OPTIMIZATION OF AN HYBRID POSITRON SOURCE USING CHANNELING

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presented by R.Chehab

OPTIMIZATION OF AN HYBRID POSITRON SOURCE USING CHANNELING

- **OUTLINE**
- * Introduction
- * The hybrid positron source: a recall
- * Optimization of the thermal effects ➔ the granular converter
- * Simulation results for CLIC and ILC
- * Test of an hybrid source with a granular converter: KEK results
- * Summary & conclusions

OPTIMIZATION OF AN HYBRID POSITRON SOURCE USING CHANNELING

- **1-INTRODUCTION**
- *** High intensity positron sources for linear colliders: ➔ important thermal effects due to high incident intensity (energy deposition , PEDD, Shocks)**
- *** Advantages of separating photon and pair production ➔ hybrid source**
- *** Necessity to control the thermal effects in the targets: crystal➔ potential lowering ; amorphous converter➔ heating & shocks**
- *** Necessity to maximize the number of accepted positrons (transverse and longitudinal acceptance)**
- *****

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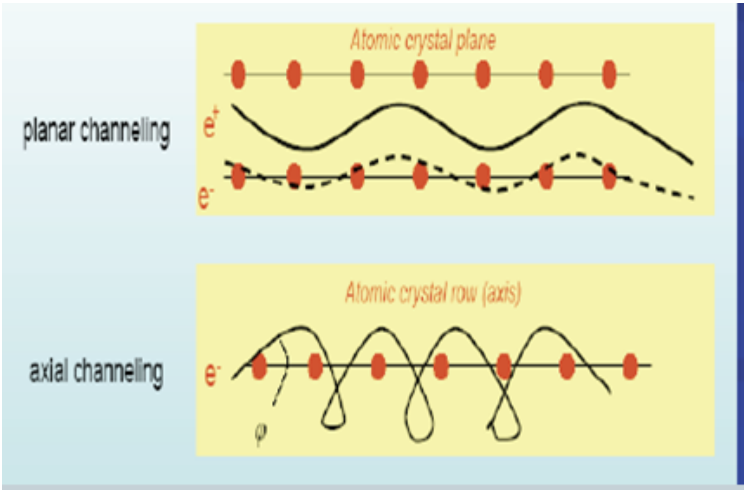
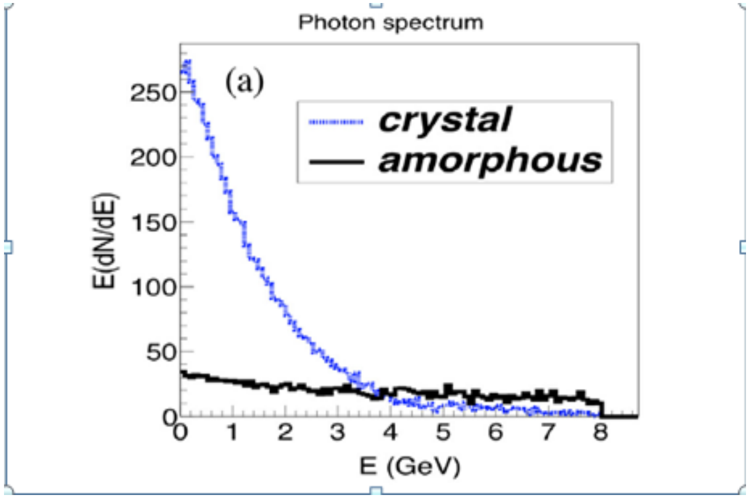
- **2-THE HYBRID SOURCE: A RECALL**
- *** High photon yield with a crystal target with axial channeling**





A high rate of soft photons is produced by e- in channeling conditions (Kumakhov)
This number is > than that of Bremsstrahlung: radiated power also larger(for W, with E- > 0.7 GeV)

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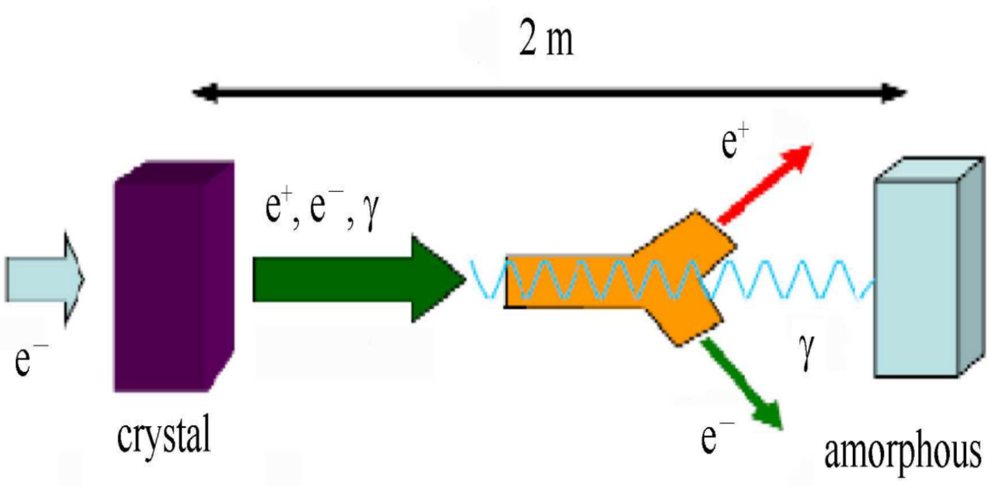
THE HYBRID SOURCE: A RECALL

The photons from the crystal are impinging on the amorphous target; the e- and e+ can be swept off or partially sent to the amorphous target. The distance L is taken from 1.5 to 4m. On the presented simulations, L=2 m. To lower the energy deposition in the converter the charged particles coming out from the crystal are swept off.



This solution has been chosen by CERN for the CLIC positron source baseline.

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- **THE HYBRID SOURCE: CHOICE OF THE CRYSTAL RADIATOR**
- **The radiated intensity and the number of photons depends on the incident electron energy, on the crystal medium (W, Si, Ge or C(d)) and, of course on the kind of channeling (axial or planar). Many kinds of crystals have been considered and tested experimentally: W (CERN/WA103 and KEK), Si and C(d) (KEK).**
- *** Energy ➔ a threshold to get $I_{ch} / I_{br} > 1$ (I the radiation intensity) is about 700 MeV for W and even higher for other crystals (see V.N.Baier et al.) . So, it is interesting to use GeV energies to get high radiation yields.**
- *** Crystal ➔ the photon yield is increasing with the atom potential : choice of high**
- **Z crystals is preferred ➔ W is often chosen**
- *** Orientation ➔ axial channeling provides higher potentials and, therefore,**
- **higher yields than planar.**
- **For most of our applications, we have chosen W crystal on <111> axial orientation. The crystal thickness is on the order of the mm (enhancement crystal/amorphous is higher with thinner crystals).**

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- **THE HYBRID SOURCE: CHOICE OF THE CONVERTER**
- **The heat load in the crystal is relatively limited due to its small thickness (~ 1 mm). However, in the converter, rather thicker, this heat load is leading to:**
- **- important average heating**
- **- high energy deposition density**
- **The first effect can be mitigated with a moving target, in order to avoid successive depositions on the same place; the second effect may lead to the target breakdown as happened for the SLC target.**
- **Some years ago, we proposed to use, for the converter, granular spheres instead of a compact target; the heat dissipation in the spheres is more efficient than in a compact device. The dissipation is increasing as the ratio of the surface on the sphere volume (1/R). Moreover, the thermal shocks in the spheres are less harmful due to their small dimensions (~ mm) which gives to the sound wave a very short time to propagate (~ 0.1µs), much shorter than the beam pulse. Such kind of targets was previously proposed, for the target of a neutrino factory triggered by intense proton beams (P.Sievers and P.Pugnat; (J.Phys.G, Nucl.Part.Phys. 29(2003)1797)**

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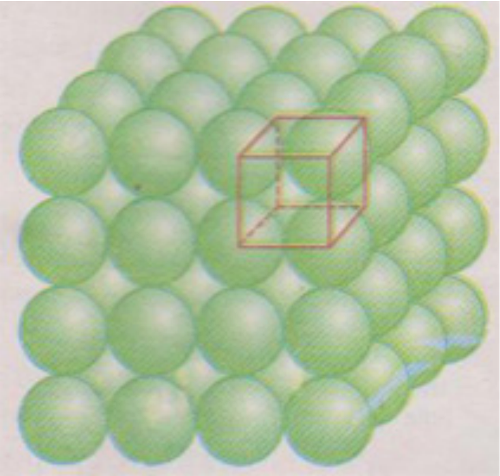
- **3-OPTIMIZATION OF THE THERMAL EFFECTS**
- **THE GRANULAR CONVERTER**
- **Tungsten spheres with 2.2 mm diameter have**
- **been fabricated by a french firm and mounted**
- **in Al frames at LAL-Orsay. The W spheres are**
- **mounted in staggered rows. The relative density**
- **of these targets is 75 % at the maximum.**
- **Simulations with comparisons between**
- **compact and granular converters providing almost the same e+ yield showed a clear advantage for the granular target with what concerns the heat dissipation and the energy deposition density. The maximum accepted value of the latter is assumed to be 35 J/g (for W) following the analyses of the SLC target breakdown.**



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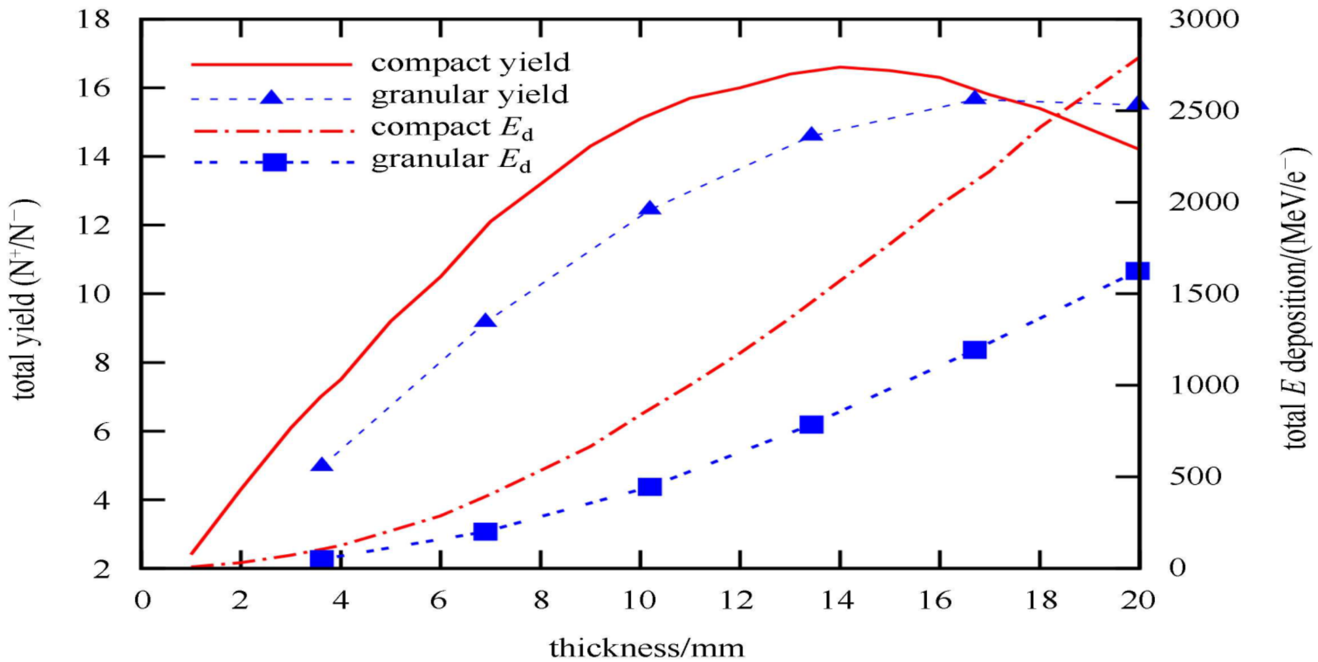
COMPARISONS BETWEEN COMPACT AND GRANULAR W CONVERTERS

Simulation results concerning the yield and the deposited energy are presented on the figure [E-=10 GeV; r(sphere) = 1 mm] cf. PhD thesis of C.Xu and Chinese Physics C Vol. 36 (2012)871



Equivalence for almost the same e+ yield: 8 mm compact ➔ 6 layers corresponding to 10.2 mm ; -15 % deposited energy for Granular

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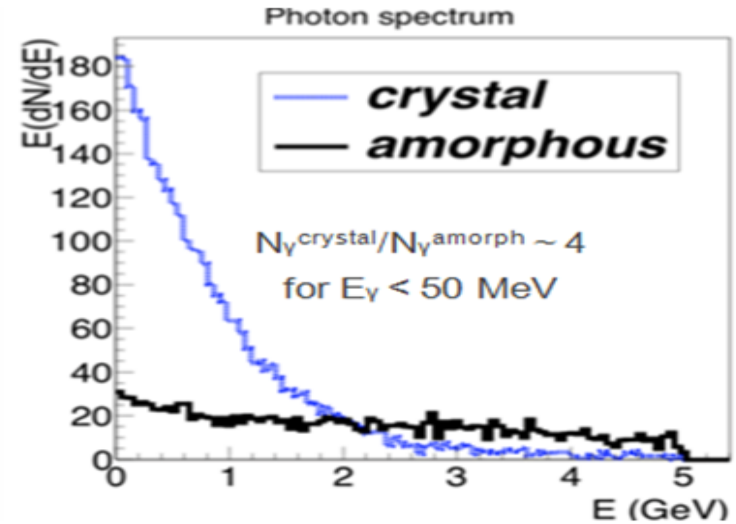
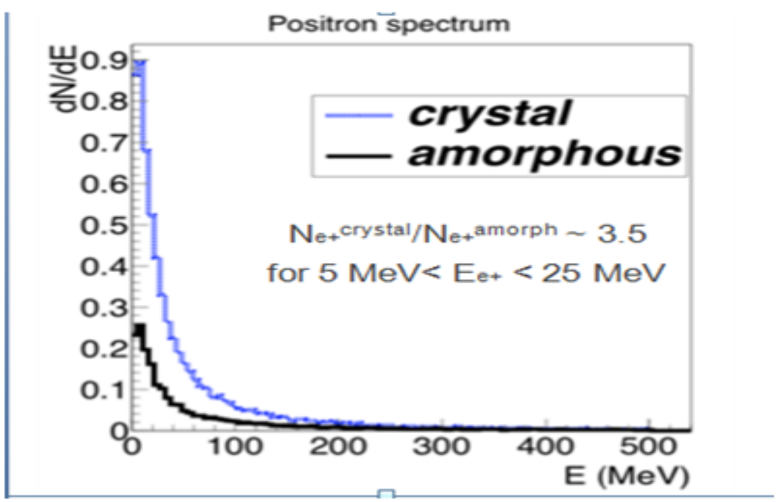
4- SIMULATION RESULTS FOR CLIC POSITRON BASELINE (with GRANULAR):

The parameters for CLIC hybrid source are: Crystal thickness: 1.4mm; converter thickness: 10 mm. Distance crystal-converter: 2 m; E-=5 GeV

One important characteristics of the positron sources using channeling radiation is the soft energy of the emitted photons and, henceforth, the soft energy of the created positrons. That is interesting for the positron capture which is easier for soft positrons. Example: CLIC





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AN HYBRID POSITRON SOURCE FOR ILC

The main problem for ILC is the very high intensity of the beam with a large duration (~ 1 ms). A solid target will not survive with such a beam➔ choice of a radiator (undulator) associated to an amorphous converter.

QUESTION: is an hybrid source applicable for ILC?

To address this point: necessity to modify the beam pulse duration creating, inside the nominal pulse, Macropulses with minitrains inside them in order to manage relaxation periods between the minitrains , avoiding thermal shock effects. Such a solution is represented here: in a 5 Hz configuration, the e+ macropulses of 40 ms duration are injected in a DR where they are stacked

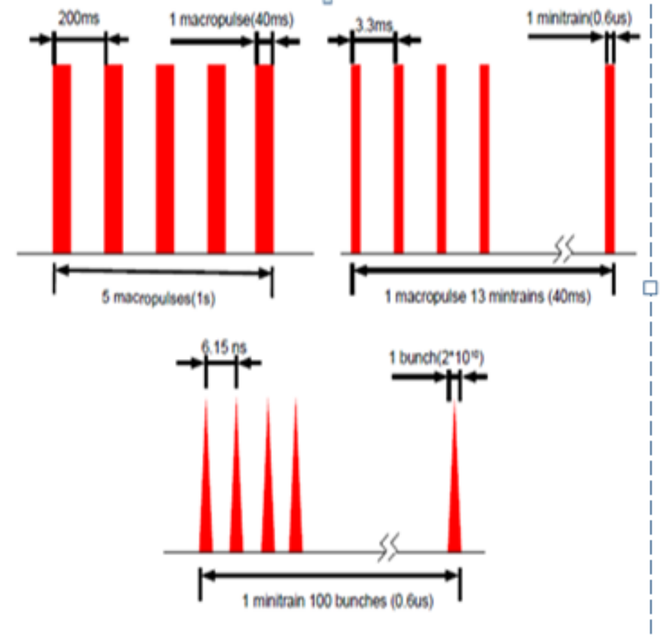

Figure 4.1: ILC beam structure. KEK scheme[42]

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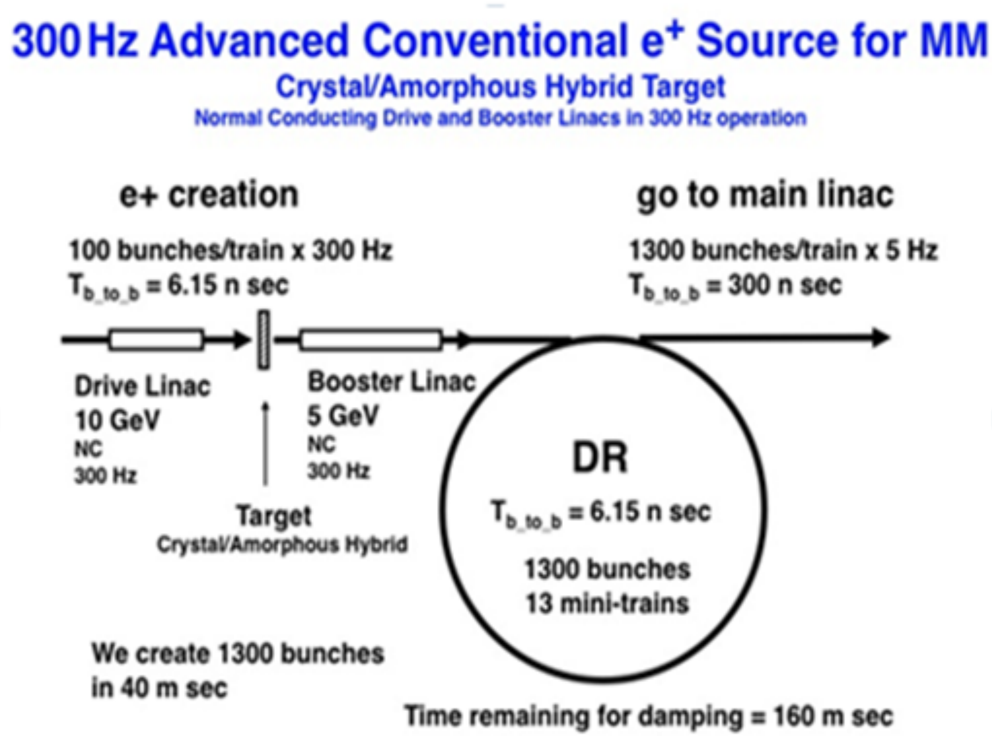
- FOR ILC: W crystal <111>, 1 mm; W converter: 8 mm; E-=10 GeV
- Yield: 13e+/e- (total);
- ~3 e+/e- at 150 MeV

In order to handle the high incident power on the target the beam pulse structure has been modified transforming the nominal 1 ms pulse into minitrains of 100 bunches generated at a frequency of 300 Hz.

A scheme after Omori proposal, but with updated number of bunches is presented.



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- **5- TEST OF AN HYBRID POSITRON SOURCE AT KEKB**

  An experiment on an hybrid source with compact W converter has been previously operated at KEK with the same lay-out. ➔ Y.Uesugi et al. NIMB 319 (2014)17-23
- We report, here, the results of the temperature measurements on the table.

Results of the temperature rise measurement. Each property corresponds to a parameter in the fitting function.

Target scheme	Thickness (mm)	a: Temperature rise (°C)	τ_1: Decay time (ms)	τ_2: Rise time (ms)
Conventional	18	1.071 ± 0.003	332 ± 3	8 ± 1
	8	0.373 ± 0.003	116 ± 1	3 ± 1
Hybrid axis on	18	0.419 ± 0.002	537 ± 1	10 ± 1
	8	0.300 ± 0.002	178 ± 2	2 ± 1
Hybrid axis off	18	0.197 ± 0.004	542 ± 3	7 ± 1
	8	0.095 ± 0.001	144 ± 4	3 ± 1

1 Hz data for the experiment at KEK (Y.Uesugi et al.)

Using the same lay-out we operated a test during autumn 2015 with a granular W target as a converter. The results are given hereafter.

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TEST OF THE HYBRID-GRANULAR TARGET ON KEKB LINAC

The 7 GeV e- beam is sent on a 1 mm W crystal; sweeping magnet and collimator let only the γ beam on the amorphous-granular W converter. Positrons are detected with Cherenkov counter. Analysis is done for 5-10-15-20 MeV e+. Photons are not detected

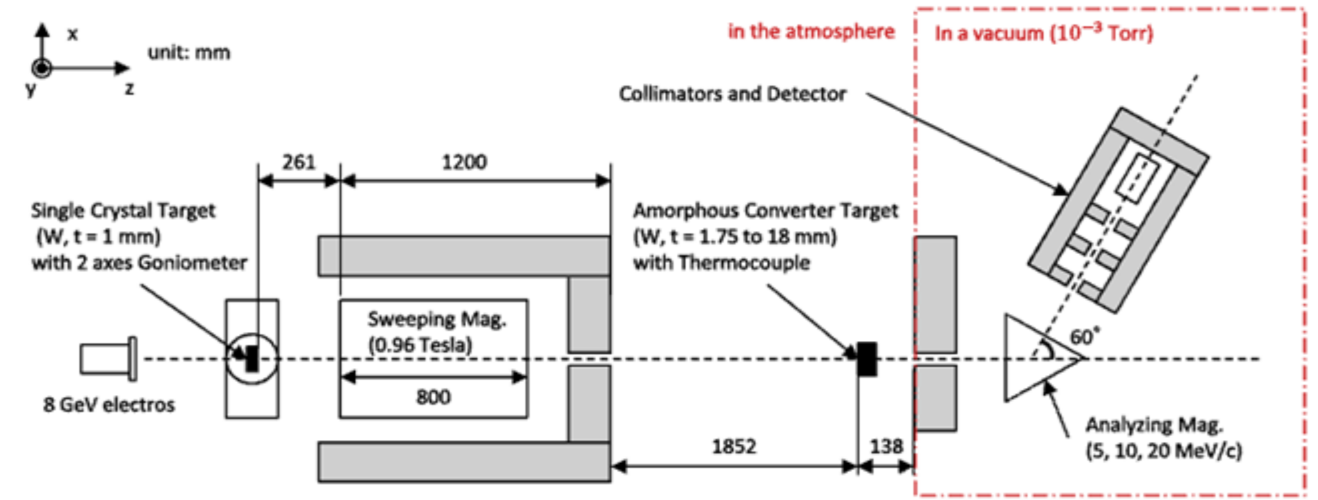

Fig. 4 Layout of the hybrid target and the positron detector system in the experiment in top view.

The typical geometrical and momentum acceptances are about: 1 msr and 2.4% (?P/P, FWHM) at P+ =20 MeV/c

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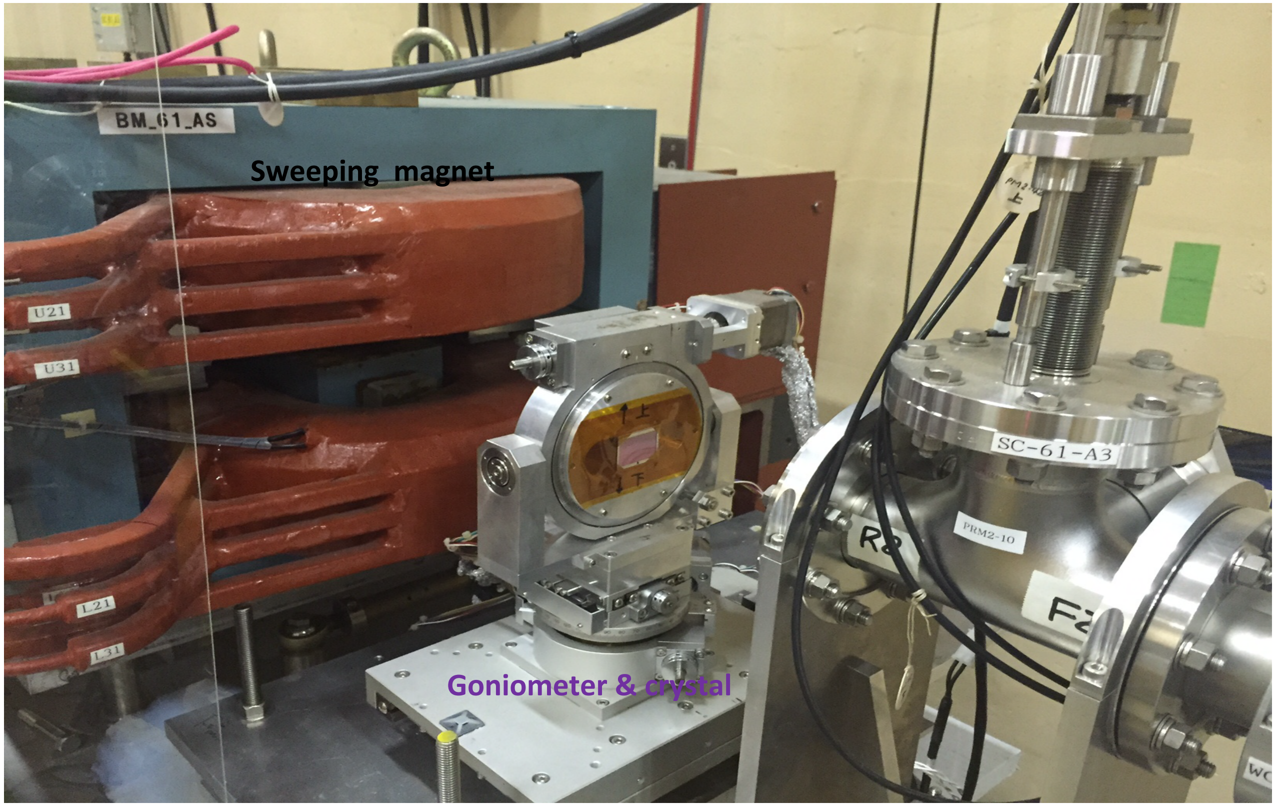
THE CRYSTAL/GONIOMETER IN THE LAY OUT



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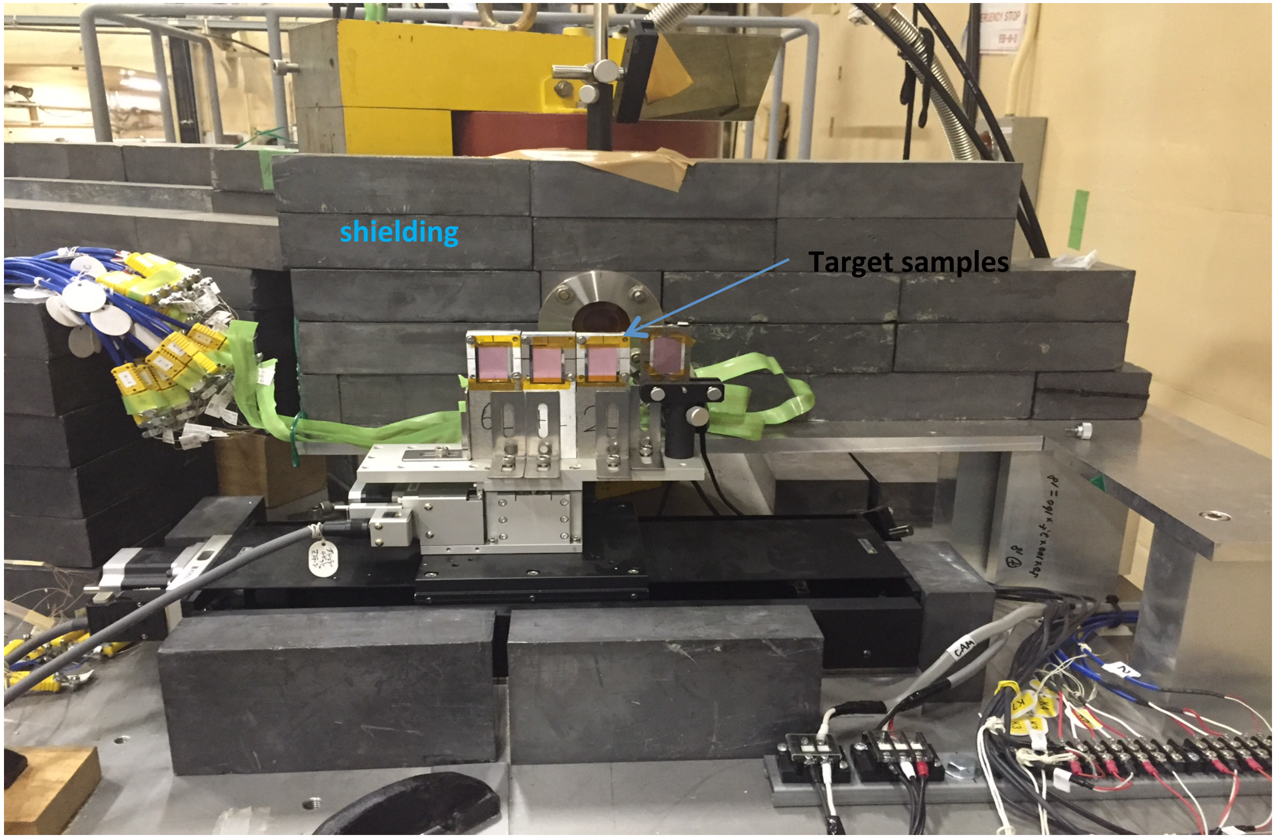
THE CONVERTER TARGETS (with Granular converter)



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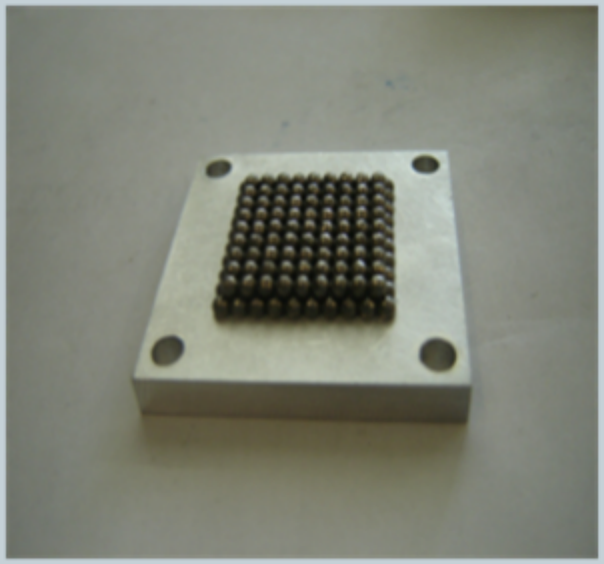
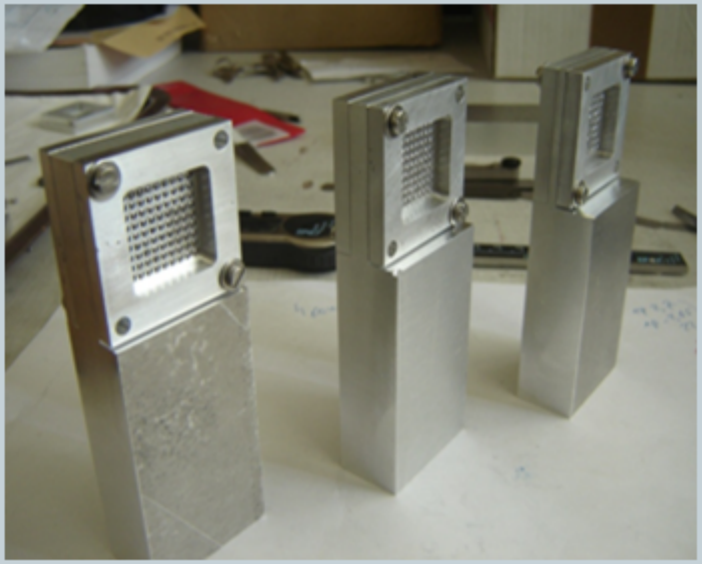
TEST OF THE HYBRID-GRANULAR TARGET AT KEK

4 granular converters with W spheres 1.1 mm radius have been built at LAL and sent to KEK. The experiments using a 7 GeV e- beam of KEKB linac started during autumn 2015. Thermocouples were fixed on some of the spheres at the exit face of the converter (Al grids with 1.8 mm holes)





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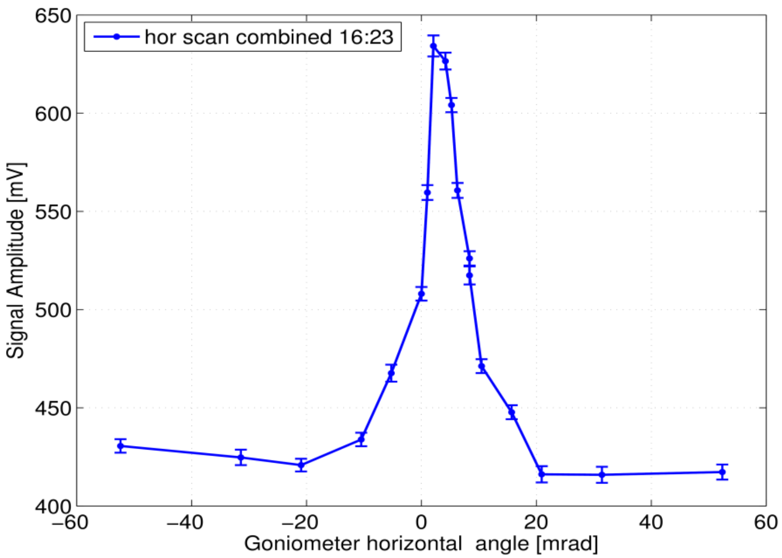
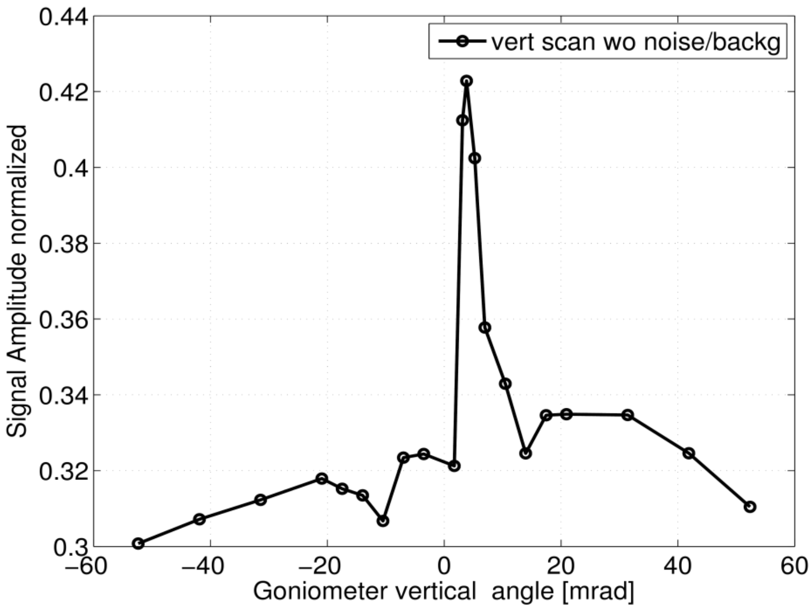
SOME RESULTS OF THE KEK TESTS:

Beam test took place last autumn at the KEKB injector linac to study the hybrid source with the granular converter. The measurements were concerning: the yield and the temperature measurements. The beam conditions were: E- = 7 GeV; [?](e-) = 1 mm; q(bunch) = 1nC; freq. = 1 to 25 Hz
Dynamical orientation of the crystal has been operated using positron detector.





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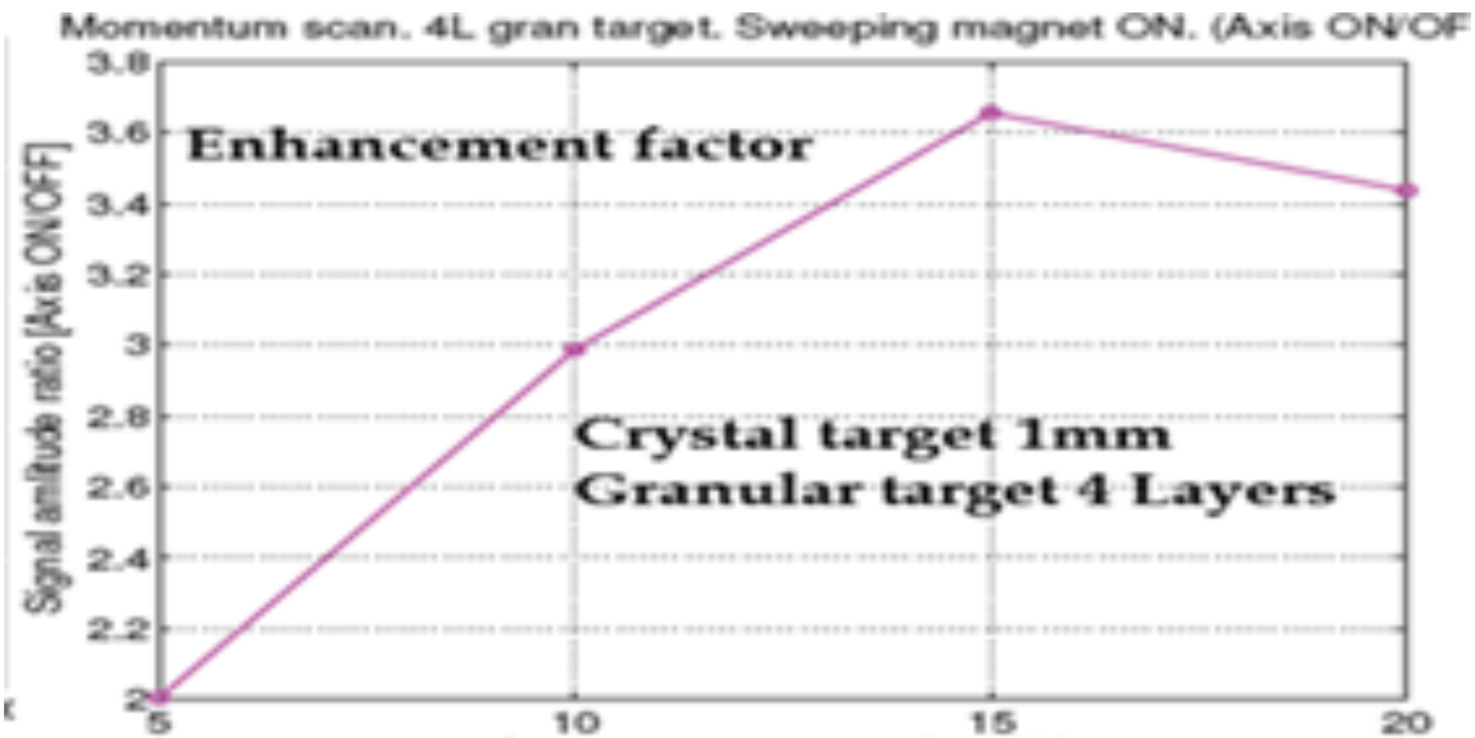
ENHANCEMENT CRYSTAL/RANDOM HAS BEEN MEASURED FOR DIFFERENT e+ ENERGIES



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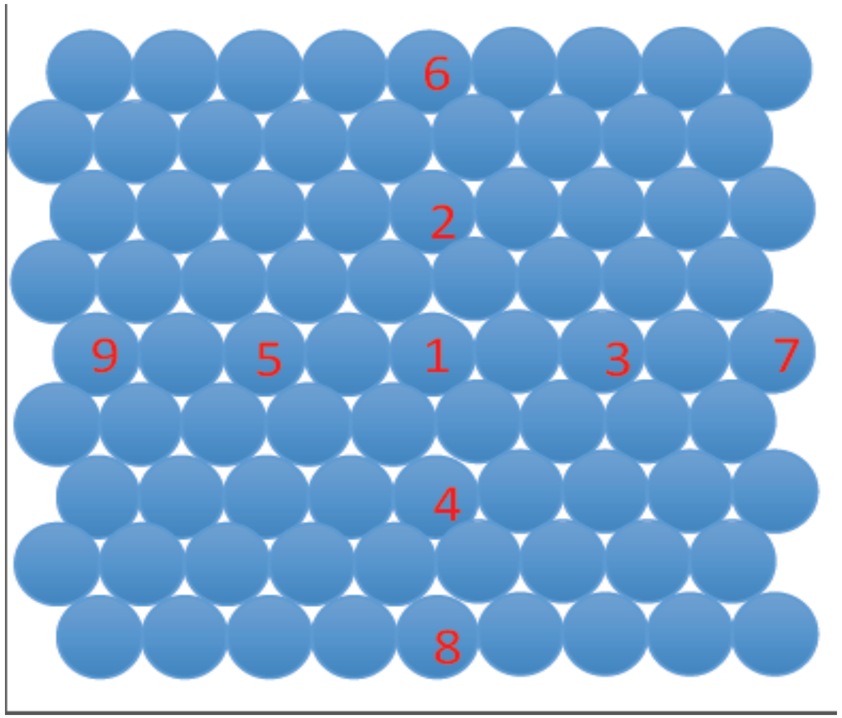
TEMPERATURE RISE

TEMPERATURE MEASUREMENTS ARE COLLECTED THROUGH TERMOCOUPLES GLUED ON SOME SPHERES AT THE EXIT FACE OF THE CONVERTER.

Data has been recorded for different repetition frequencies: 1, 5, 10 and 25 Hz. After analysis, we present , here, the results for 1 and 25 Hz. The thermocouples have been identified with numbers in order to get the temperature rise distribution on the exit face of the converter.



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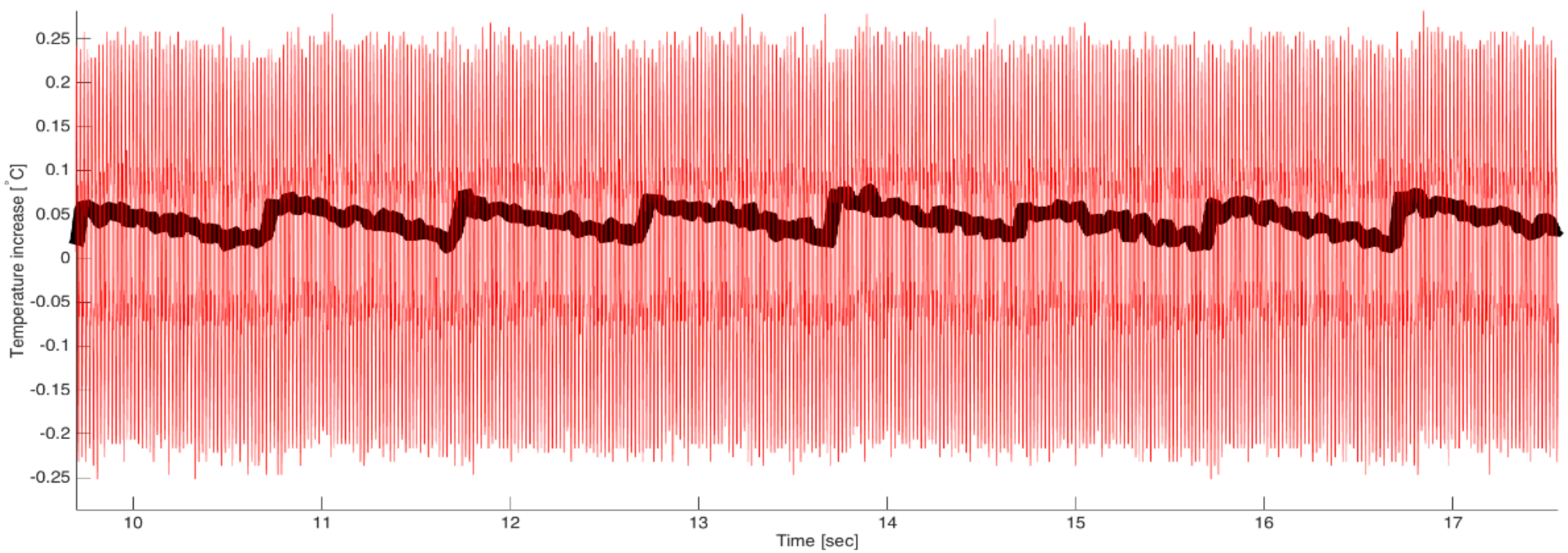
MEASUREMENTS AT 1 Hz

There is one bunch per second; the data for the rise-time is presented with and without filtering. In bold, is the filtered data. The maximum temperature rise is ~ 0.1 degree. Rise time is about 40 ms, though the beam pulse is clearly shorter. ; the decay time is about 500 ms.



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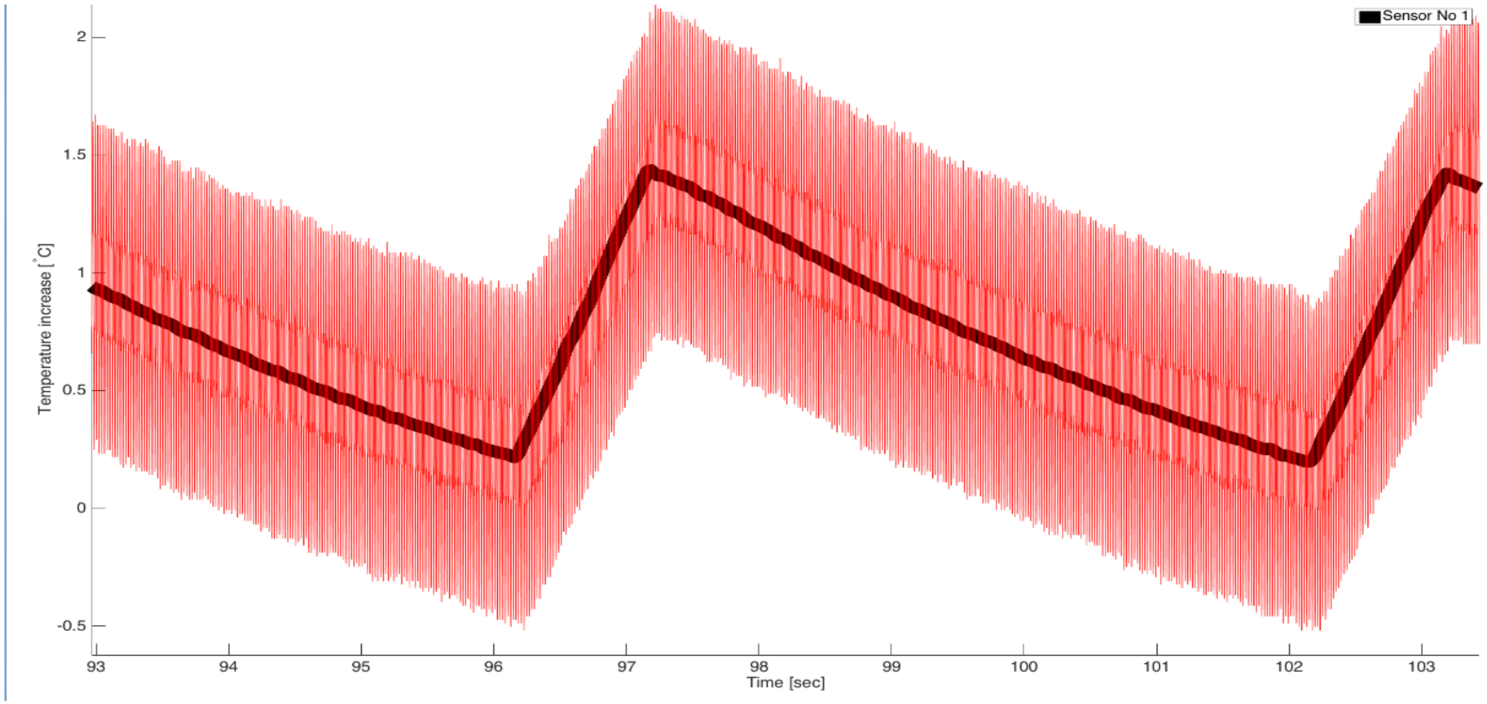
MEASUREMENTS AT 25 Hz

The temperature rise is ~ 1.5 degrees. Here also filtered (bold) and no-filtered data are presented. The beam is ON during 1 s and OFF during 5 s.



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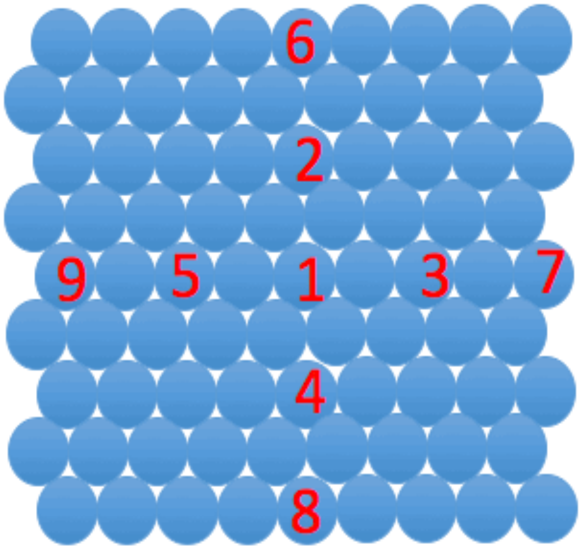
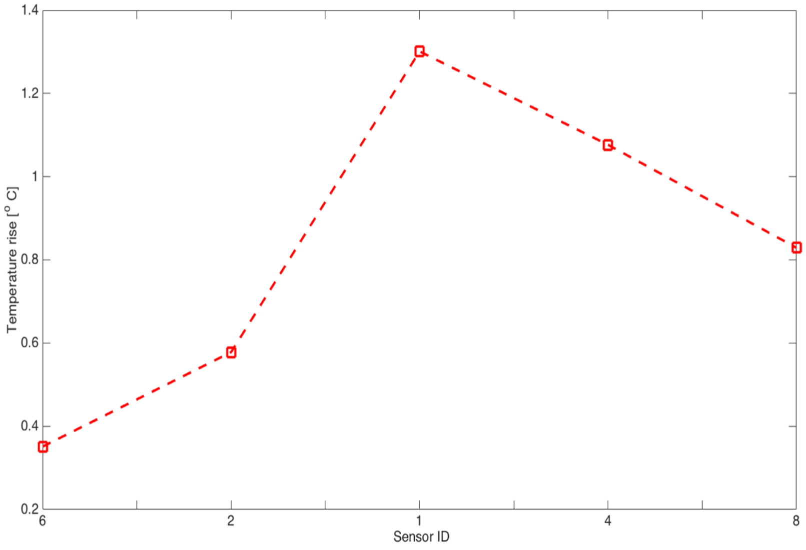
TEMPERATURE PROFILE:

The data given by the thermocouples enable us to get the temperature profile on the exit face of the converter. Here are presented the temperatures along a vertical axis on the spheres: 6, 2, 1 (center) 4 and 8. The repetition frequency is 25 Hz. The number of layers is: 4

Exit face of the converter (4 layers)



TEMPERATURE RISE/Vertical axis



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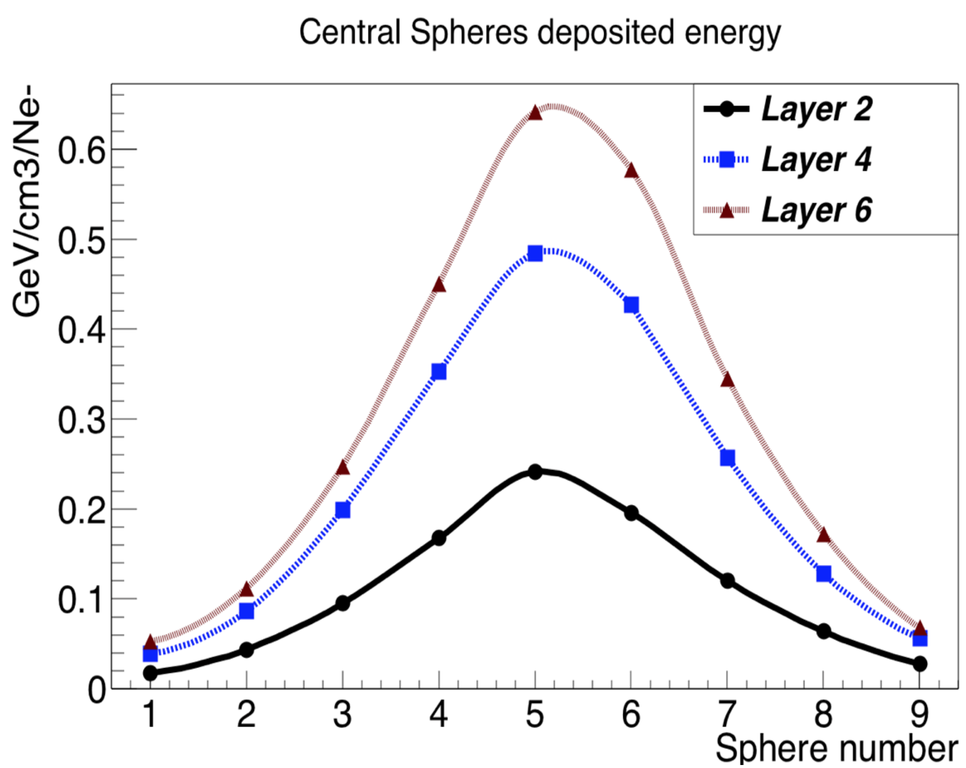
TEMPERATURE DATA ANALYSIS: from the temperature values obtained with the thermocouples we may find out the energy deposited in the spheres using the ANSYS code. And from these deposited energies we may extract the deposited energy density in the spheres (in GeV/cm3/e-). This determination provides the PEDD, generally in the central sphere (shower axis).

On the figure are represented the deposited energies density for 2, 4 and 6 layers of W spheres of 2.2 mm diameter obtained with GEANT4 simulation. The case corresponds to an hybrid source with:

- 5 GeV incident electron beam
-- ?(e-) = 2.5 mm
-- distance between crystal and converter: 2 meters.

Such kind of simulation (with KEK parameters) will be compared to ANSYS results. **Work to be done after 2d run (Oct.2016)**



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- **IS THE CHOICE OF A GRANULAR CONVERTER CONVENIENT FOR THE SHOCKS?**
- **Besides the thermal effects in the converter, we have to make sure that the thermo-mechanical shocks induced in the converter by short incident pulses will not lead to a breakdown as observed on the SLC target. This is an effect of the high value of the PEDD (Peak Energy Deposition Density). Simulations have been operated using ANSYS by S.Jin (IHEP) with the collaboration of P.Sievers in the following conditions:**
- **- Pulses of 1 μs**
- **- Spheres of 2 mm diameter (similar to the spheres of KEK converter)**
- **It turned out that the thermal shocks were 10 times lower than in a bulk material (40 Mpa instead of 400 Mpa). {Ultimate strength for W➔ ~1GPa}**
- **This advantage is very important for the reliability of the target.**

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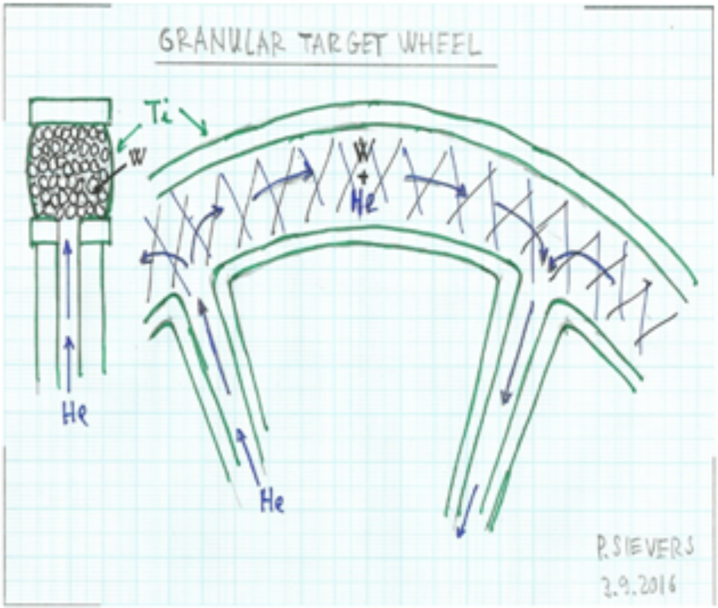
COOLING OF THE GRANULAR CONVERTER: TWO OPTIONS→ He gas or water
Suggestions of Peter Sievers

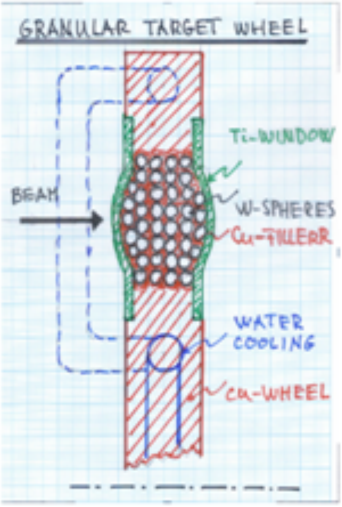
Cooling with He gas



Water cooling

COOLING OF THE GRANULAR CONVERTER:

A rotating wheel with a velocity of 4m/s and a diameter of 1 m is considered. The W spheres are embeded in copper which is cooled. Windows crossed by the beam are in Ti.
From P.Sievers (POSIPOL 2014)



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HEATING AND COOLING: THE CRYSTAL

With an incident e- beam of 10 GeV and a transverse size of 2.5 mm rms, the energy deposited and PEDD/μpulse are:

E_{dep}= 2.6 Joule

PEDD➔ 5.8J/g

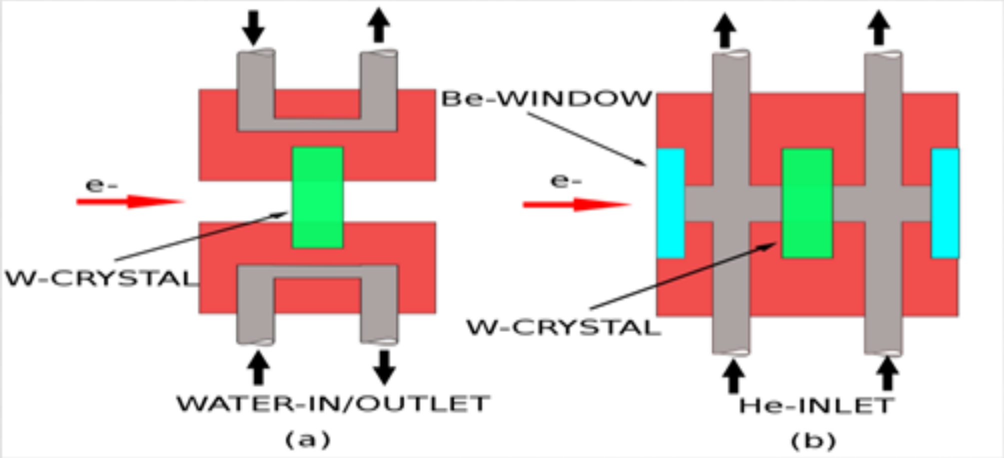
The crystal needs cooling:➔ solution: a 5-crystal holder in a goniometer.

Cooling is realized with water or He jet.

Max. Temperature rise is:

275°K =>>Water

406°K=>> He



OPTIMIZATION OF AN HYBRID POSITRON SOURCE USING CHANNELING

- **SUMMARY AND CONCLUSIONS**
- **(a) The use of an hybrid positron source has the following advantages:**
- *** A large number of soft photons is created in the crystal and contributes to generate a high yield of soft positrons easier to capture and accelerate.**
- *** Using the sweeping magnet between the crystal and the converter helps to alleviate the energy deposition and the PEDD in the converter.**
- **(b) Substituting a granular target to a compact one for the conversion allows to:**
- **# have a better thermal dissipation**
- **# avoid destructive shocks in the target**
- **All these arguments contribute to a better reliability of the positron source.**

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- **PLANS FOR THE NEAR FUTURE**
- **The results gathered with the KEKB test are encouraging and should be completed (with different granular converters and a comparison with a compact target). That will be done this autumn (21-22 October). Some improvements are foreseen concerning the goniometer control and the measurement of the photons.**
- **Concerning the simulations: there are going on with different parameters of the hybrid source. Extended simulations with ANSYS, using GEANT4 data, are foreseen in order to have a complete description of the thermal problems (heating and shocks) for different applications.**

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- **ACKNOWLEDGEMENTS**
- **We are grateful to Vadym Denysenko and Volodymyr Rodin students at Taras Shevchenko National Kyiv University for their collaboration.**