Status of CEPC MOST-2 R&D in NJU

Ming Qi

Task and Requirements

- Complete the original prototype of **inner silicon track detector,** verify the main design indicators through **beam test, spatial resolution is 3-5 um**.

- Design a silicon detector with **1 MRad total ionization dose** (TID); Solving the key issues for process and test. Doing **beam test** to certify the main design conclusion.

- Nanjing University is in charge of **the beam test** and **irradiation experiment** of these related devices.

Progress in first year

- Understanding the radiation damage mechanism to the silicon based devices/detectors

- Investigating the available beam line facilities around the world

- Training students and young scientists
  - **Two PhD students worked at IHEP this summer, and developing an analysis database and the chip test board.**

◆ **To understand the radiation damage mechanism to the silicon-based devices/detectors.**

- **The signal loss is mainly proportional to the Non-Ionizing Energy Loss (NIEL);**

For a given energy and type of particle the non-ionizing energy loss is obtained by calculating the integral

$$(dE/dx)_{n.i.} = N \sum_{Z,A} \int_{E_R^{min}}^{E_R^{max}} (d\sigma/dE_R) T(E_R) dE_R \quad (1)$$

- **sometimes it depends on the effect of a single particle (SEE).**

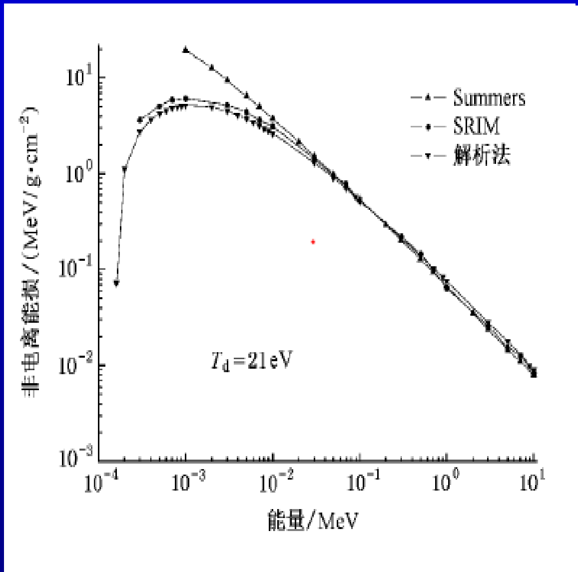
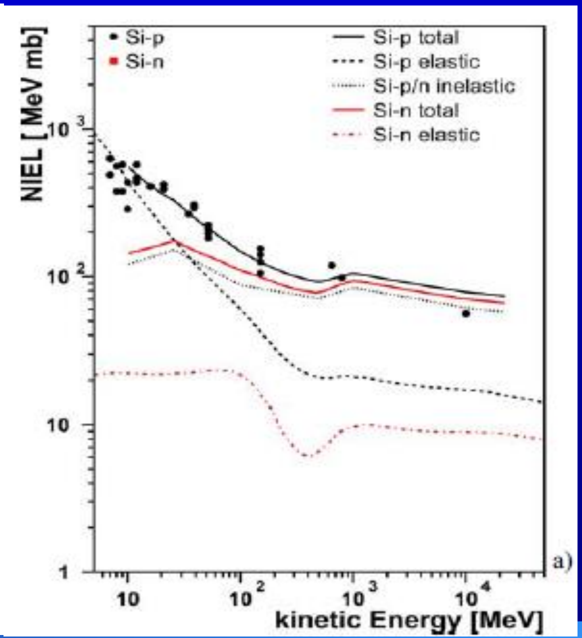
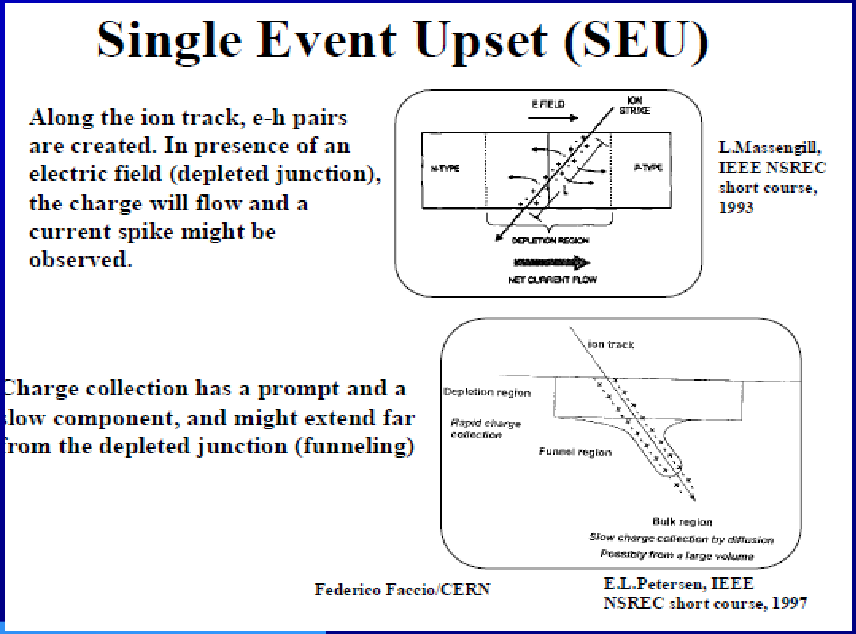


图 2 质子在 Si 材料中的 NIEL 和能量的关系



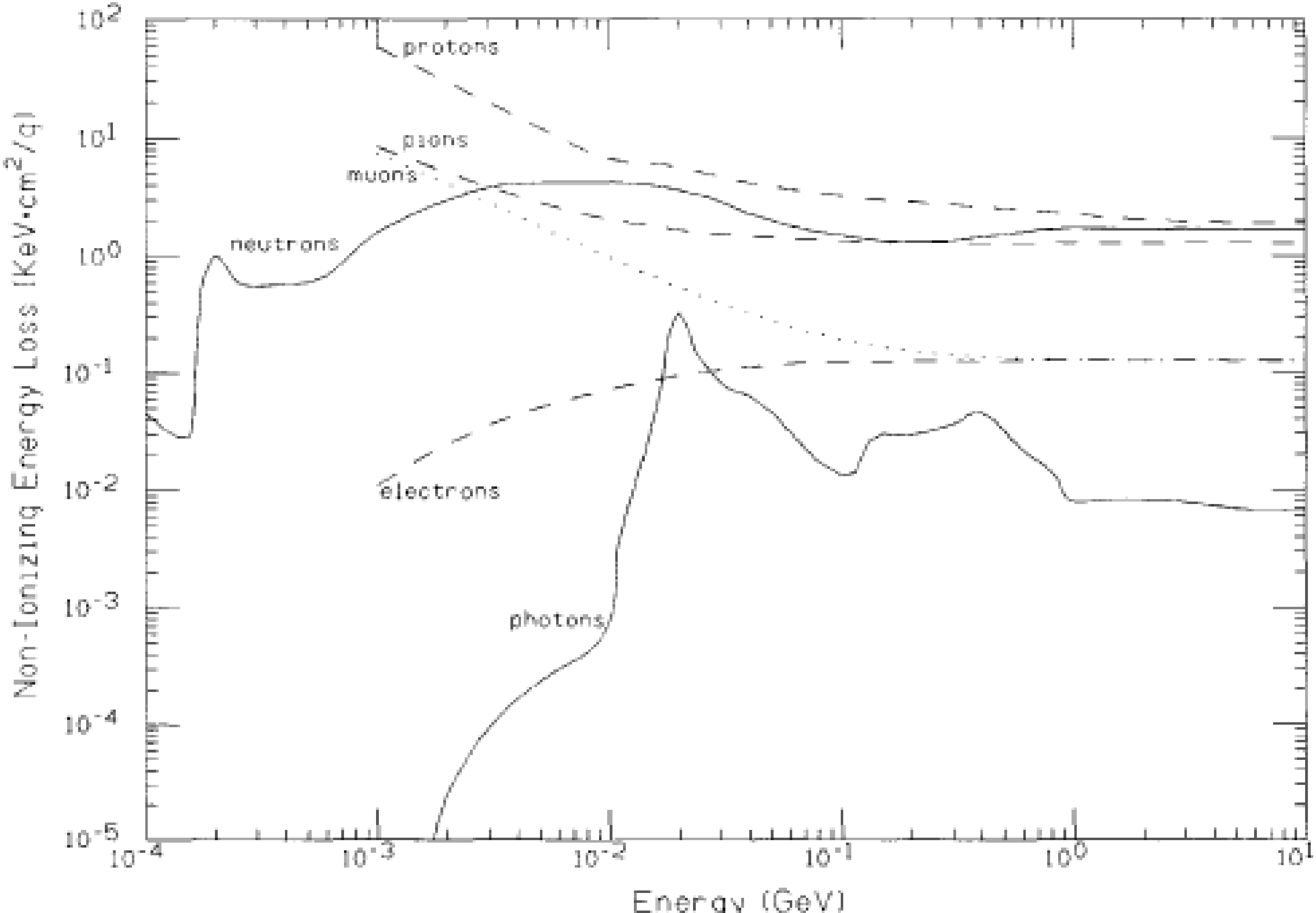


- **In the case of incident particle with lower beam energies (below 10 MeV), the NIEL effect is dominated by the long-range Rutherford scattering, which falls like $1/E^2$ and creates many small scale lattice displacements.**

- **At intermediate energies (above 10 MeV – 100 GeV), the anomalous elastic Rutherford scattering from the nuclear interactions between the incoming beam and the nuclei starts to play an important role, thus lead to strong lattice defects and impurities forming.**

- **In the ultra-relativistic energy range, at more than 100 GeV – a few TeV , radiative processes such as $e^+ e^-$ pair production and bremsstrahlung become dominant and contribute to the major fraction of energy loss.**

Fig. 1. Non-Ionizing Energy Loss versus Incident Energy



The beam line facilities around the world

- Several beam line facilities have been investigated:

  PS/SPS in CERN, proton, pion, ~24-100 GeV

  PIF in PSI, Switzerland, proton, pion, ~10-230 MeV

  IBR-II in Dubna, Russia, neutron, γ ray, ~1-5 MeV

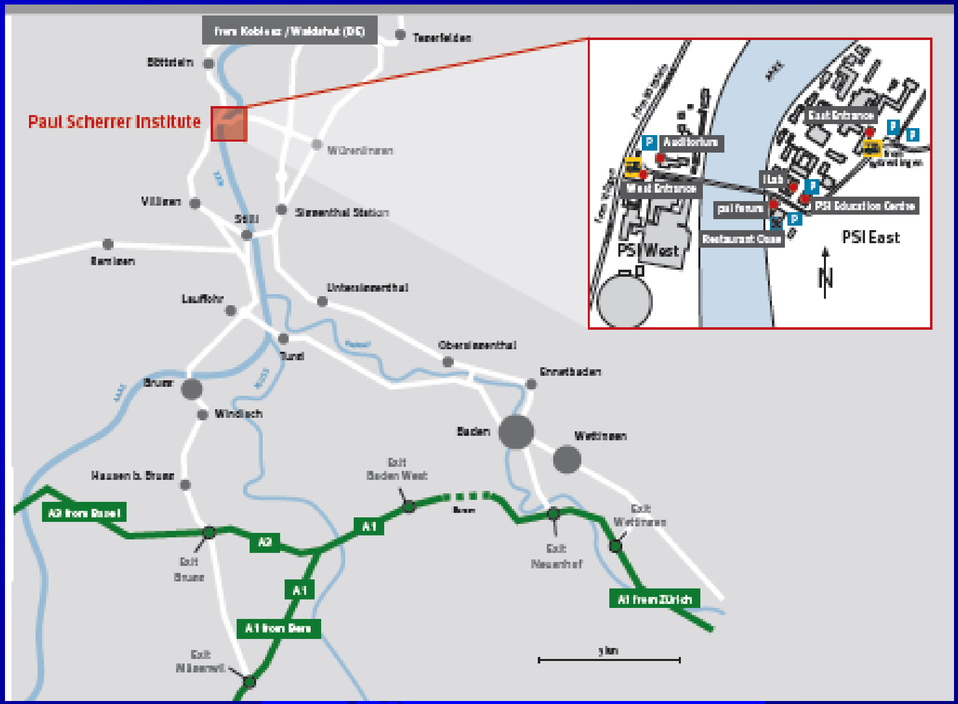
  DESY II in Hamburg, Germany, electron, ~3.5-5.0 GeV

  CYCIAE-100 in CIAE Beijing, China, proton, ~ 75-100 MeV

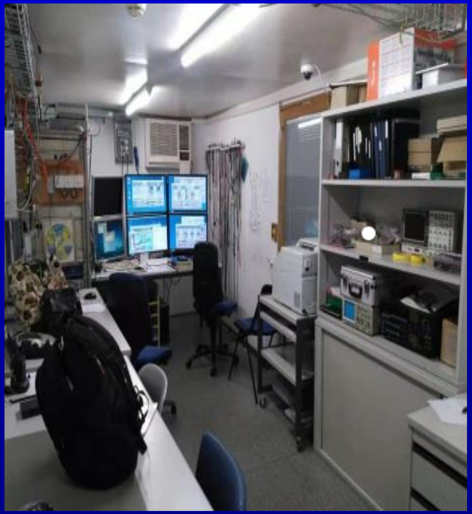
- The testing setup, involve in some of the related equipments and components are in the collecting and preparing from now.

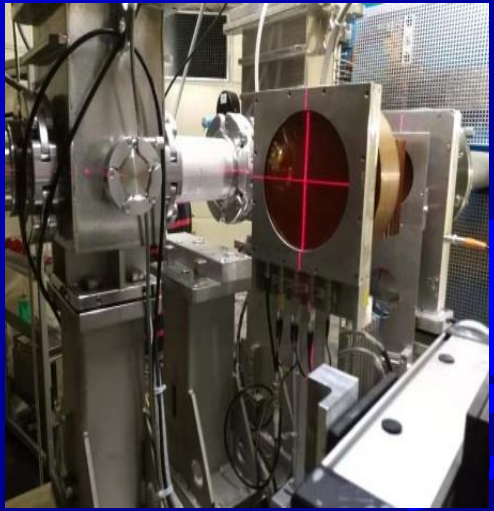
The Paul Scherrer Institute(PSI)

- The Paul Scherrer Institute PSI is the largest research institute for natural and engineering sciences in Switzerland, conducting cutting-edge research in three main fields: matter and materials, energy and environment and human health. PSI develops, builds and operates complex large research facilities.



◆ The Proton Irradiation Facility (PIF) was constructed for testing of spacecraft components, the high intensity proton accelerator complex produces a beam every day. The facility is designed in a user friendly manner and is commonly available. It enables generating of realistic proton spectra (10-230 MeV) encountered at any potential orbit in space.





- proton beam current (neutron, Pi, limited condition):
  2 – 5 nA / s
- Beam energy: 10 - 230 MeV
- Flux: 3.0 - 4.0 e10 / s, or more;
- total irradiation fluence: 5.0 e14, 1.0 e15, … 6.0 e15;
- beam irradiation dose exact control and measurement;
- beam Running Chart and Beam Absorber available;
- the favored beam time: 2020 - 2021 for the 2-3 times;
- some of testing setup and accessories can provide;
- PSI can make offer to a good deal on fulfill all our needs.

Training students and young scientists

◆ In July to August this year, Nanjing University has sent two students to the Electronics Research Group, the Institute of High Energy Physics of the Chinese Academy of Sciences for study and training. They have a preliminary understanding of the design concept of the Silicon Tracker chip, and to get some simulation experiences of related design software.

After returning back to Nanjing, an analysis database and the chip test boards are under further development.

CEPC team members in NJU

Name	Position	FTE
Ming Qi	Professor (Phy)	0.6
Xiaoli Ji	Professor (EE)	0.5
Lei Zhang	Professor (Phy)	0.3
Liangliang Han	PhD student (Phy)	0.3
Chang Liu	Master student (EE)	0.8

Next Plan and Outlook

During the process of chip design and development, beam test is a very important part. If it is not prepared enough, we may not get valuable feedback, which leads to a large amount of time and money being wasted.

◆ plan to do 2-3 times beam tests for the CEPC pixel chips and/or modules in the following years, to study the performance, to measure the hit efficiency and point resolutions, etc.

◆ also plan to complete at least once irradiation test under the proton or neutron beamline, to determine the radiation tolerance and related static/dynamic performances, to understand more deeply about the radiation damage mechanism for these silicon-based devices, and so on.

◆ further discuss about the different selections of beam test facilities with our colleagues in details, including the necessity and feasibility of relevant experiments.

Many thanks for your attention !