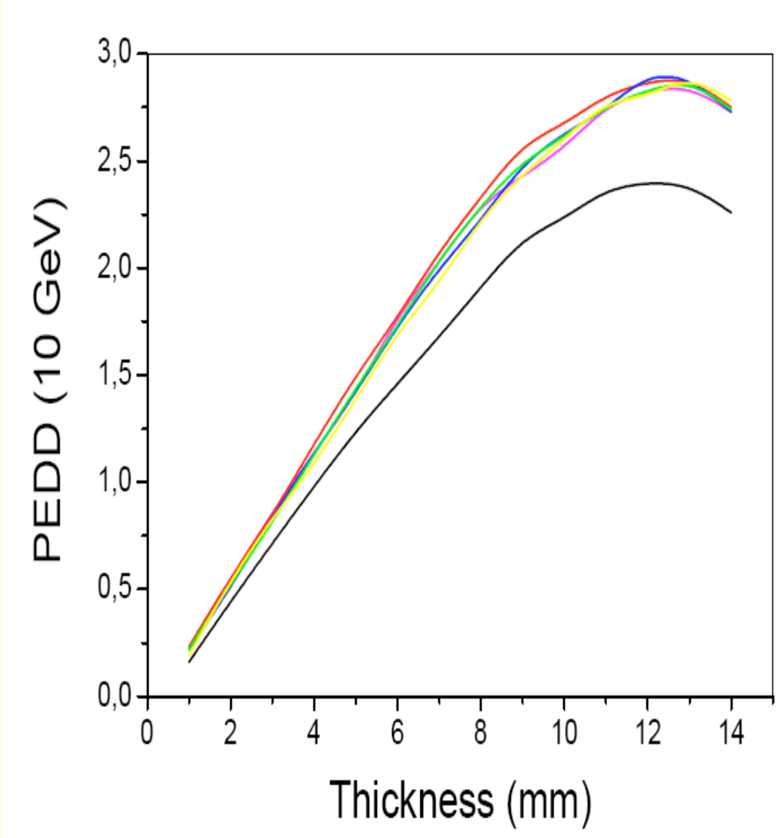
- **THE PEDD (ILC)**
- **On the figure the PEDD is**
- **given in GeV/cm3/e-**
- **The PEDD is growing from**
- **1.90 Gev/cm3/e- (only g) to a**
- **mean value of 2.3 GeV/cm3/e-**
- **(g, e-, e+) for the 8 mm amorphous target.**
- **Maximum PEDD is for 13 mm**
- **thickness where it reaches 2.9**
- **That brings the PEDD per**
- **modified ILC pulse to 31.3 J/g,**
- **just below the limit (35J/g) for**
- **the [1mm crystal, 8 mm amorphous] targets and 10 GeV e- beam (σ=2.5 mm)**



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- PRELIMINARY CONCLUSIONS
- 1) FOR CLIC
- The hybrid positron source is able to provide the needed accepted yield for CLIC. A yield of more than 1 e+/e- is reachable using only photons coming from the crystal and *a fortiori* also e- and e+ coming from the crystal and over an Energy threshold.
- The PEDD remains under the critical value of 35 J/g (for W) both for the thin crystal and the thick amorphous target. The energy thresholds, for which charged particles impinge also on the amorphous target are starting from 50 MeV. Most of the energy deposited (and the PEDD) is due to the photons (more than 80 %).
- All the results concerning the yield as the PEDD correspond to an rms radius of 2.5 mm for the incident electron beam. Such dimension is compatible with the AMD geometrical acceptance (almost 6 mm)
- The main results were concerning a distance of 2 meters between the 2 targets; this distance can be extended to 3 meters without problem for the yield which should remain > 1e+/e- using γ , e- and e+ as resulting from a rough evaluation

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- PRELIMINARY CONCLUSIONS (continued)
- 2) FOR ILC
- With the parameters chosen (W crystal thickness of 1 mm; amorphous W thickness of 8 mm; incident energy E-= 10 GeV; beam incident rms radius σ= 2.5 mm) the accepted positron yield using an AMD matching system is of 2.25 e+/e- when only photons are impinging on the amorphous target and about 2.75 e+/e- when also e- and e+ above 50 MeV are allowed to impinge on the amorphous target. This is satisfying the ILC requirements.
- Concerning the PEDD the modification of the incident beam before the target, as defined above, leads to a PEDD/pulse (2.10^{12}e-/pulse) of 31.3 J/g, which is just below the limit of 35 J/g. However such a solution is to be checked with the actual thermal behaviour of the target and needs further investigations. Anyway, the use of an hybrid target (with all its advantages) needs a preliminary transformation of the nominal ILC pulse, restoring its time structure after the positron target.
- As for CLIC, the optimization of the parameters of the hybrid source can be operated.