Hybrid e+ source update: beam test at KEKB linac

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Introduction

- A beam test to study Hybrid e+ source took place at KEKB linac last October
- We performed and ran out the simulations for analysis and possible optimization of the set-up

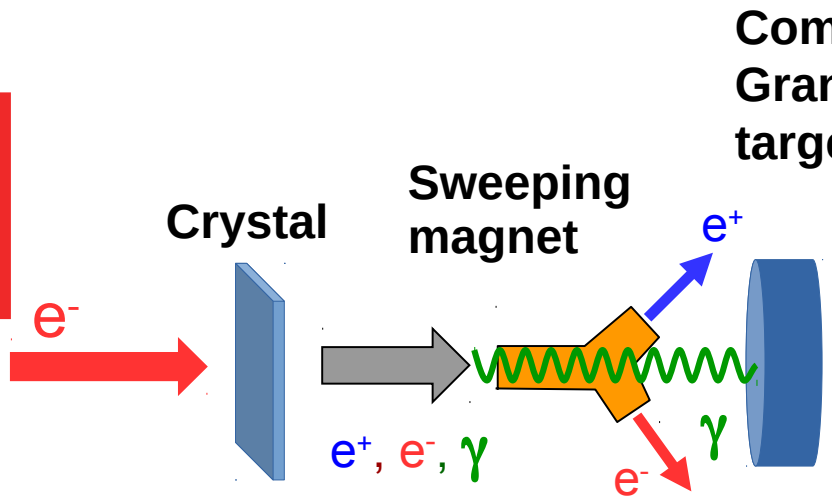
Positron source group: **X. Artru, I. Chaikovska, R. Chehab, K. Furukawa, H. Guler, T. Kamitani, F. Miyahara, M. Satoh, Y. Seimiya, V. Rodin, P. Sievers, T. Suwada, K. Umemori**

Outline

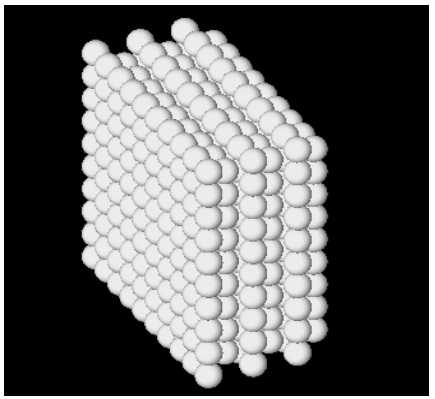
- Hybrid source for positron production.
- Geant4 simulation of the experimental setup.
- Influence of magnetic field and other aspects of the experiment on the e+ detection.
- Simulation & experiment comparison.
- Summary.

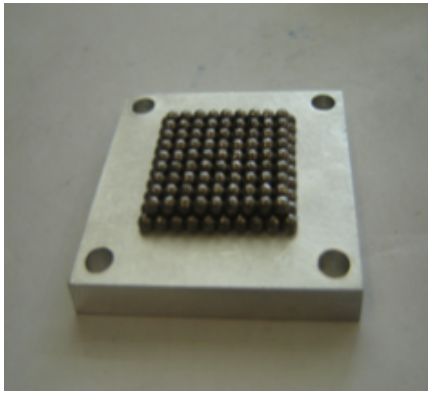
Hybrid positron source

- Hybrid scheme is based on a relatively new kind of e+ source using the intense radiation emitted by high energy (few GeV) electrons channeled along a crystal axis => channeling radiation.
- Channeling radiation in axially oriented crystals is a powerful source of photons => useful to produce the high intensity e+ beams.
- There were several experiments to study the hybrid e+ source (proof-of-principle experiment in Orsay, experiment WA 103 @ CERN and experiment @ KEK).

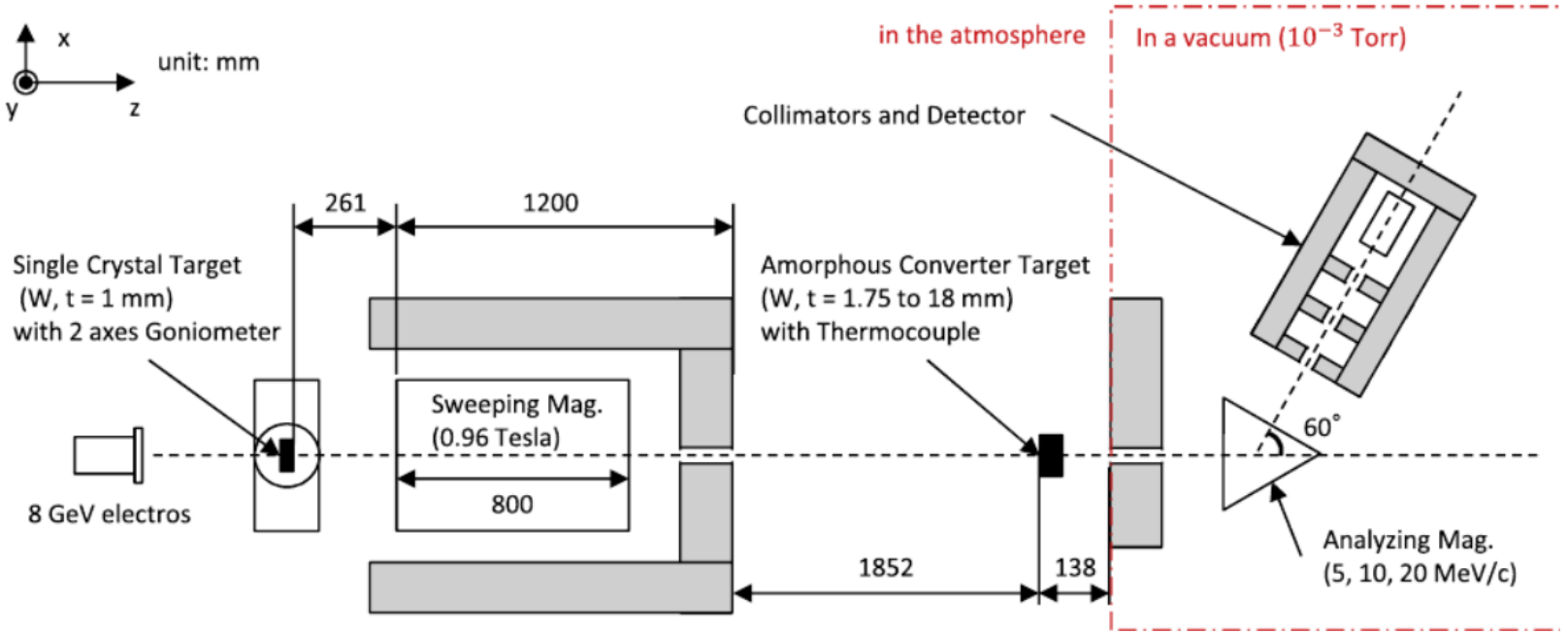


Granular targets





Hybrid sheme: Experimental layout



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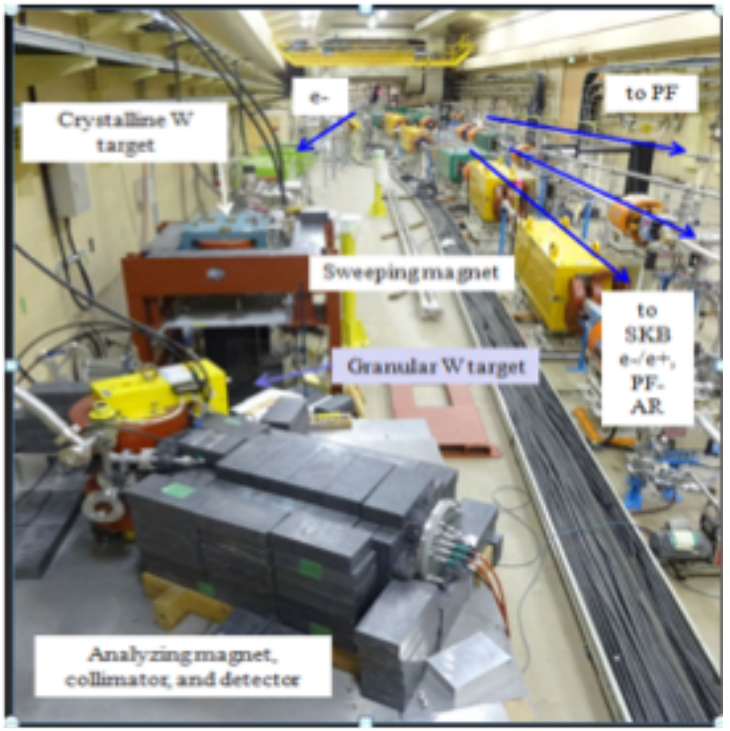
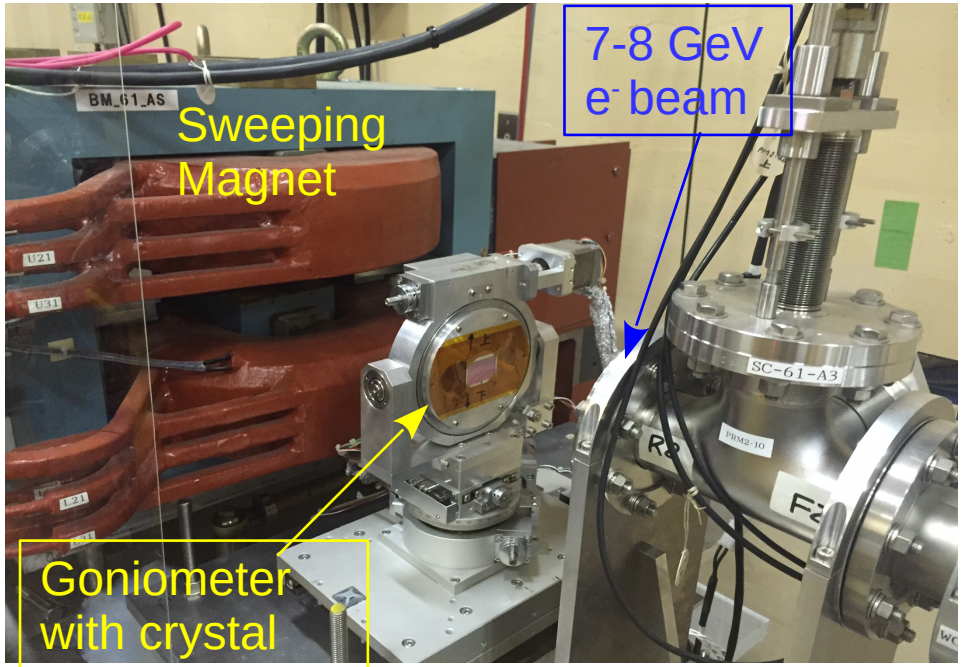
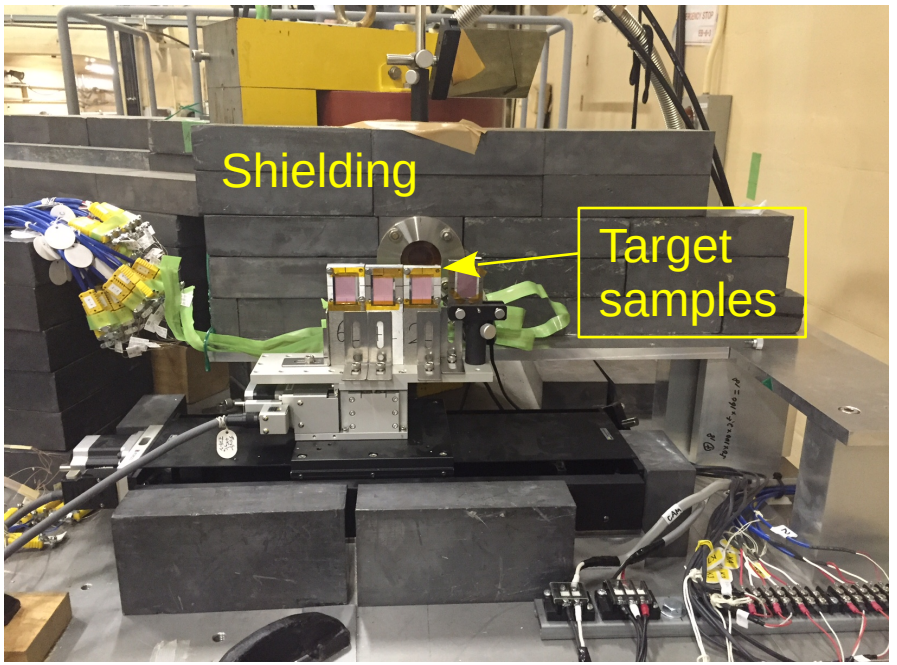
- Beam test took place last autumn at the KEKB injector linac to study the granular converter. Next one => this autumn.
- **Goals: e+ yield and temperature measurements to compare different targets (Conventional&Granular) => e+ source performances.**

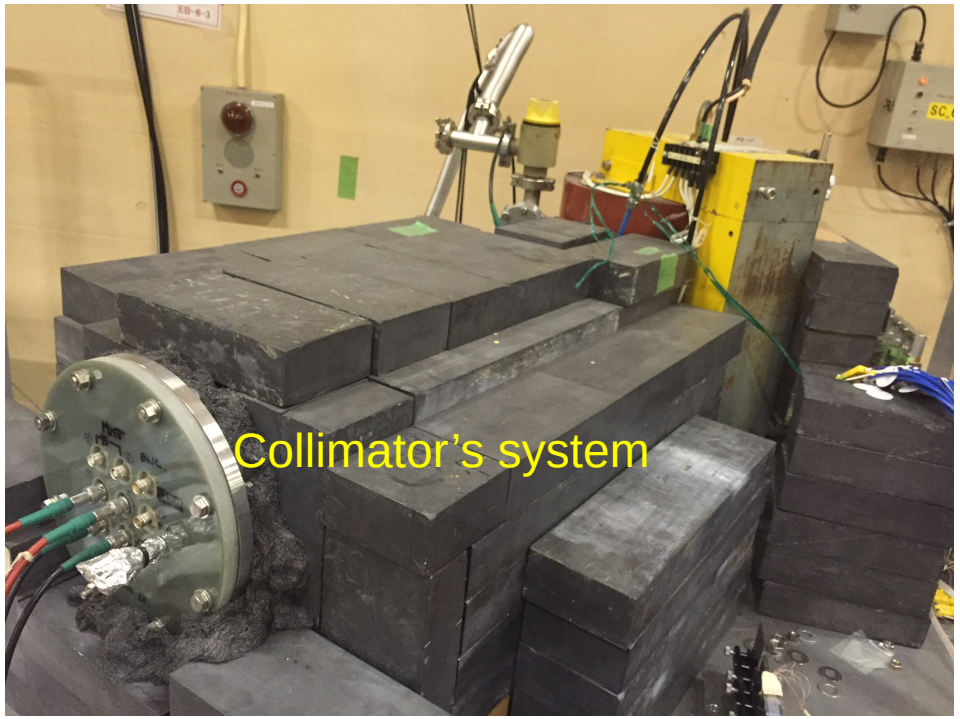


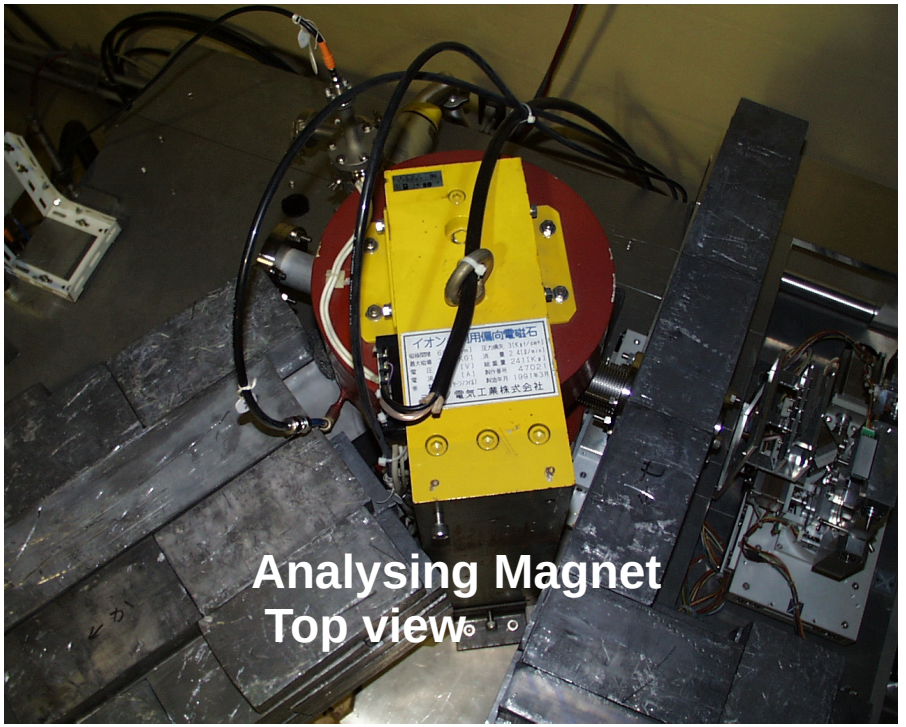
* Scheme source: Y. Uesugi et al. /Nuclear Instruments and Methods in Physics Research B 319 (2014) 17–23

Hybrid scheme: Experimental layout

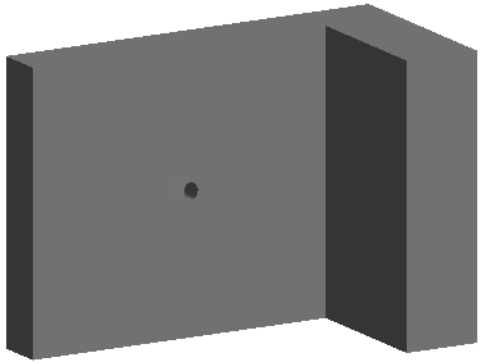




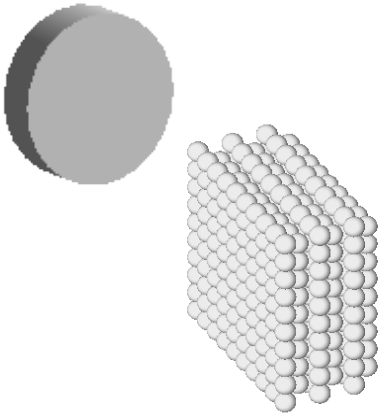




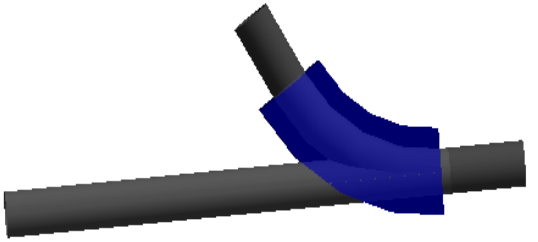
Experimental set-up simulated in Geant4



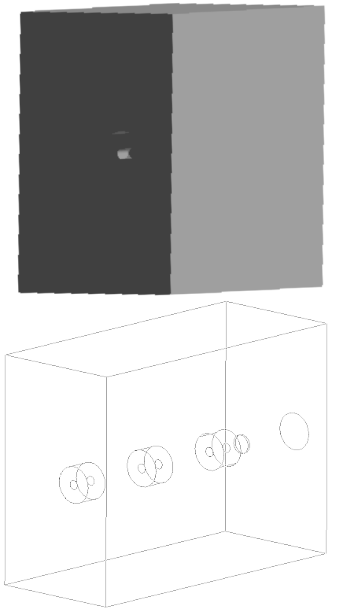
Front shielding consist of tungsten



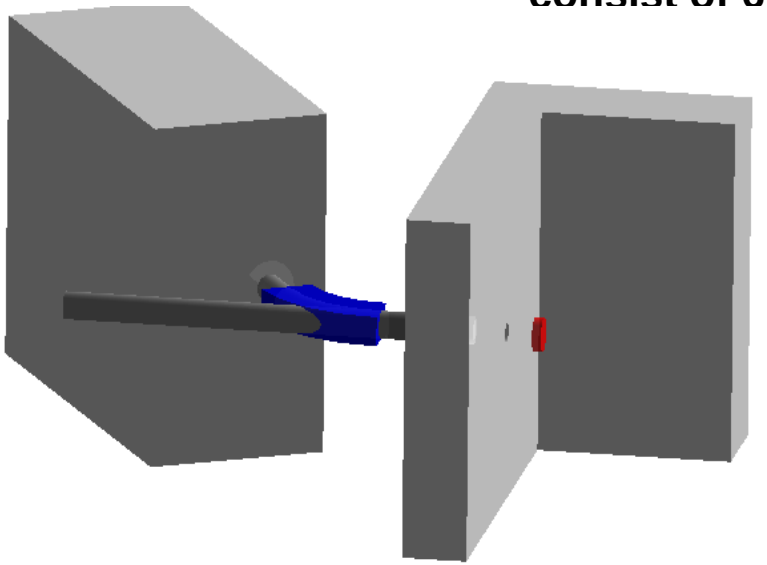
Bulk and granular targets, W
In this case granular consist of 6 layers.



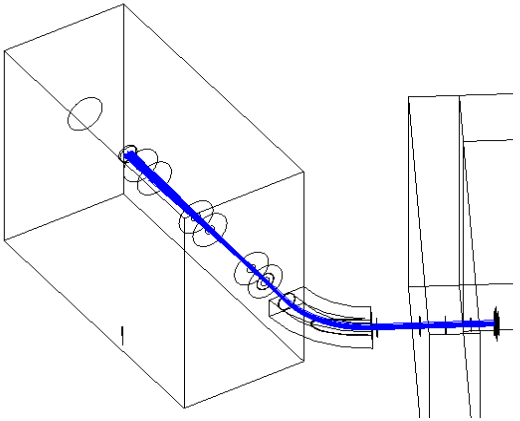
Analyzing magnet with pipes

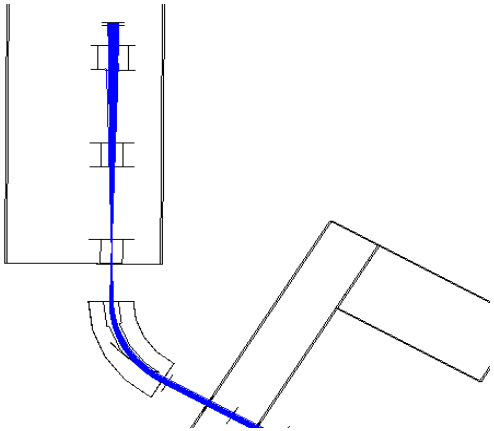


Collimator system with detector



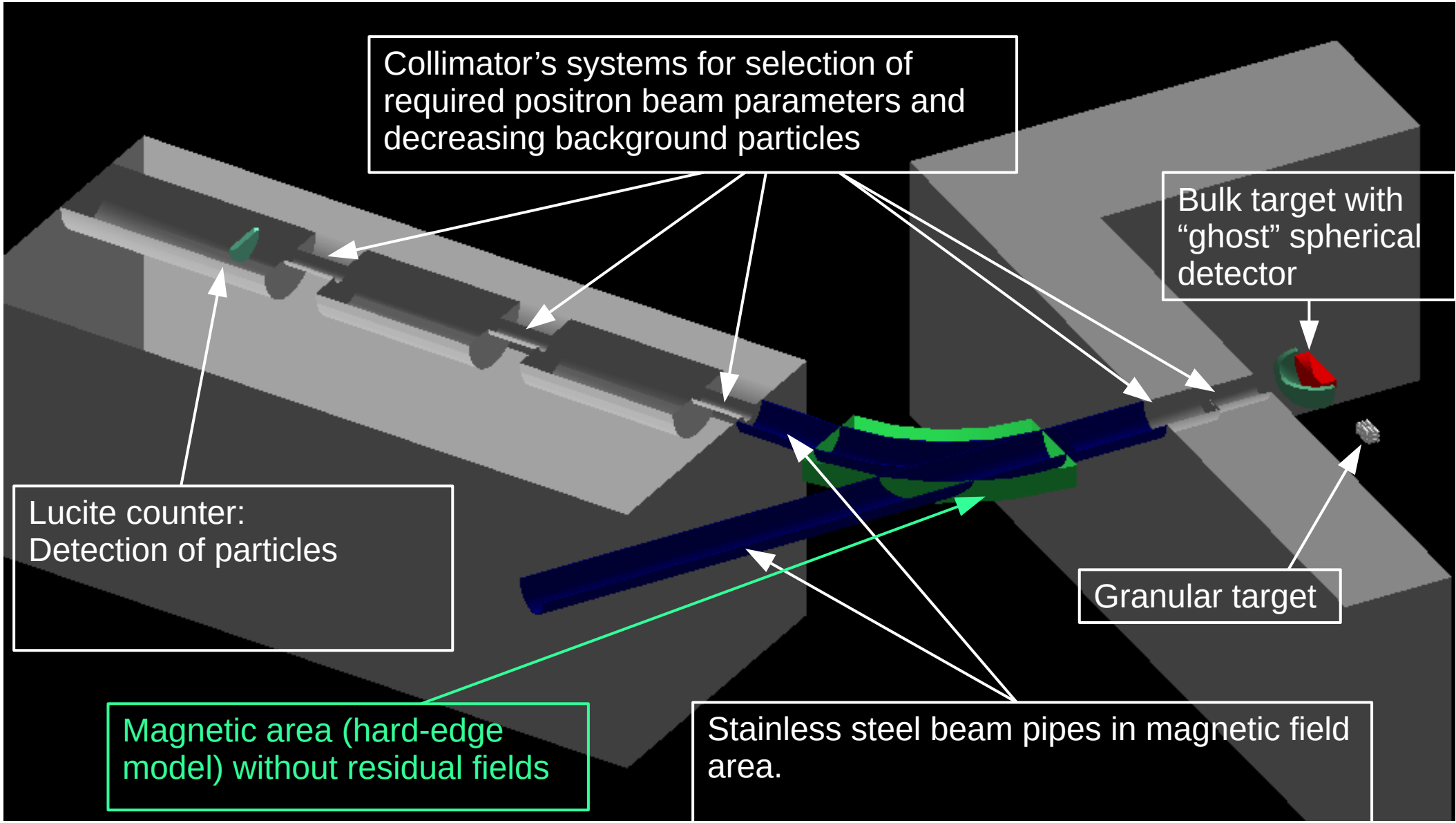
Global view



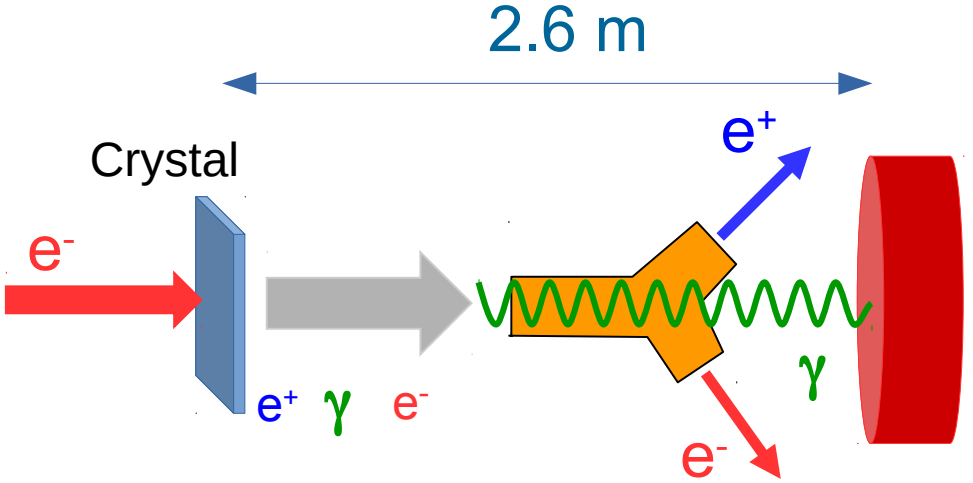


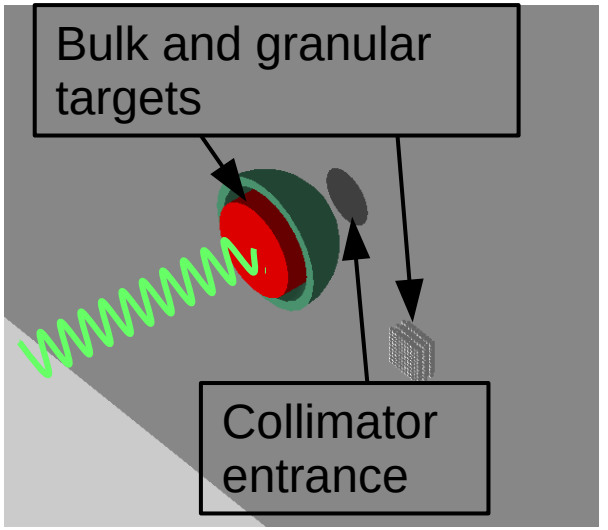
Beam test of set-up

More details about parts of simulation setup



Geant4 model description





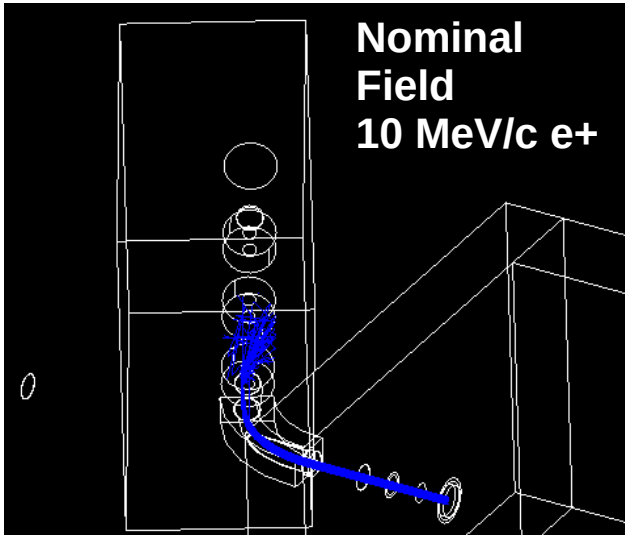
Simulations were carried out under the following conditions:

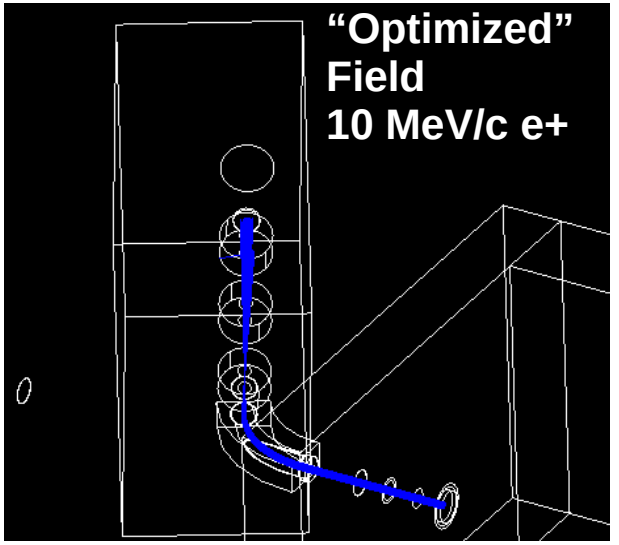
- Radiator => 1 mm thick W crystal, Convertor => 8 mm compact or granular W targets.
- Two states of Sweeping Magnet (SM)

  SM => ON/OFF.
- SM OFF state allows charged particles to reach the target-converter.
- Two states of the crystal alignment using goniometer.

  Crystal Axis => ON/OFF.
- Axis OFF state is the ordinary bremsstrahlung radiation (no photon enhancement given by channeling).
- Thus we can check a few variants of positron production + conventional scheme without crystal.

Simulation of the detector acceptance





- From simulation we found that nominal magnetic field B may be not optimized with respect to e+ detection efficiency. In the following, we will use nominal and “optimized” notation for the magnetic field B.

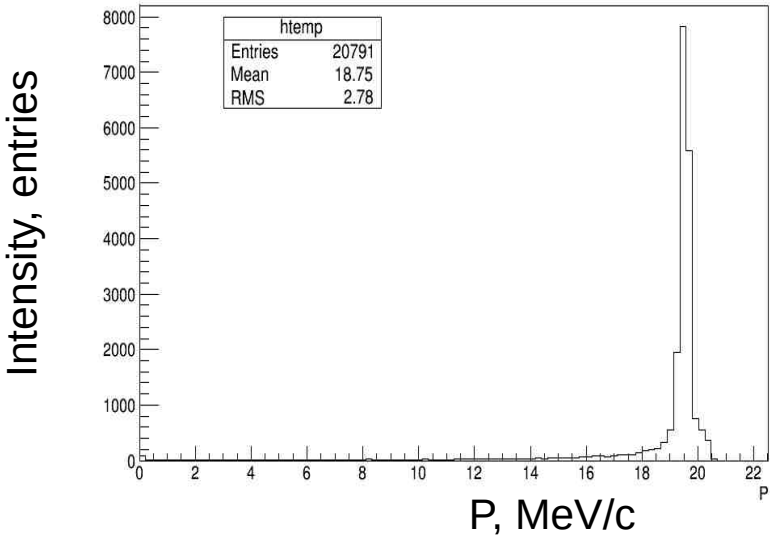
- To detect the e+, the Analyzing Magnet working points are set for e+ momentum – 20, 15,10 and 5 MeV/c. This corresponds to:
- B nominal: 0.355 T, 0.266 T, 0.177 T, 0.087 T
- B “optimized” : 0.365 T, 0.276 T, 0.187 T, 0.097 T => maximizes the number of e+ detected.

Simulation of the detector acceptance

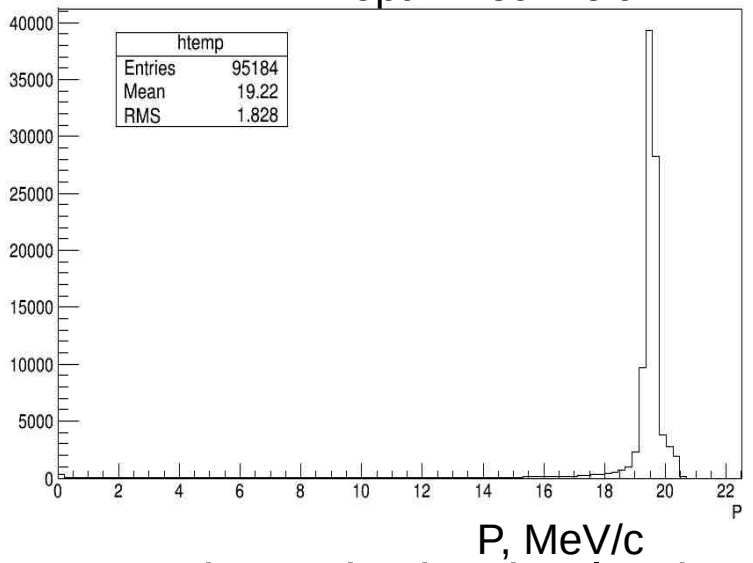
- During simulation two sets of magnetic field values were used: nominal and “optimized”. Initial number of monoenergetic positrons I_0 – 10^5 particles.

P, MeV/c	B “optimized”, T	B nominal,T	I/I_0, B “optimized”	I/I_0 B nominal	ΔP/P, % B “optimized”	ΔP/P, % B nominal
20	0.365	0.355	0.952	0.208	2.69	2.76
15	0.276	0.266	0.95	0.03	3.09	3.1
10	0.177	0.187	0.946	0.001	3.5	4.5
5	0.087	0.097	0.932	0	4.62	-

B nominal field



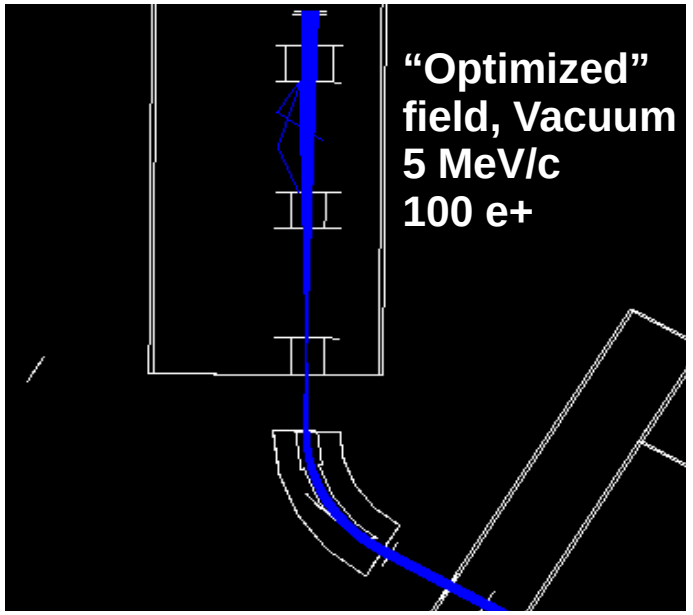
B “optimized” field

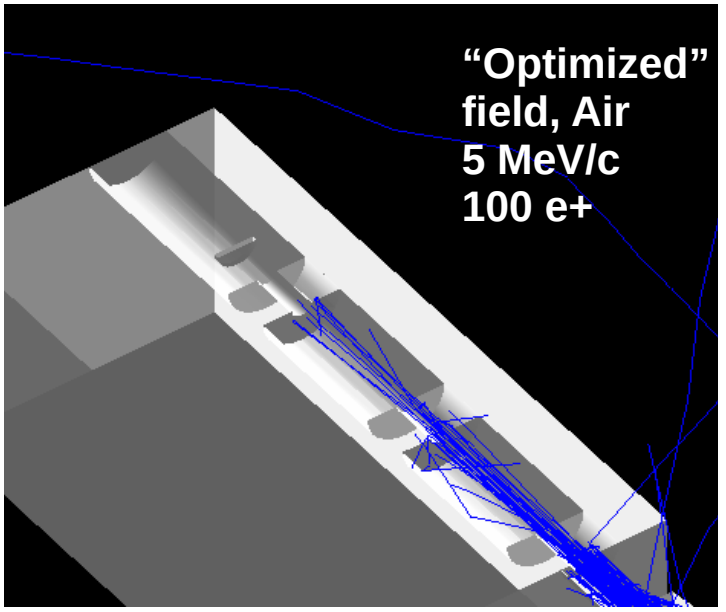


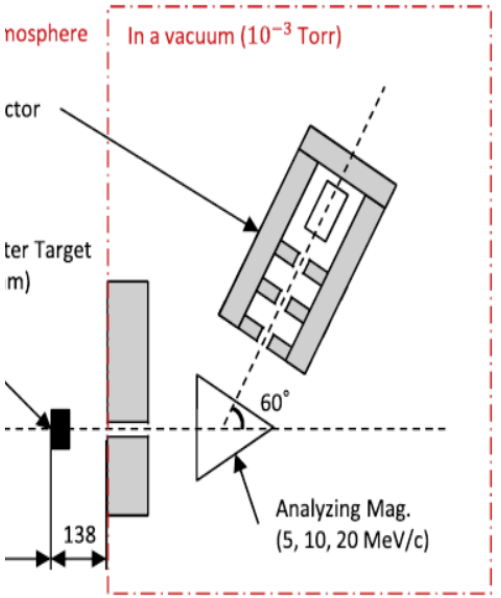
- The momentum acceptance is very close to previous obtained value by using the detector simulation code GEANT3 : 2.4% (ΔP/P, FWHM) at P_{e+} 20 MeV/c*.

*T. SUWADA et al. PHYSICAL REVIEW E 67, 016502 2003

Air-Vacuum effect in e+ detection system





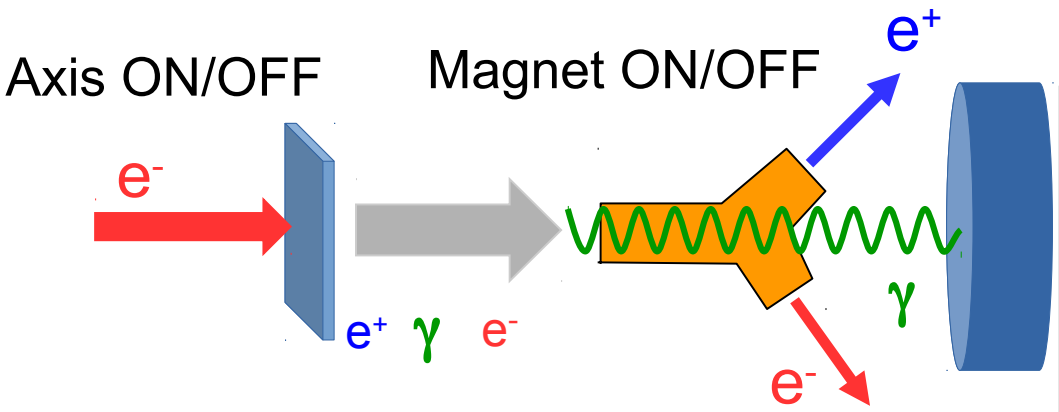


Vacuum region

- After the target-converter, the e+ detection system must be under the vacuum with pressure 10^{-3} Torr.
- But during the first beam test, the kapton window was broken => we decided to simulate the impact of air on e+ detection (air pressure 760 Torr).
- Simulations indeed show the decrease of e+ intensity on the detector (lucite counter) with respect to the system under the vacuum:

B, T	0.355	0.266	0.177	0.087
P,MeV/c	20	15	10	5
I_{air}/I_{vacuum}, %	56.4	51.8	34.7	15.2

Different variants of positron production



- Different scenarios of positron production were considered.
- Available options to change:
  - alignment of the crystal relatively to the electron beam
  -status of Sweeping Magnet

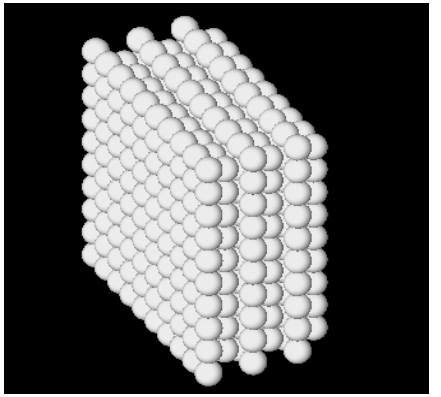
- Axis ON and Sweeping Magnet ON (channeling γ only):
  - Positron yield: **10.19 e^+/e^-**
  - Energy deposition per electron:

    449.6 MeV/e^-
- Axis ON and Sweeping Magnet OFF (channeling γ +charged particles):
  - Positron yield: **14.9 e^+/e^-**
  - Energy deposition per electron:

    603.9 MeV/e^-
- Axis OFF and Sweeping Magnet ON (ordinary bremsstrahlung):
  - Positron yield: **2.5 e^+/e^-**
  - Energy deposition per electron:

    87.9 MeV/e^-

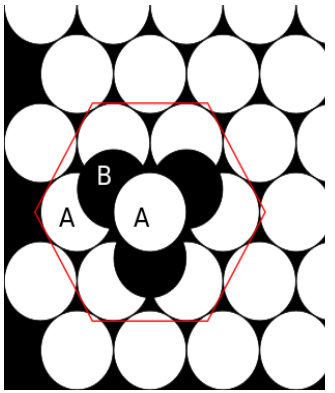
Simulation of granular target-converter



Granular target. 6 layers 3 - 10x10; 3 – 9x9; Simulation view.

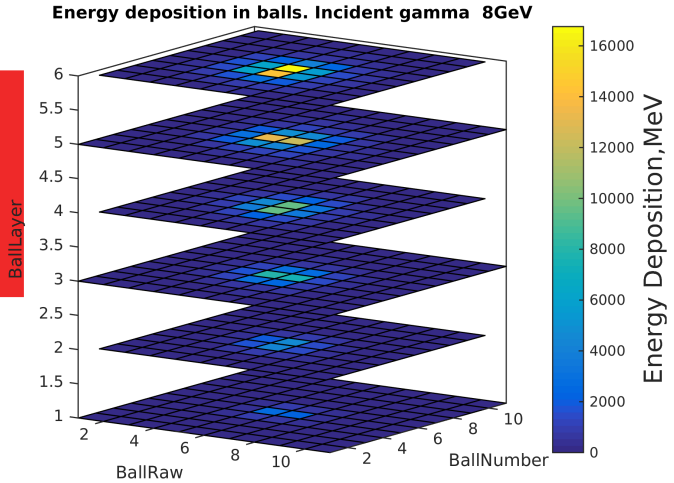
- The simulations were carried out for the granular target.
- 4 granular targets have been built at LAL-Orsay with the spheres of 1.1 mm radius (2, 4 ,6, 8 layers).
- 9 thermocouples were put on the exit faces to measure the temperature rise (energy deposition distribution) =>

see the slides of H. Guler.



Hexagonal close-packed (hcp) variant.

- Initial beam parameters:
  Intensity:$11*10^4$ 8 GeV e^-,
  Beam size σ 1 mm
  Axis ON,
  Sweeping magnet ON

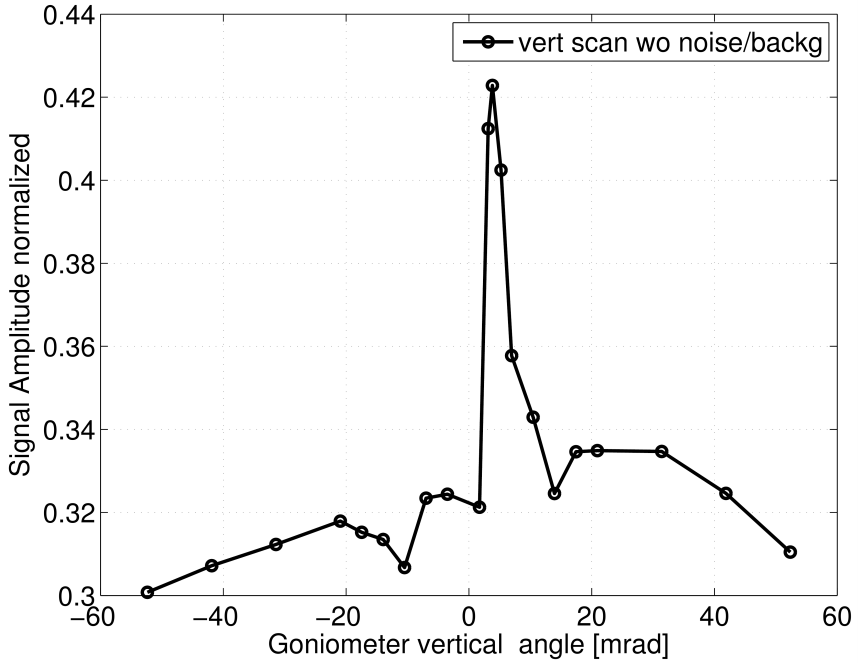


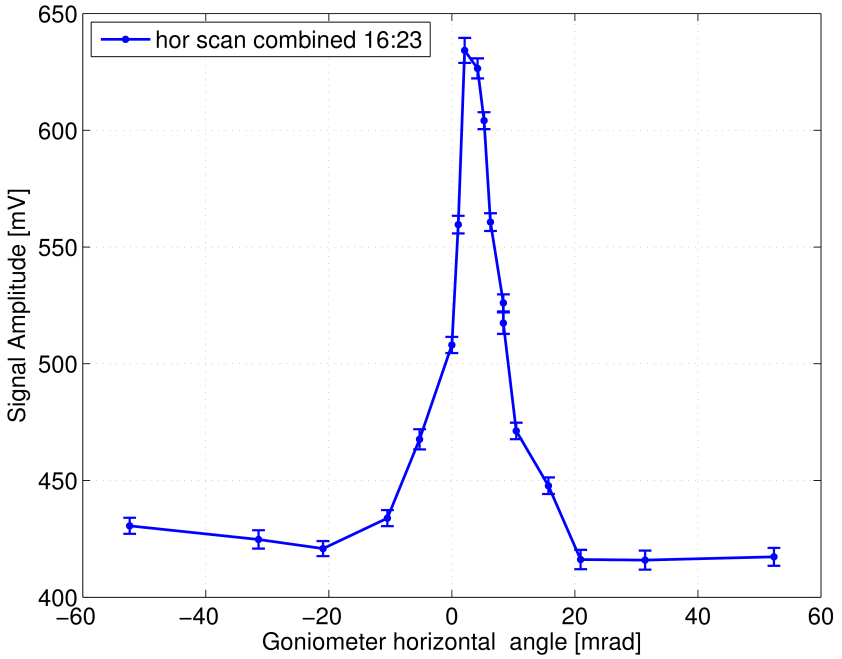
Typical energy deposition for this type of target

Granular target 6 layers R of ball 1,1 mm	Positron yield, Ne^+/Ne^-	Edep, MeV/e^-
Thickness: 11.72 mm	8.6	306.8
Bulk target (compact)		
Thickness: 8 mm	9.97	442.3

Experimental results: Rocking Curve

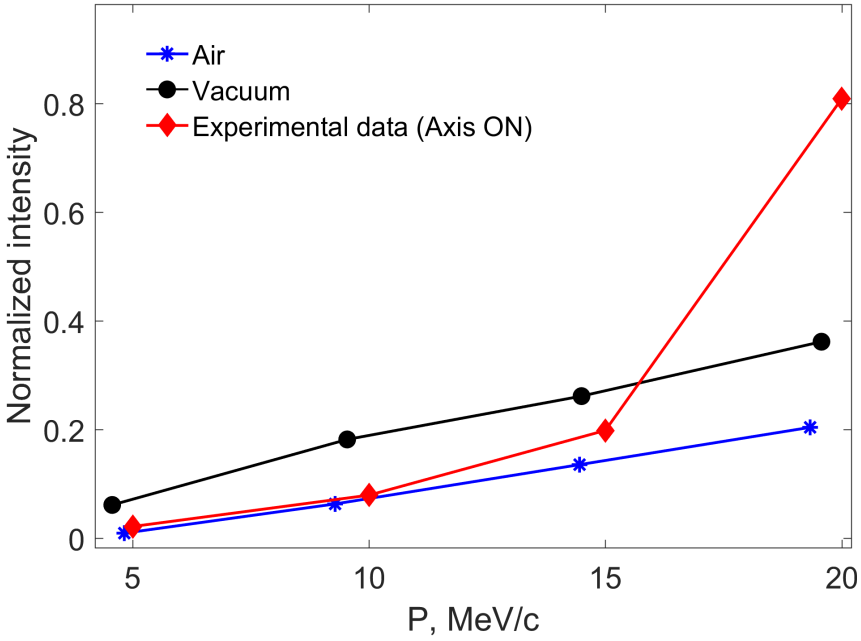
- Prior to the tests, the crystal has been aligned with respect to the electron beam direction to ensure the channeling regime (2-axes goniometer).
- Rocking curve shows the the e+ yield measured while changing relative angle between the crystal axis and electron beam direction.
  - The optimum alignment is found when e+ yield is maximized during 2-D angular scan.



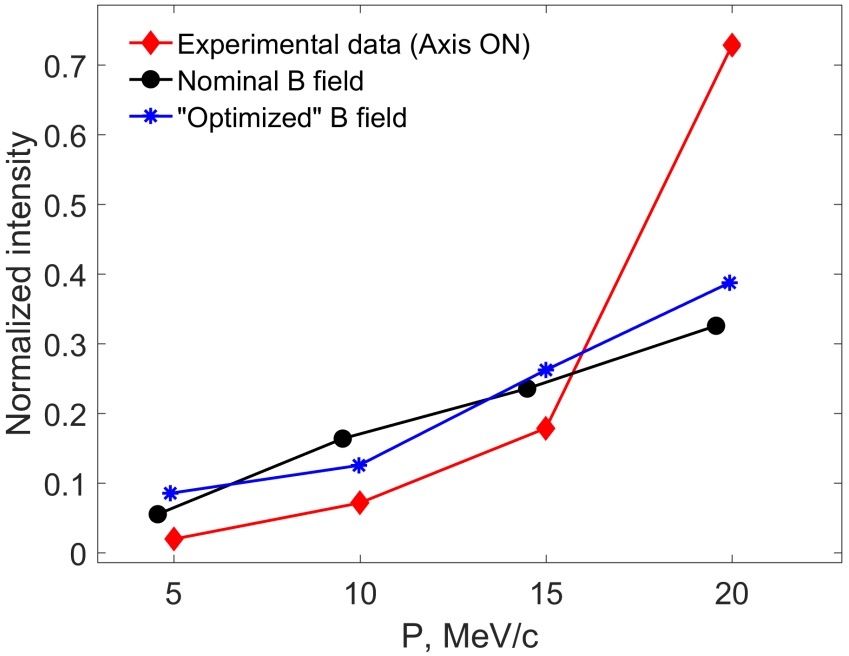


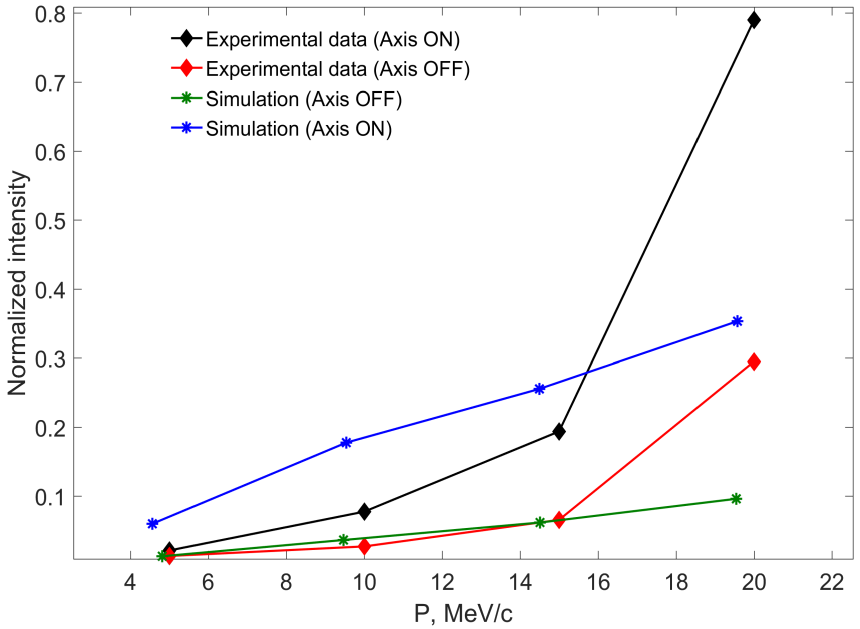
Experiment vs. Simulation comparison

Vacuum-Air effect for the e+ detection



Effect of Nominal/"Optimized" B field (vacuum)





Effect of crystal alignment. Axis ON/OFF. (nominal B field, vacuum)

Summary

- New option of the hybrid source with a granular converter => experimental tests are mandatory => beam test at the KEKB linac.
- The data from the first beam test are analyzed. For better understanding of the already obtained results (and expectations for the next data runs) detailed simulations of the experimental set-up are of great importance.
- Therefore, we have started the Geant4 simulations of the experimental set-up to estimate the target energy deposition, e+ yield and detection acceptance. Work is ongoing.
- Different configurations had been studied to characterize the hybrid e+ production (compact/granular converter, axis ON/OFF, Sweeping Magnet ON/OFF, conventional scheme…).
- The results of the current simulations are in good agreement with the original simulations and describe fairly well the main behavior of the experimental data concerning the compact target-converter.
- Next step: experimental data/simulation comparison for the granular target and a full simulation of the upcoming beam test.