R&D status of the hybrid positron source

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Presented by Hayg Guler

Outline

- Introduction
- The hybrid e+ source with a granular converter
- Simulations results (GEANT4)
  - Hybrid e+ source for the ILC and CLIC
  - Comparison conventional/hybrid e+ source
- Experimental studies → Test at KEK
- Summary and conclusions

Introduction

- Common feature for linear collider : huge number of particle to fit into damping ring acceptance
  →Strong need for intense positron source
- Since 25 years, proposition to use of crystals as positron sources via channeling radiation
  - very promising results as shown in CERN and KEK experiments.
  - Main concern : Lower the PEDD and keep Yield high

→Recent investigations : Recent investigations led to the concept of an hybrid source

→Separated crystal-radiator and the amorphous converter

→ swept off charged particles (→ reduce PEDD)

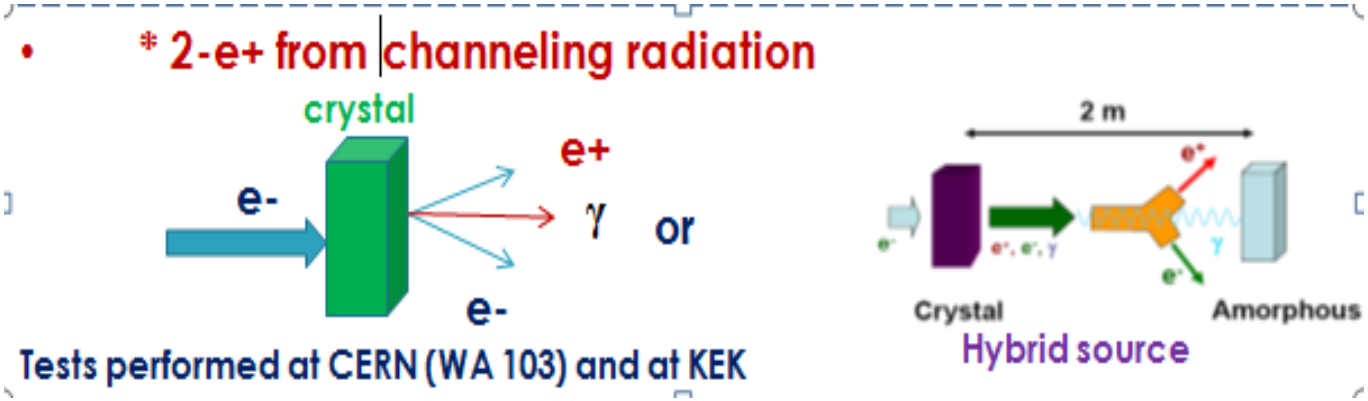
→Granular amorphous converter → increase heat dissipation

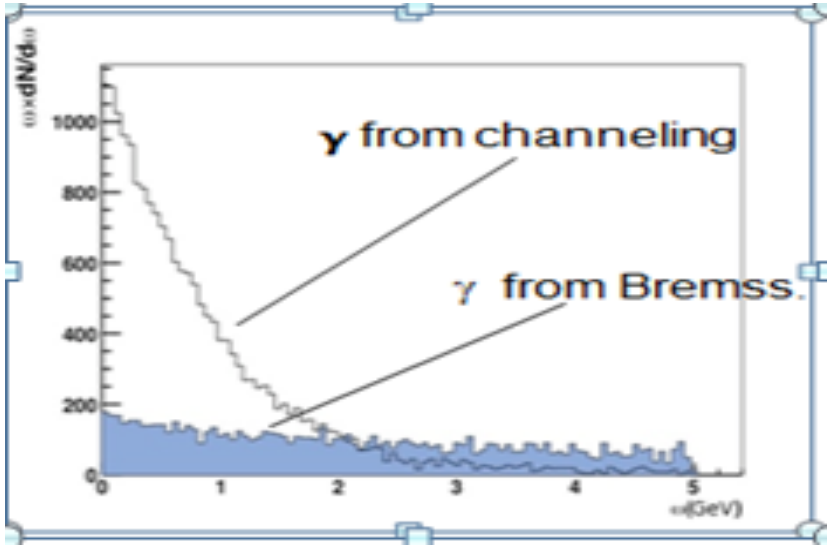
e+ production via channeling

- 2 methods could be compared
  - Electrons traverse dense material (high Z like W)
    - EM shower development with energy distributed up to input e- energy
  - Electrons (few GeV) traverse a crystal with motion in direction of its axis (111)
    - Enhancement of the photons production (compared to bremsstrahlung) in particular for soft photons

    → easier capture by matching devices

e+ production via channeling



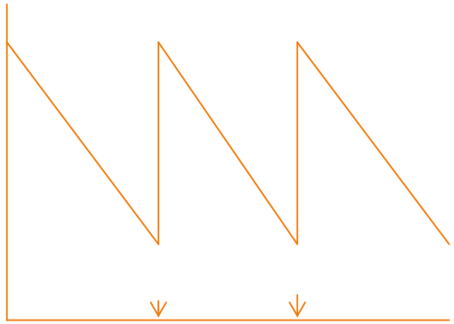


- The vertical scale is E.dN/dE. As bremsstrahlung spectrum has a 1/E behaviour it exhibits an almost constant dependence.
- known matching devices put after the converter capture more efficiently soft positrons (typically from some MeV to 20-30 MeV)

Hybrid source with granular converter

GRANULAR VS COMPACT POSITRON CONVERTERS…

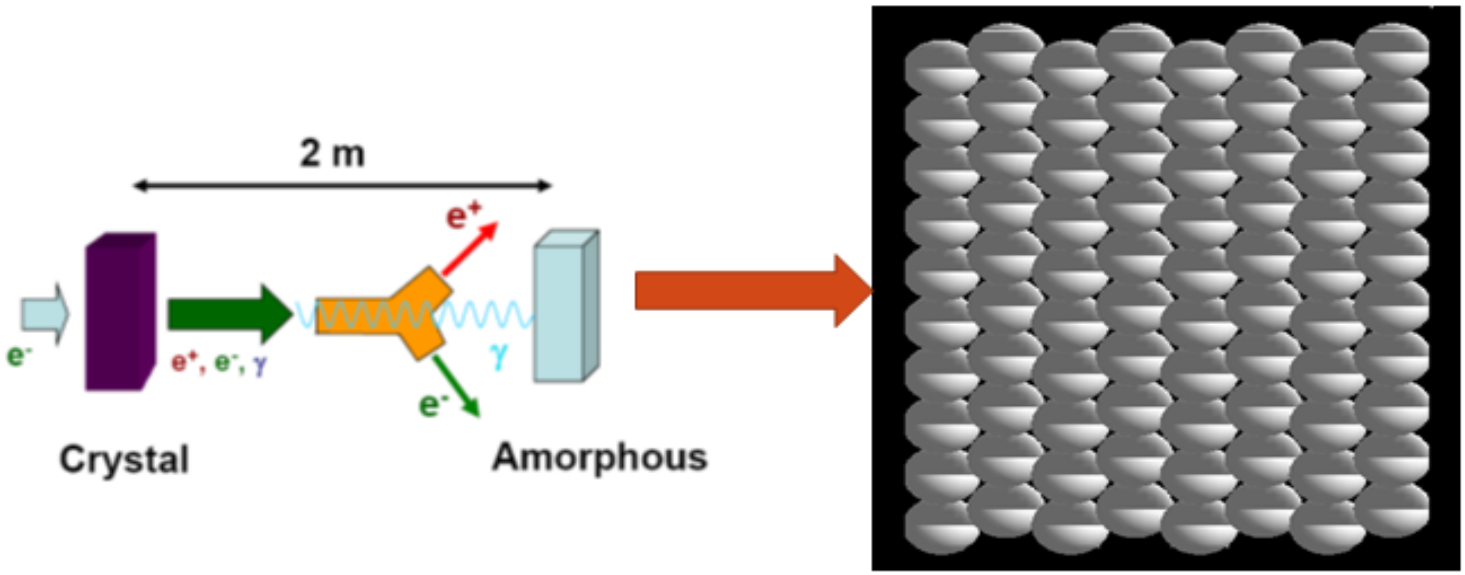
- **ADVANTAGES OF THE GRANULAR TARGETS**
- **If we consider the convective cooling in a pulsed**
- **temperature regime, the decay time is given by:**
- **$\tau = C.m/\alpha.F$**
- **Where C is the specific heat, m, the sphere mass,**
- **α, the convection cooling coefficient, and F, the**
- **sphere surface. This expression may be written:**
- **$\tau = C.\rho.R/3.\alpha$**
- **With ρ, the density and R the radius of the sphere;**
- **As for a sphere, F/V is 3/R**
- **it shows clearly that a fast cooling requires small R value. So, using small spheres present a real interest to ensure rapid cooling. However, some practical limit to small radii is leading to the choice of R~ 1 mm, at least.**



(The decay is exponential)

Hybrid source with granular converter

- **THE SCHEME**



The amorphous converter is made of a great number of small spheres with a radius of 1-2 mm.The spheres are put in a container with entrance/exit windows in Beryllium and up and bottom windows in titanium.

Simulations using GEANT4 : Questions we needed to answer

- What are the **positrons yields** at the exit of the granular converter ?
- What is the **positron energy distribution** at the exit of the granular converter ?
- What is the **deposited energy in the granular converter** ?
  → What is the corresponding **increase of temperature ?**
- What is the **PEDD** in the granular converter (deposited energy in the central sphere ?)
- What is the ideal **sphere size** in the granular converter ?
- What is the ideal **number of layers** for the granular converter ?
- How the **deposited energy is distributed between spheres** ?
- How is the **yield compared to compact amorphous converter** ?
- How is the **total deposited energy compared to compact amorphous converter** ?
- How is the **PEDD compared to compact amorphous converter** ?

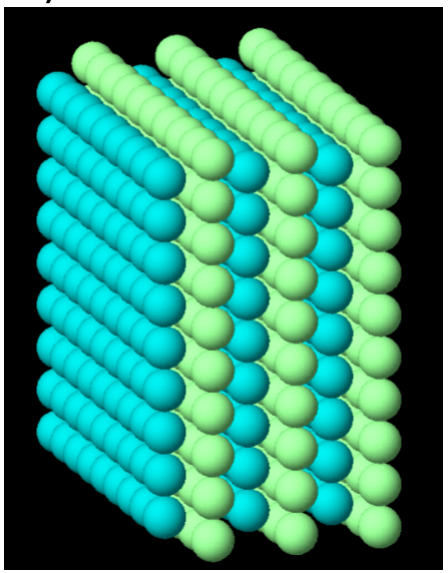
Input parameter for the simulation

ILC scheme

- Incident e- : 10 GeV
- Granular converter : r=1.1mm
  - 2, 4, 6 or 8 staggered layers (10x10 and 9x9 spheres)

CLIC scheme

- Incident e- : 5 GeV
- Granular converter : r=1.1mm
  - 2, 4, 6 or 8 staggered layers (10x10 and 9x9 spheres)

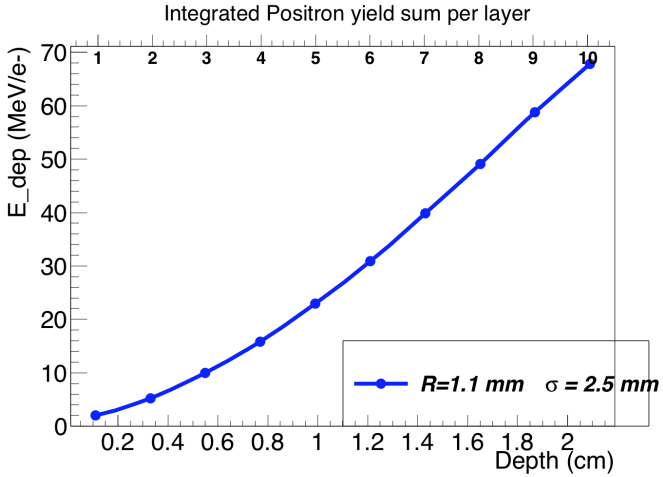


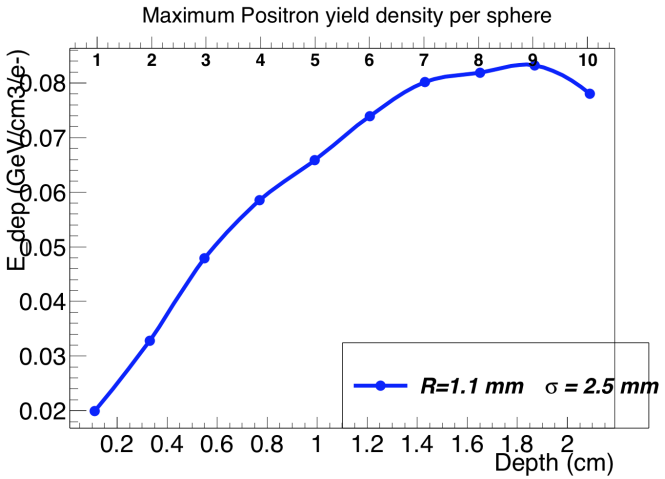
Simulation results : how many layers

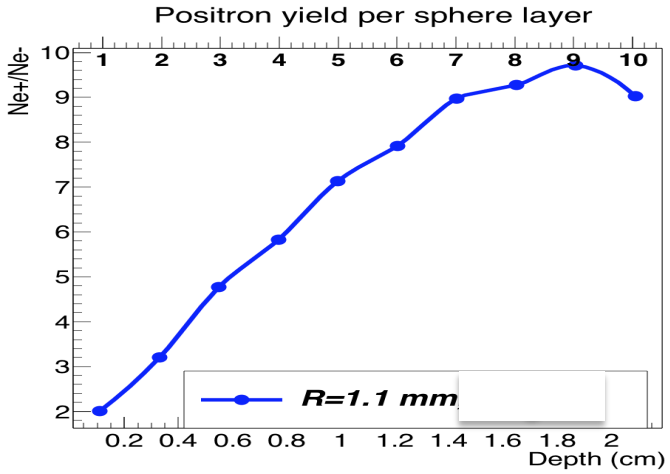
Choice of number of layers for the granular converter

3 conditions should be first full fill :

1. High positron yields (depends on needs)
2. Low PEDD in order to prevent target breakdown
3. Low total deposited energy to prevent target heating







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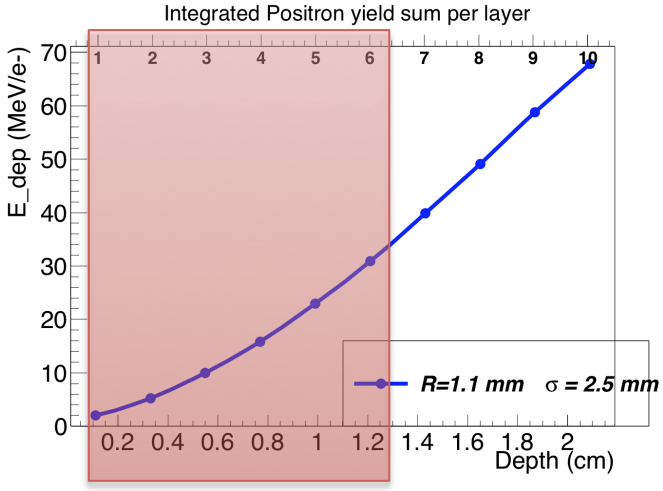
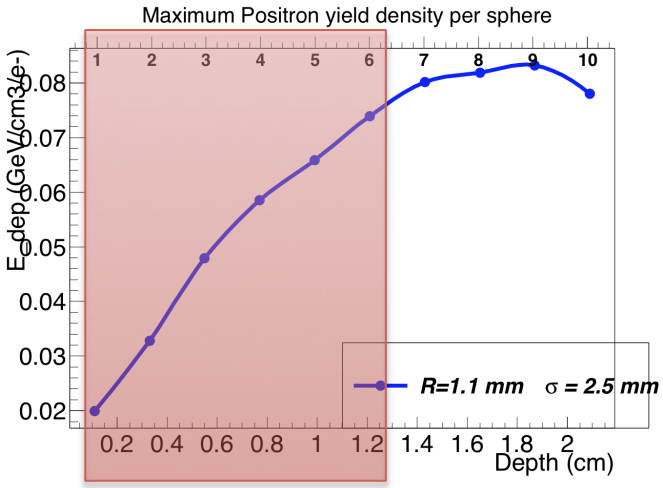
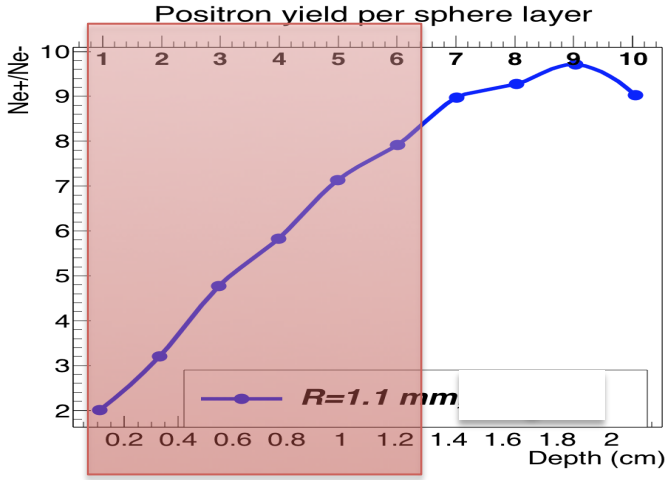






Simulation results : compare sphere size for PEDD

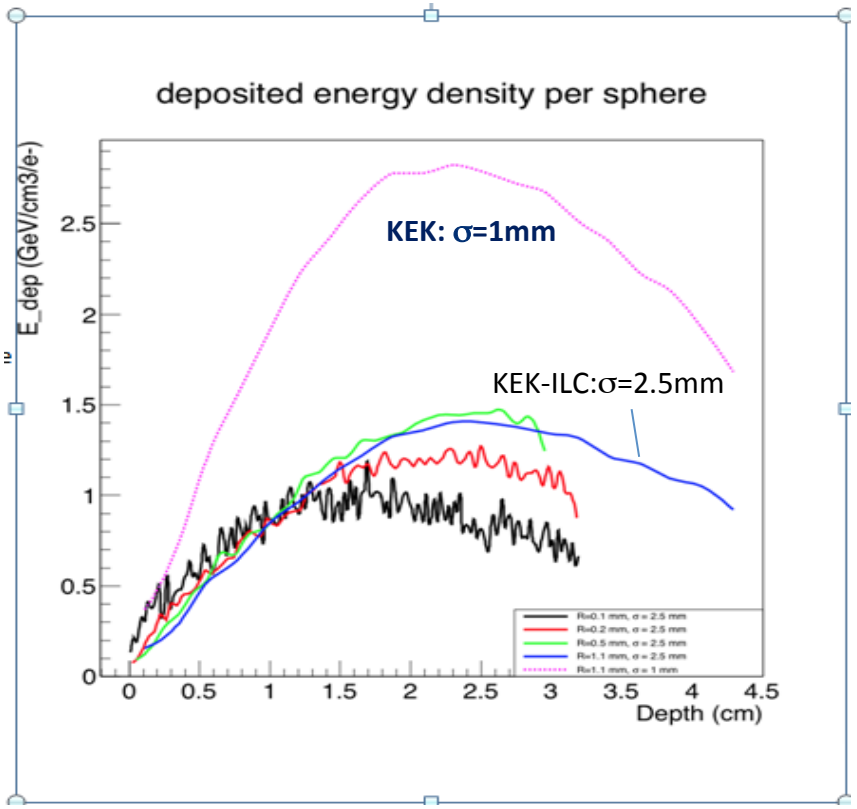
ENERGY DEPOSITION DENSITY

The energy deposition density in the central sphere (even rank of slice) has been calculated for the 2 cases:

- KEKB beam (σ=1 mm) ILC beam(σ=2.5 mm)
- R=1.1, 0.5, 0.2 and 0.1 mm

Up to 1.5 cm thickness :

- E_dep independent on sphere size up to 1.5cm thickness
- Good approximation for the PEDD if we take r=1.1mm and up to the thickness <1.5cm



Incident electron energy is 8 GeV for all curves

Simulation results for ILC and CLIC

CLIC case

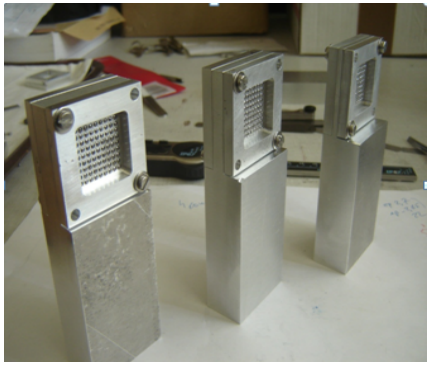
- Granular target: 6 layers
- Total positron yield of about ~8 e+/e-
- Deposited energy of ~250 MeV/e-
- Energy deposition density of about ~0.7 GeV/cm^3/e-

ILC case

- Granular target: 6 layers
- Total positron yield of about ~14 e+/e-
- Deposited energy of ~400 MeV/e-
- Energy deposition density of about ~1.4 GeV/cm^3/e-

Tests at KEKB Linac
October 10th 11th 12th 2015

With KEKB Linac Team members :
K.Furukawa, T.Kamitani, F.Miyahara, M.Satoh, T.Suwada, K.Umemori, Yuuji Seimiya, Kensei Umemori



Test of October : Installation layout

THE EXPERIMENTAL LAY-OUT: the beam test is done at KEK injector linac, 3d SY. The crystal is mounted on a 2-axis goniometer. Analyzing magnet, collimators and detectors are in vacuum conditions (10^{-3} Torr). Geometrical acceptance of the detector is small (0.22msr)

Scheme of the installation

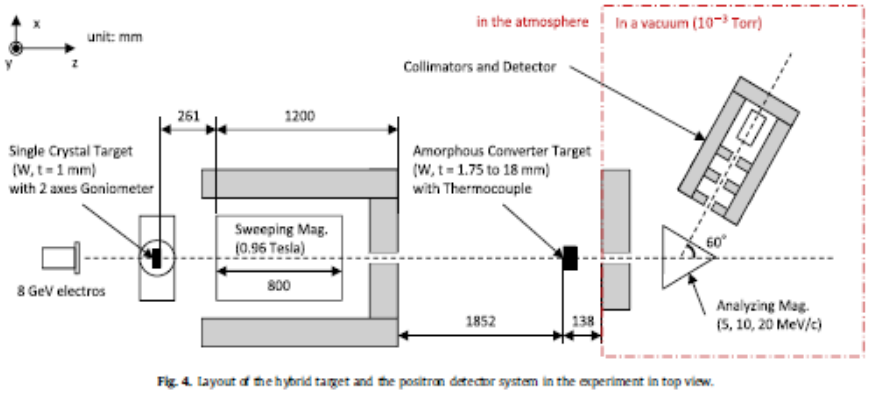
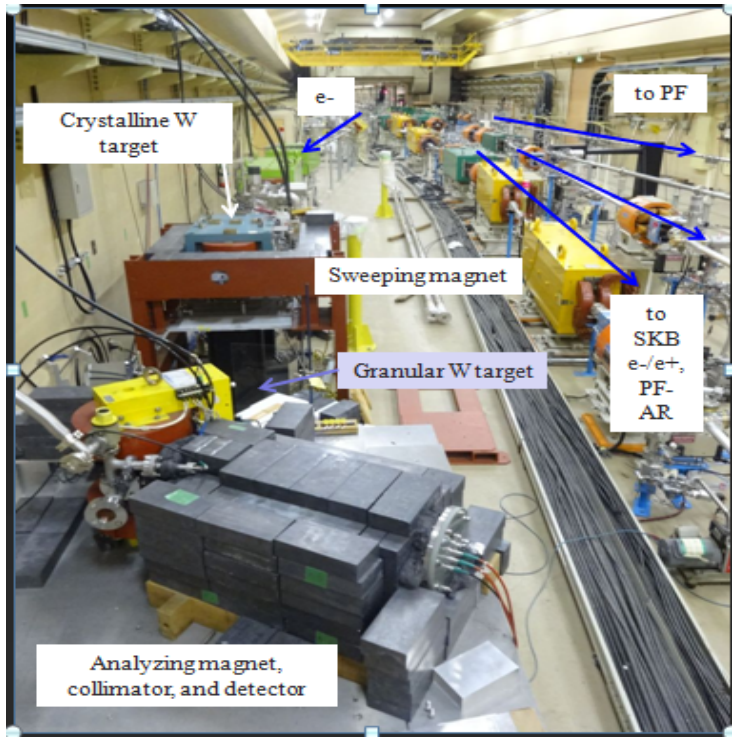


Fig. 4. Layout of the hybrid target and the positron detector system in the experiment in top view.



Previous measurement

Nuclear Instruments and Methods in Physics Research B 319 (2014) 17–23

Experimental setup : crystal alignment

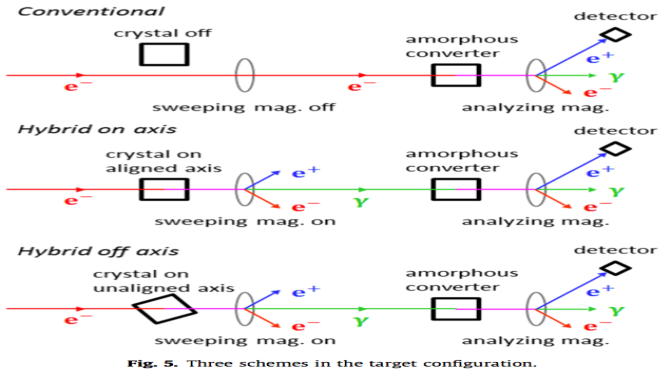
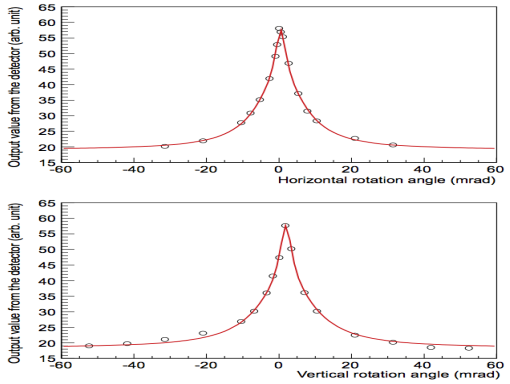
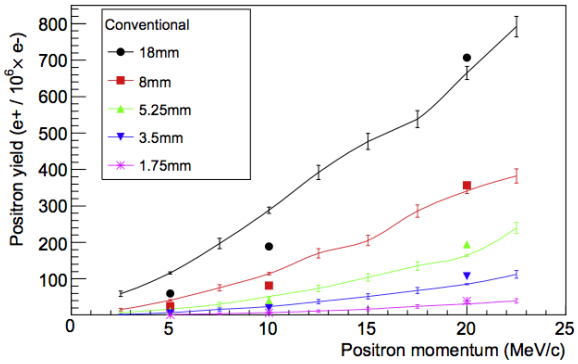


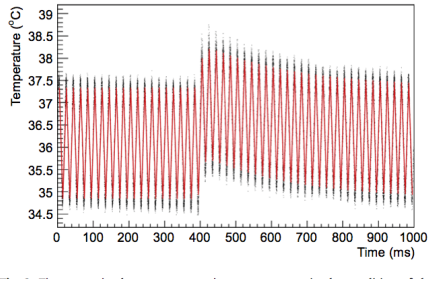
Fig. 5. Three schemes in the target configuration.

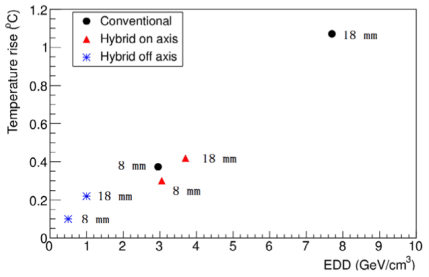


Yields measurement



Amorphous converter temperature measurement





What's new from previous measurement

- Experimental setup is basically the same
- Beam Energy ≈7 GeV
- 4 different Granular converter all equipped with thermocouples (9 in exit window)
- Possibility to use different beam repetition rates :
  - Used ones 1Hz, 5Hz, 10 Hz, 25Hz Continuous
  - Special pattern : 1s (5, 10 or 25Hz) 5s (no beam)

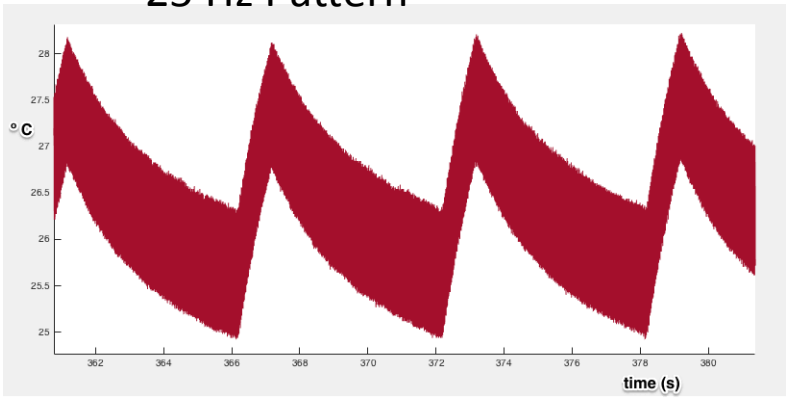
Some preliminary results (analyze ongoing)

- Channeling axis found using goniometer
  - lucite Cherenkov detector to measure e+
  - Analyzing magnet : 5, 10 and 20 MeV e+
  - Use 8mm compact W target
  - Use 4 (and 6) layers granular target
  - Data taken with and without sweeping magnet
- Temperature measurement
  - 9 thermocouples on exit face of granular target
    - Measurement of lateral density distribution along a central axis
  - Data taken at different beam repetition rates
    - 1, 5, 10 and 25 Hz continuous
    - 5, 10 and 25Hz pattern : 1s:ON and 5s: OFF

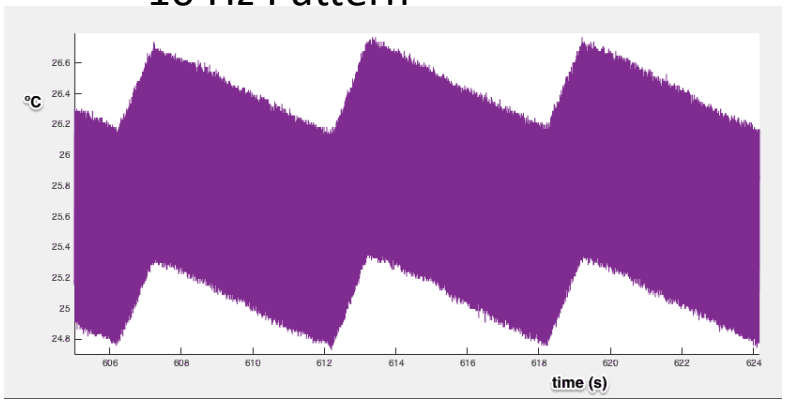
Some very preliminary results

(temperature data : 4 Layers granular / central thermocouple)

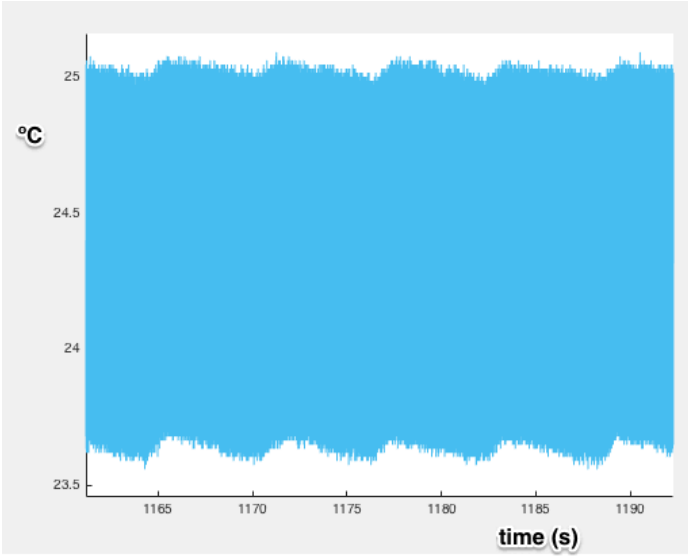
25 Hz Pattern



10 Hz Pattern



5 Hz Pattern



Conclusion and outlook

- Choosing a hybrid e+ source using channeling already meets the requirements of the ILC and CLIC.
- Very fruitful collaboration with KEKB Linac colleagues. Still room to explore :
  - Measure all granular targets temperature
  - Compare to compact converter
  - Improve beam orbit stability / channeling axis research
- Simulations of the temperature distribution of the W spheres and evaluations of the granular converter thermal shocks are ongoing.
  - Data taken at KEKB Linac should improve our understanding on heat dissipation