GEANT4 simulation about the laboratory astrophysics in Taiwan –

Shower Profiles with an 1.5 GeV Electron Beam on Metal

Prof. C.H. Wang

Department of Electro-Optical Engineering, National United U., Taiwan

Members of this Experiment

C.-C. Chen[b], F.-Y. Chang[a], C.-W. Chen[b], K.-T. Hsu.[d],M. A. Huang[c], W-Y. P. Hwang[b], G.-L. Lin[a] ,T.-C. Liu[a]

(a) Institute of Physics, National Chiao-Tung University, 1001 Ta Hsueh Rd., Hsin-Chu 300, TAIWAN, ROC

(b) Institute of Astrophysics, National Taiwan University, 1, Sec. 4, Roosevelt Rd. Taipei 106, TAIWAN, ROC

(c) National United University, 1, Lien-da, Kung-ching Li, Miao-Li 36003, TAIWAN, ROC

(d) *National Synchrotron Radiation Research Center, Hsin-Chu 300, TAIWAN, ROC*

Outline

- **Introduction**
- **FLASH experiment**
- **Detection of UHECR (Utra High Energy Cosmic Ray)**
- **Experiment Design & Setup**
- **Simulation**
- **Summary**

Introduction

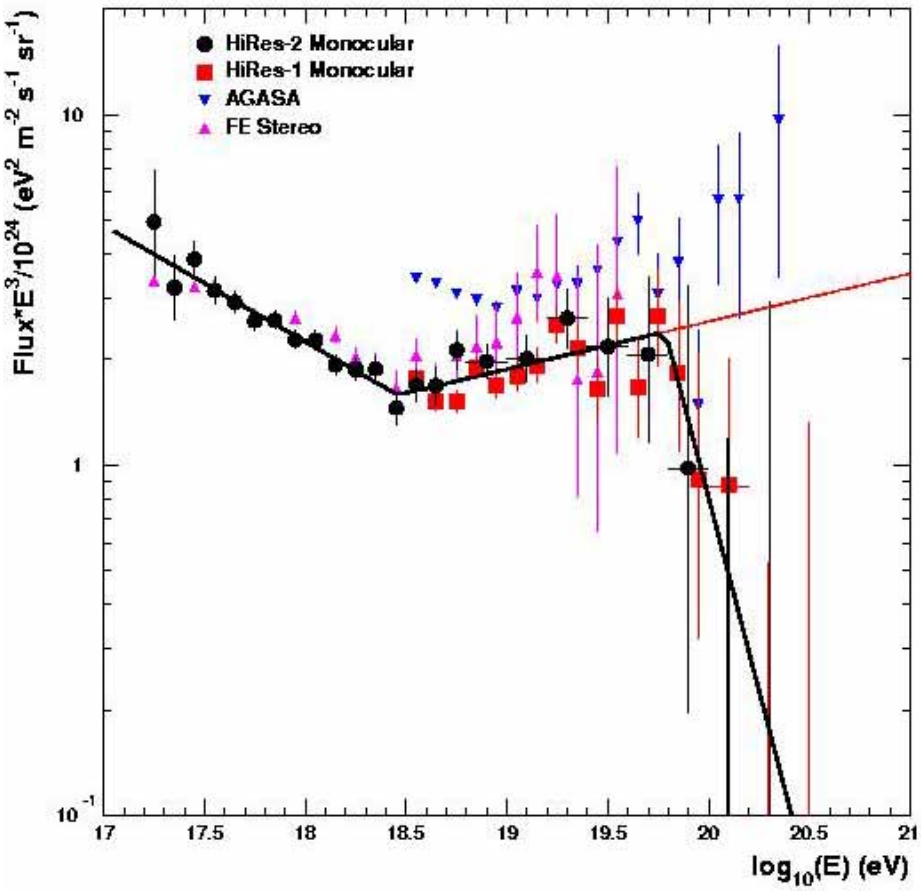
- The cosmic ray spectrum above 10^{19} eV is not well understood. Assume 10^{19} eV proton generate showers with GeV level, it is appropriate to use the GeV electron beam to study the shower profile with the total sum shower energy ~ 10^{19} eV.

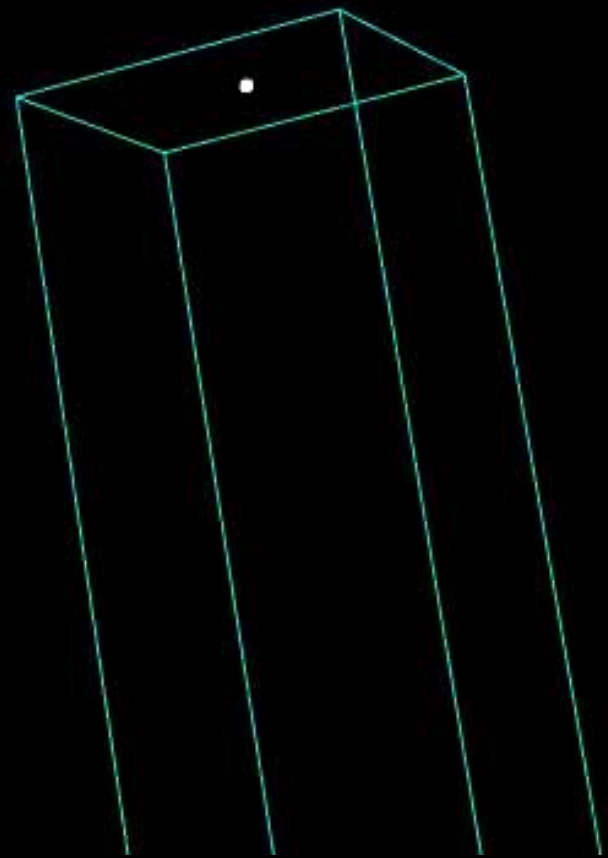
- The strategy is to produce a shower in the lab with a similar characteristics to the EM shower in the air.

- A pilot experiment to the FLASH experiment (Comparison of Air Fluorescence and Ionization Measurements of E.M. Shower Depth Profiles.).

The Motivation For FLASH

- The ultra-high energy cosmic ray (UHECR) spectra measured by HiRes (fluorescence) and AGASA (scintillation counter ground array) differ significantly in slope for $E \sim 10^{20}$ eV.
- This discrepancy can be possibly accounted for by a systematic difference in the energy scale (~25%)





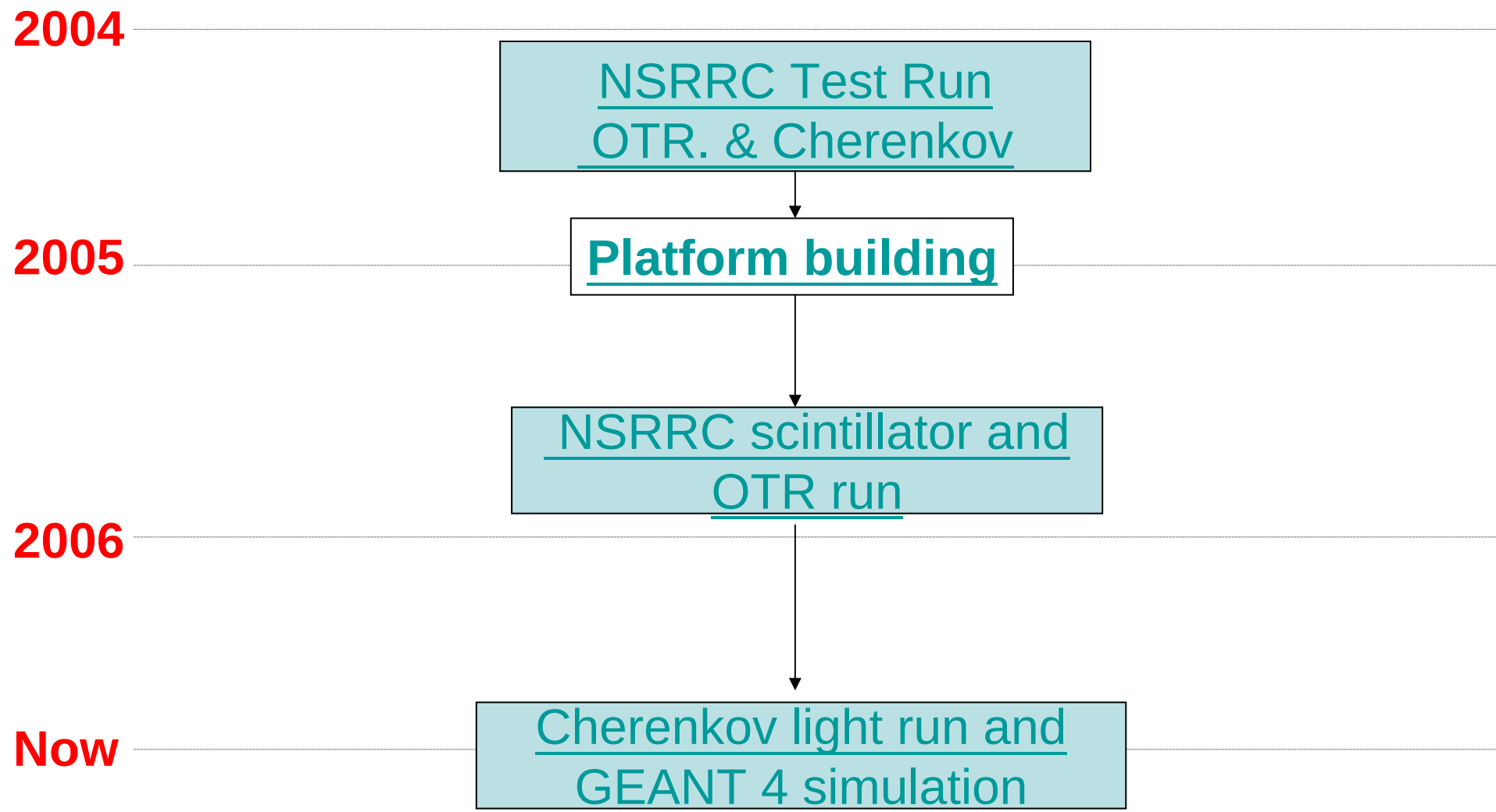
Exit

Experiment Strategy

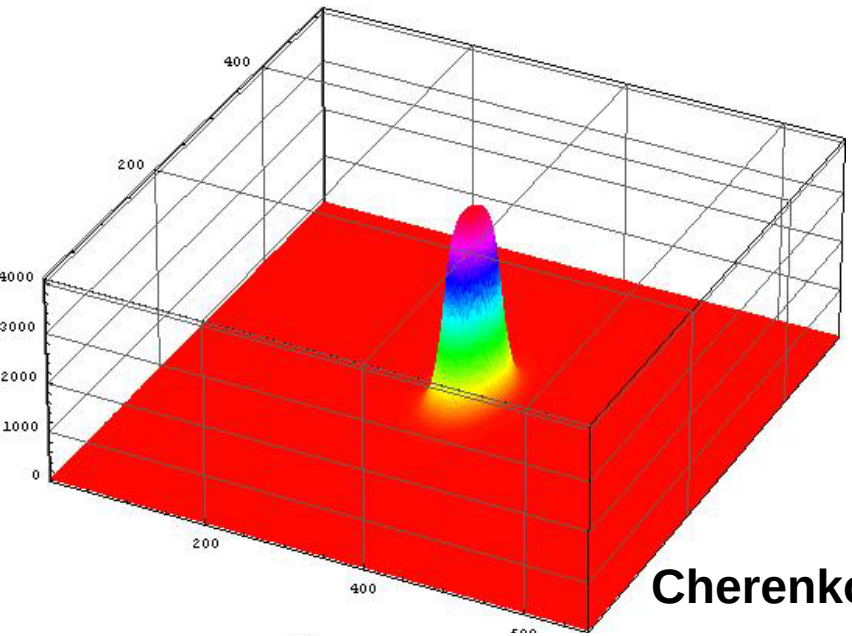
- We use the electron beam from National Synchrotron Radiation Research Center (NSRRC) with the target made of aluminum.
- Use CCD to measure the Cherenkov light.
- FLUKA is used to design the experiment.
- GEANT4 is used to compare the data.

The different of properties between Al and Al_20_3 <10%

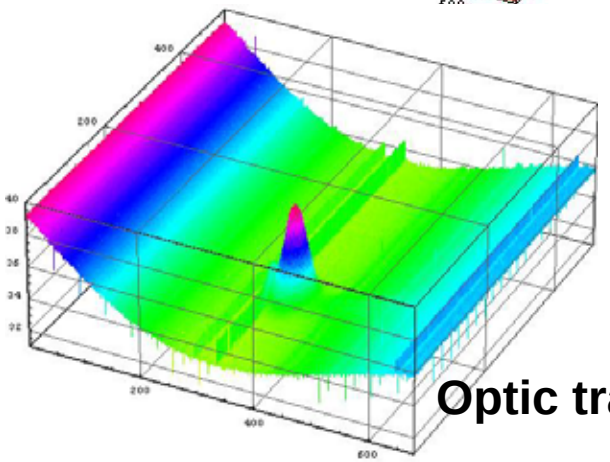
	Al	Al_2O_3	Air
Nuclear collision	70.6 (113%)	67 (108%)	62
Nuclear interaction length	106.4(118%)	98.9(109.8%)	90
Radiation length	24.01(65.6%)	27.94 (76.2%)	36.66
Critical	52.55MeV(65.62%)	54MeV(67.5%)	80 ; 87MeV


2004
NSRRC Test Run
OTR. & Cherenkov
2005
Platform building
NSRRC scintillator and
OTR run
2006
Now
Cherenkov light run and
GEANT 4 simulation

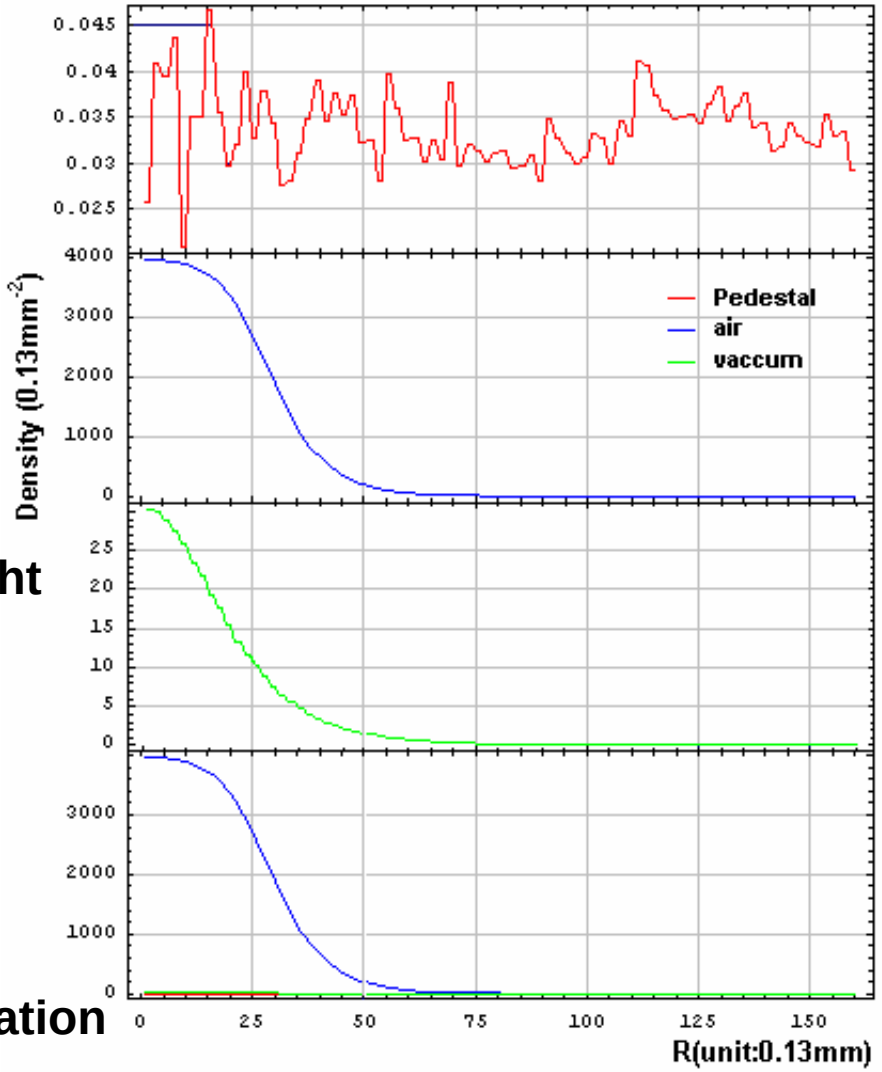
Cherenkov & OTR (2004)



Cherenkov light

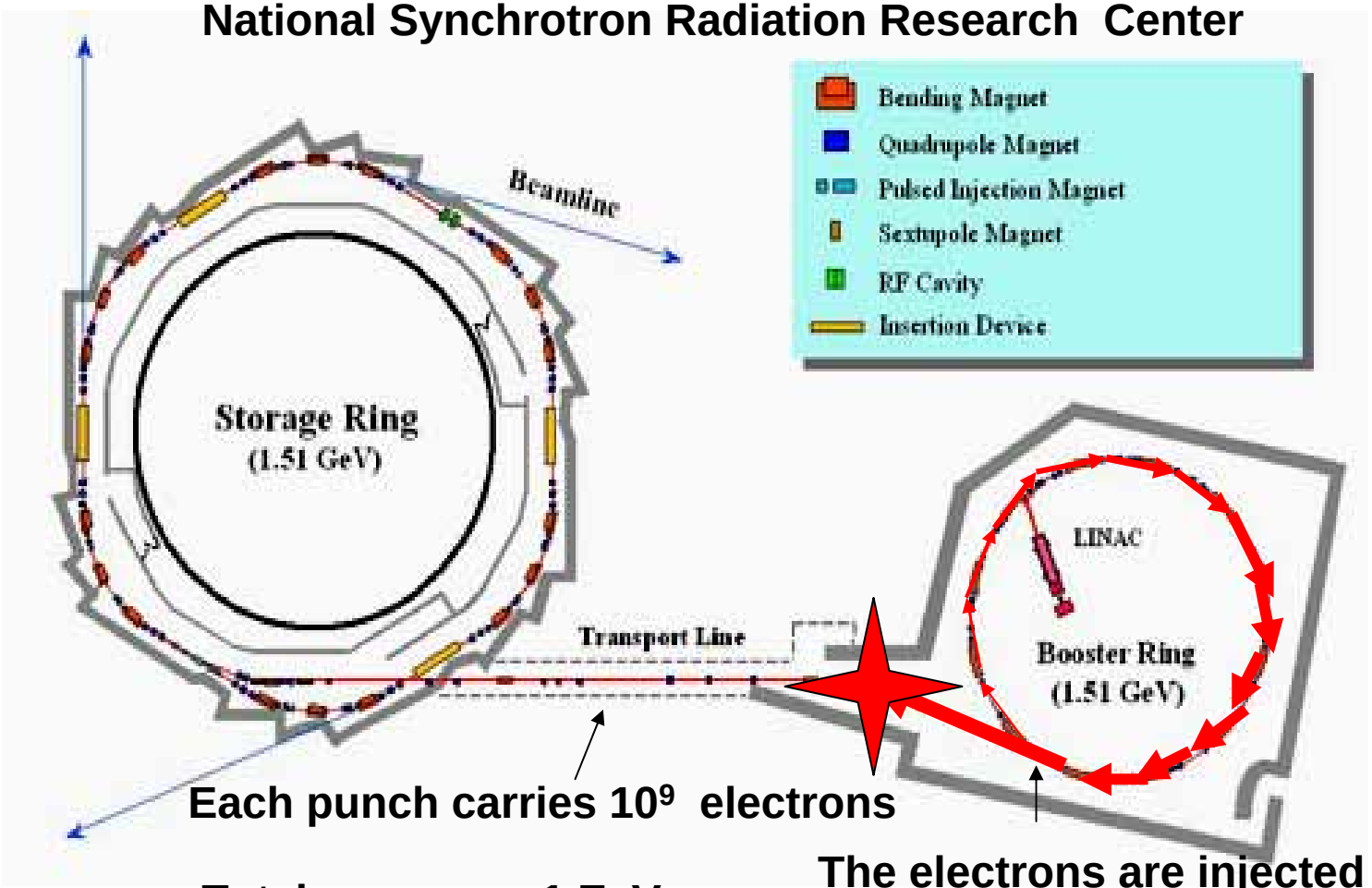


Optic transition radiation



Experiment electron beam

National Synchrotron Radiation Research Center

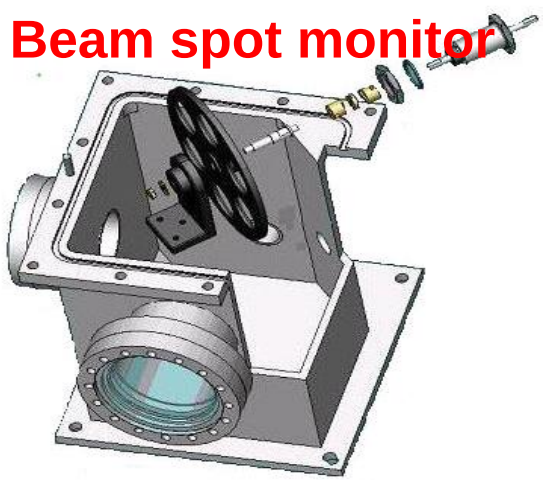


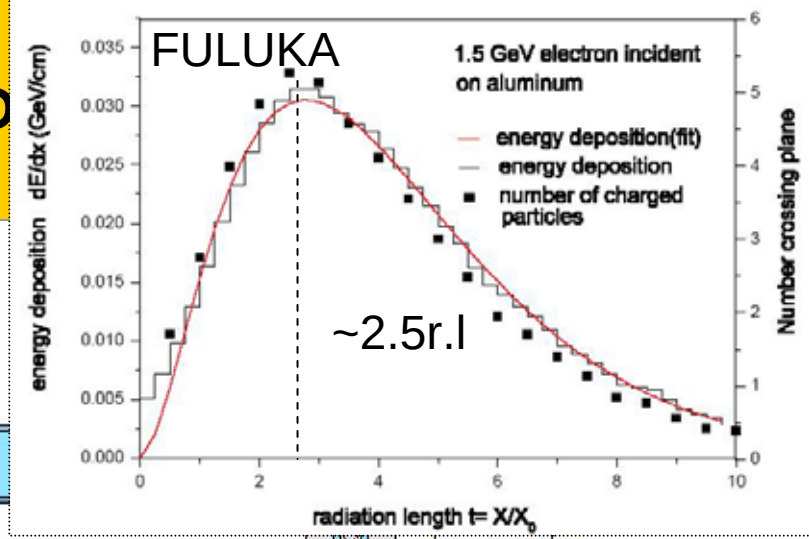
Each punch carries 10^9 electrons

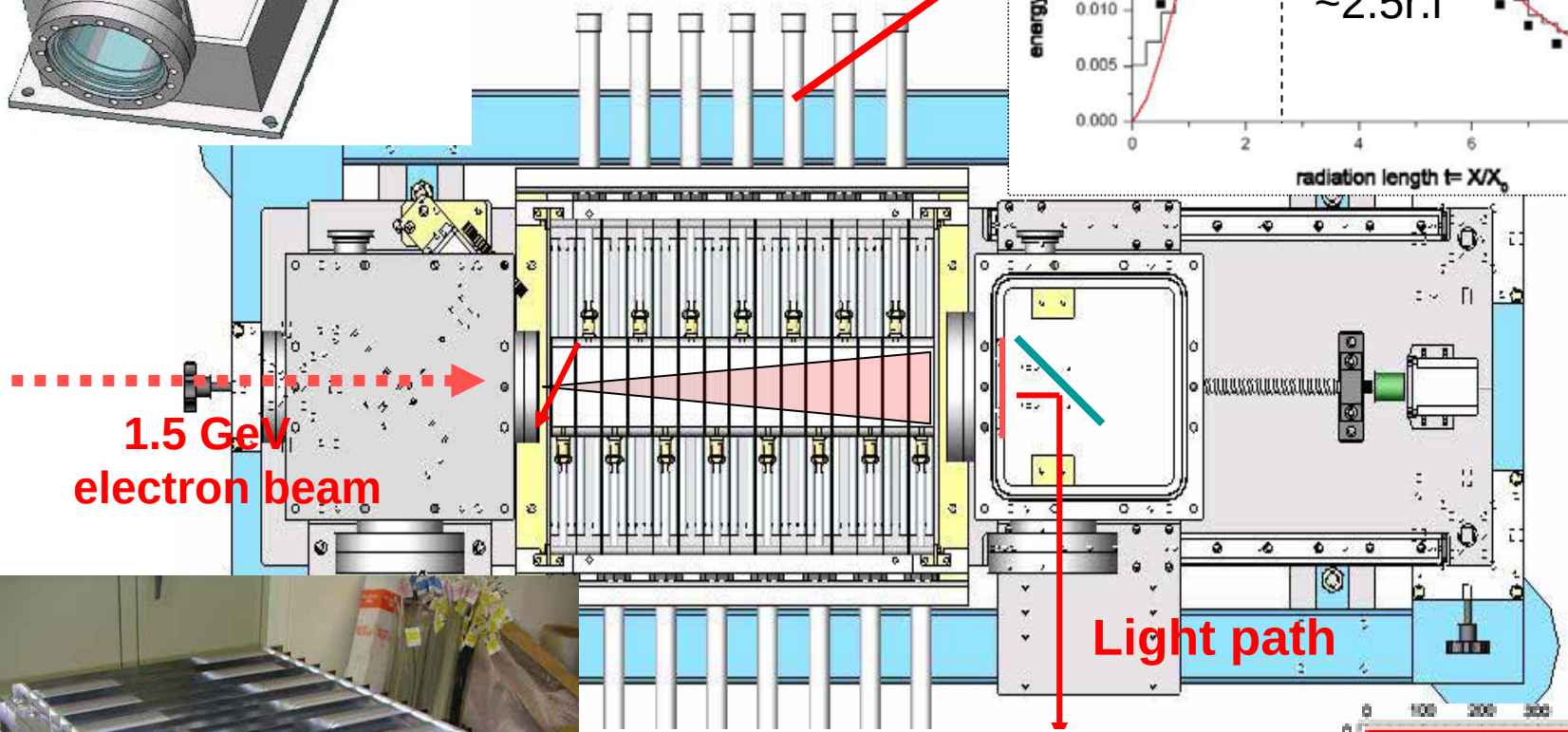
Total energy ~ 1 EeV

The electrons are injected from booster ring with 10 Hz frequency

xperimental P



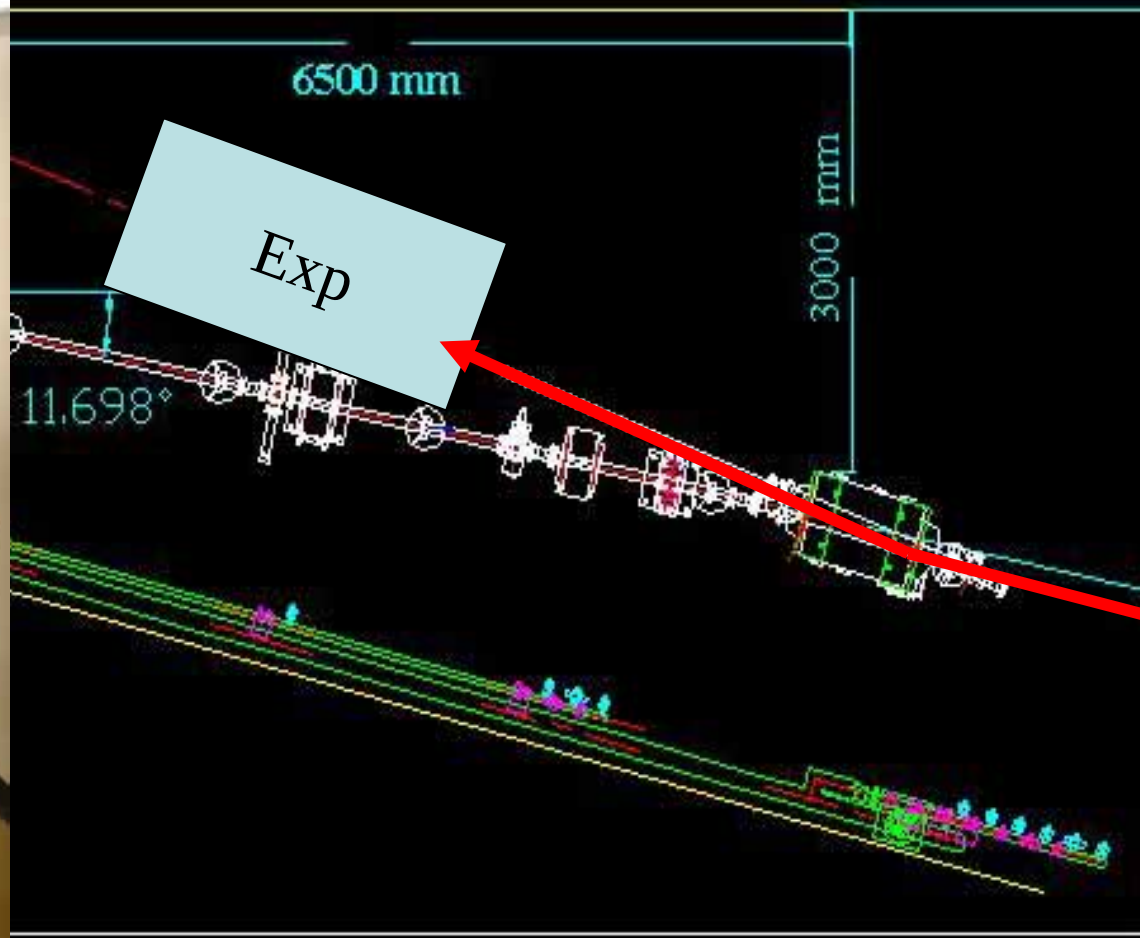


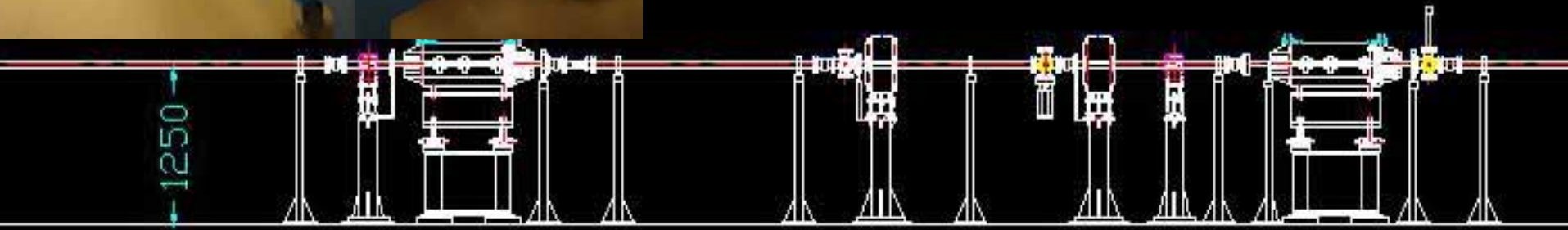


Each block contains 1/3 R.L.

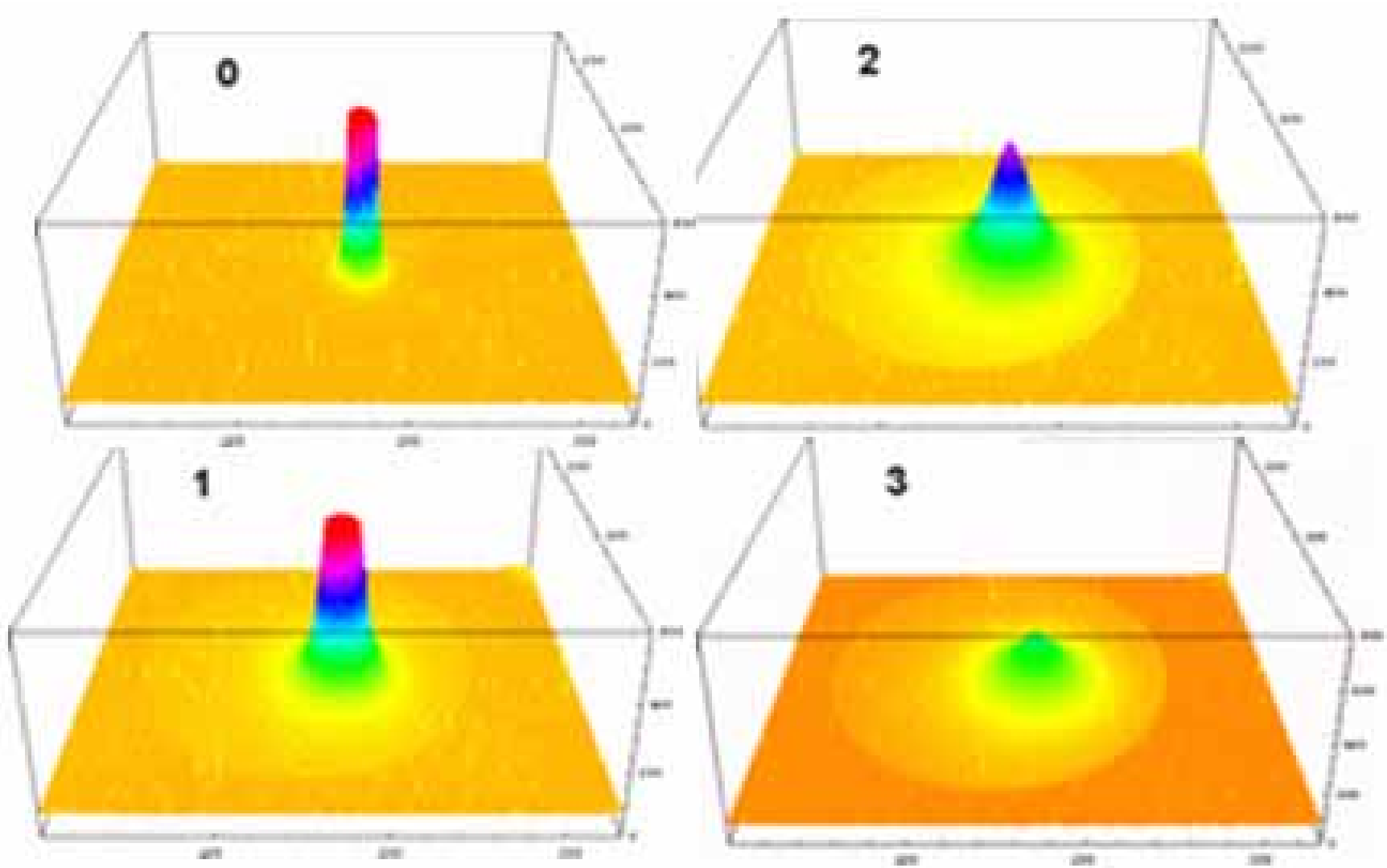
Lateral Profile


28 3:03PM

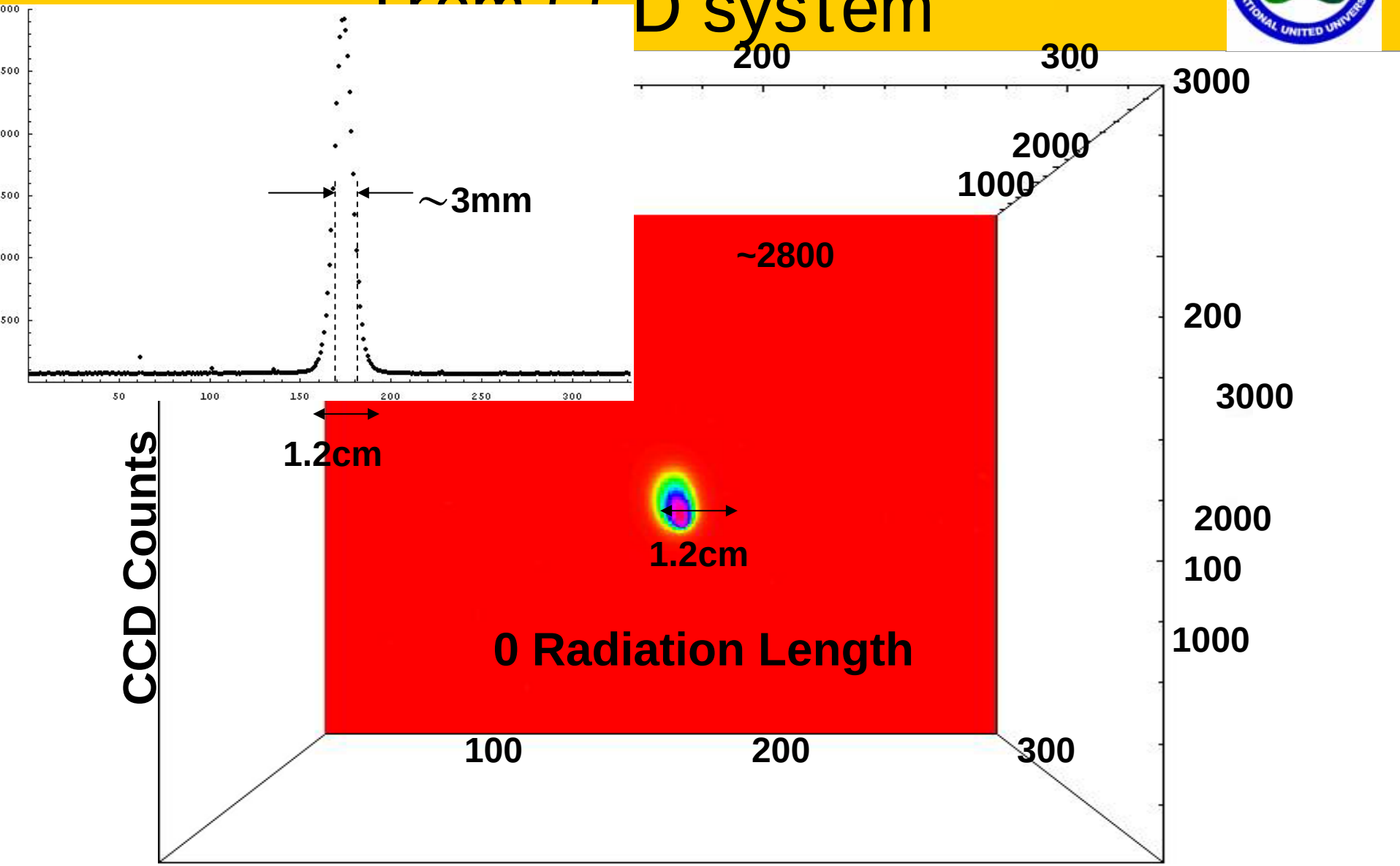

6500 mm
3000 mm
Exp
11.698°


1250

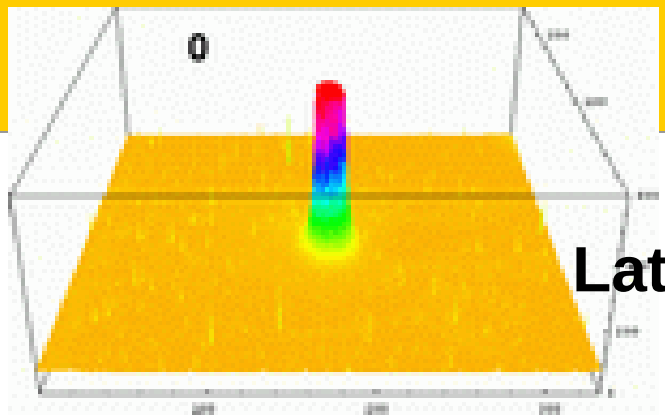
Observed lateral profiles in different radiation length.

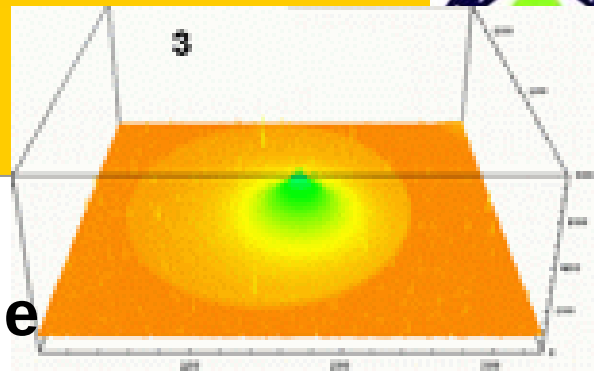


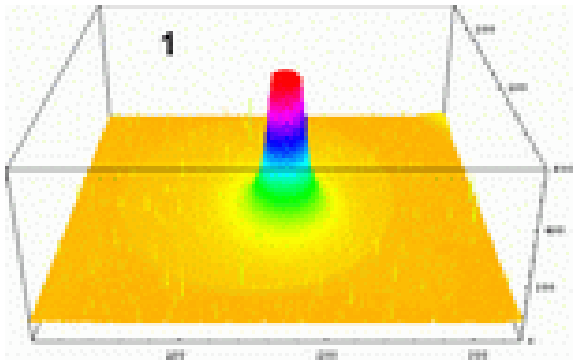
Initial beam lateral profile from CCD system

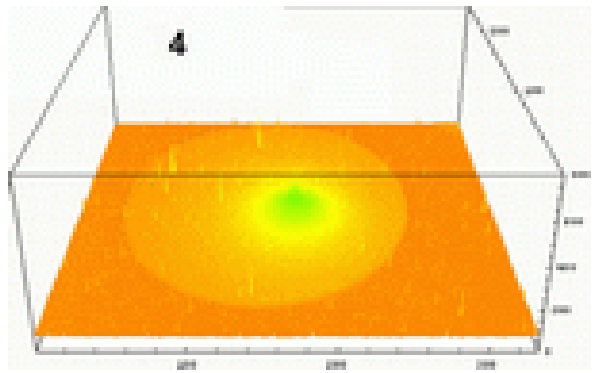


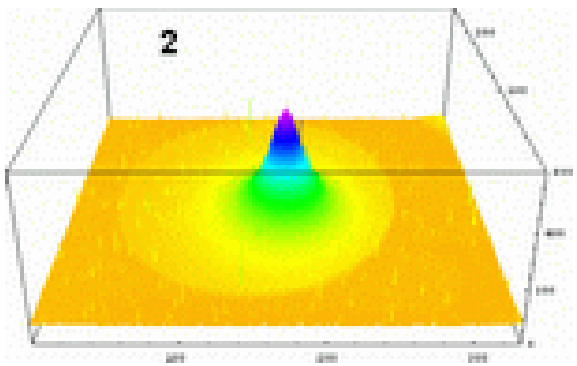
Lateral profile movie

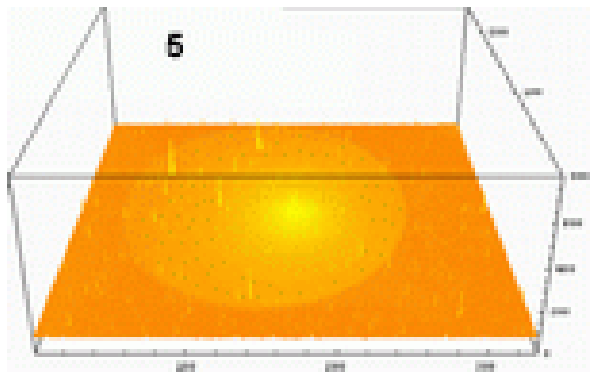




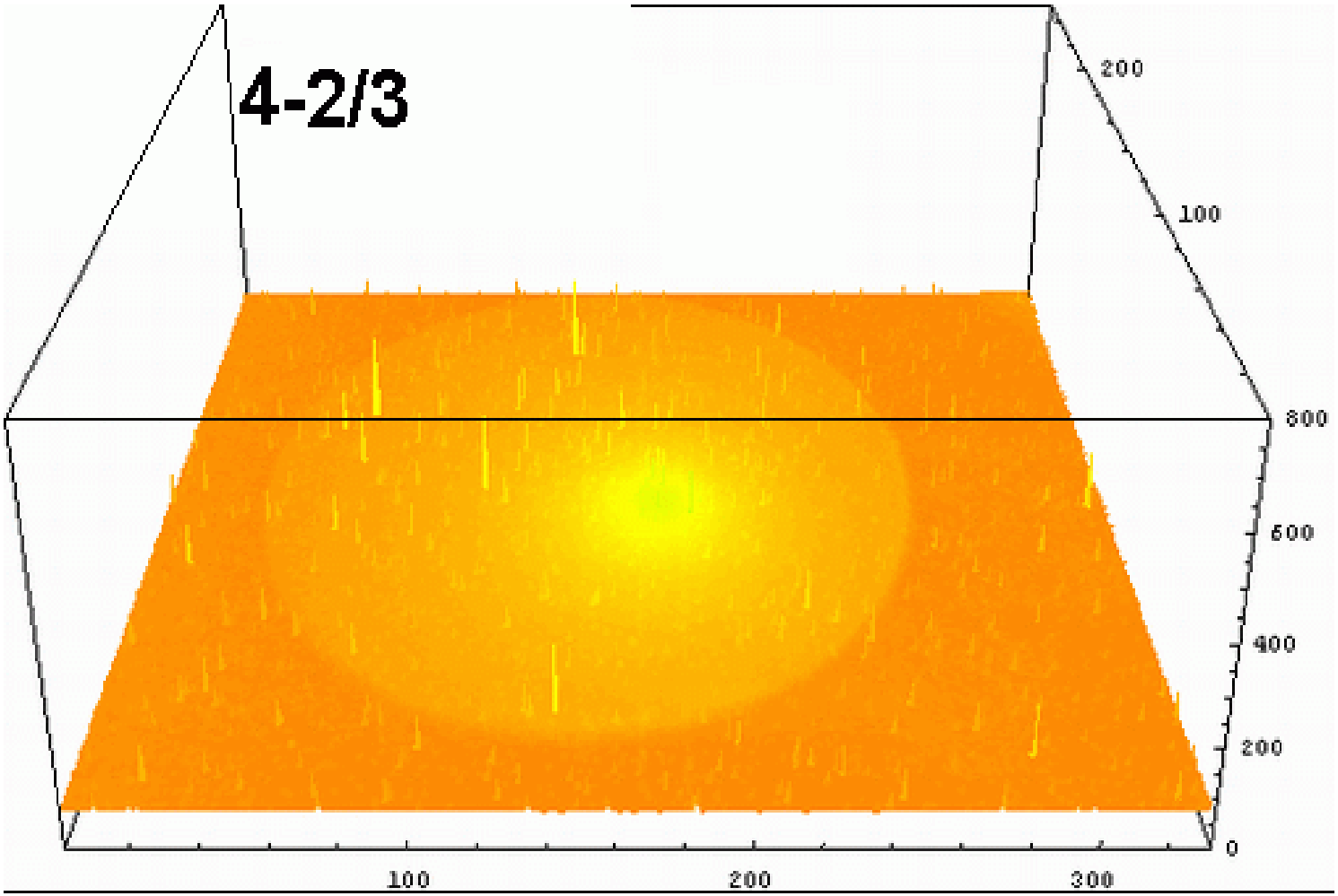








Shower lateral profile



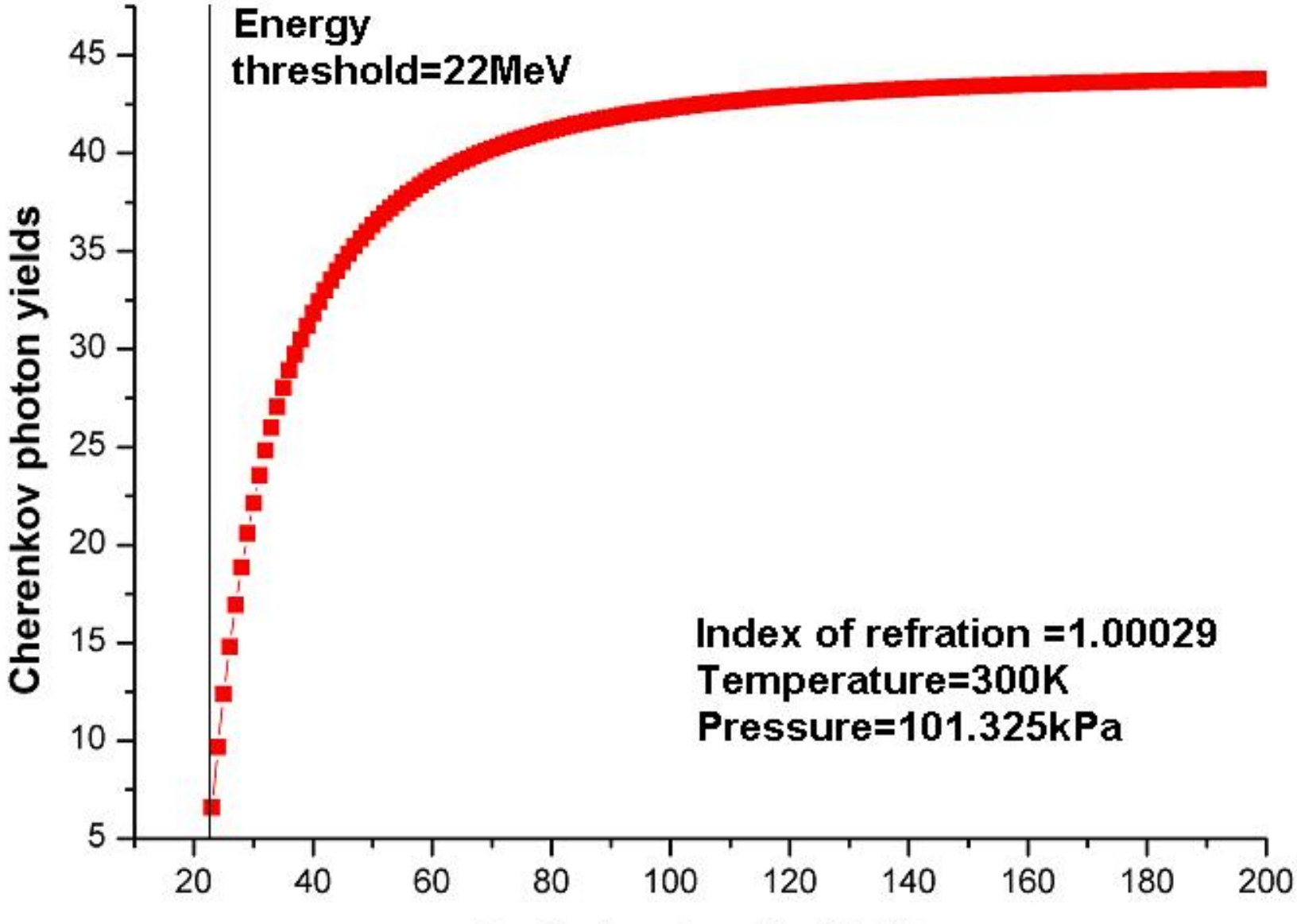
Count Number

Comparison the strength between OTR and Cherenkov light

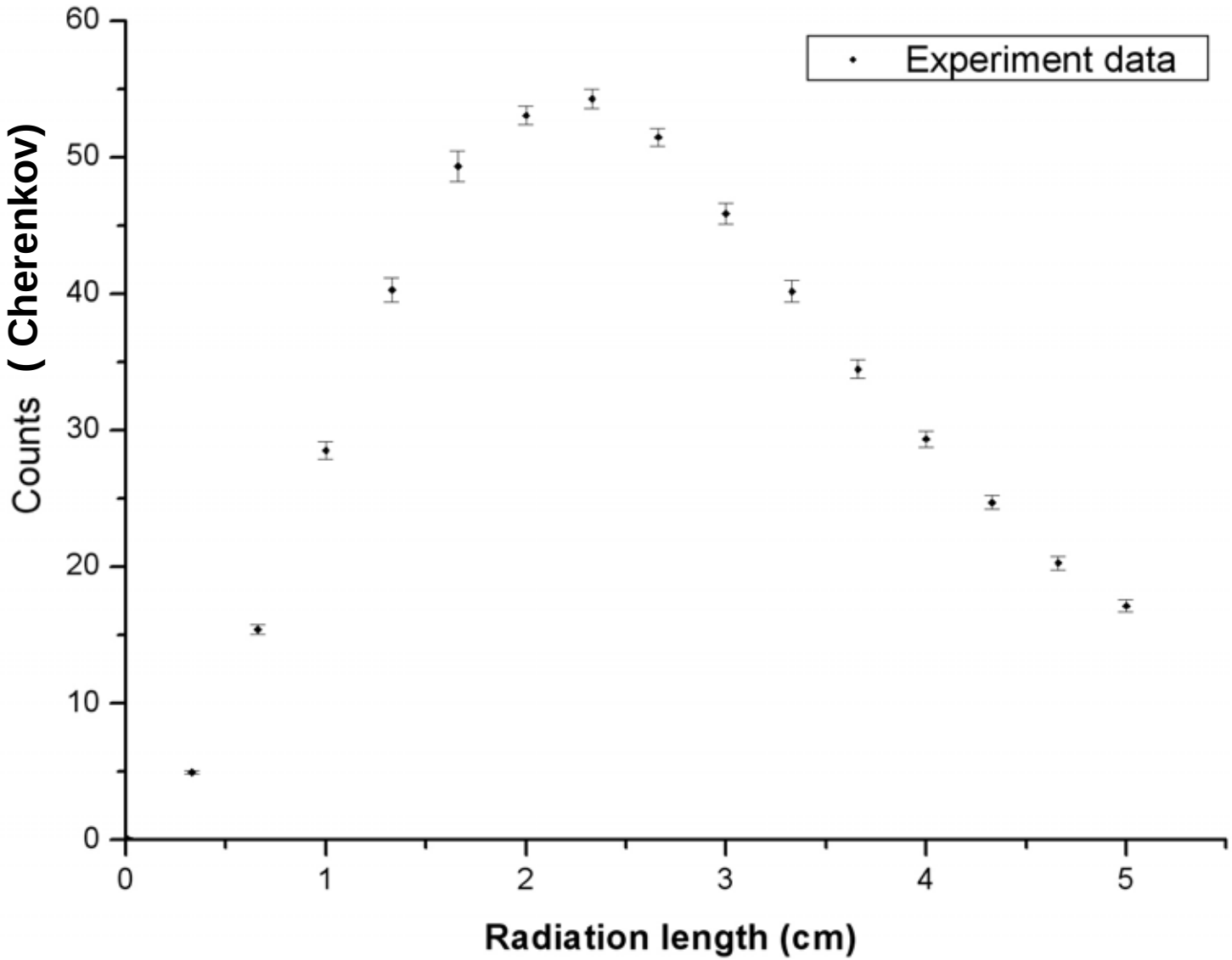
- OTR
- Exposure time: 2S
- Current : 3-5 mA
- Count: 0.0 r.l ~100
  1.0 r.l ~200
  2.0 r.l ~140
  3.0 r.l ~80
  5.0 r.l ~0

- Cherenkov
- Exposure time: 10mS
- Current : 3-5 mA
- Count: 0.0 r.l ~250
  1.0 r.l ~2020
  2.0 r.l ~2700
  3.0 r.l ~2000
  5.0 r.l ~860

Cherenkov threshold



Cherenkov Experiment data



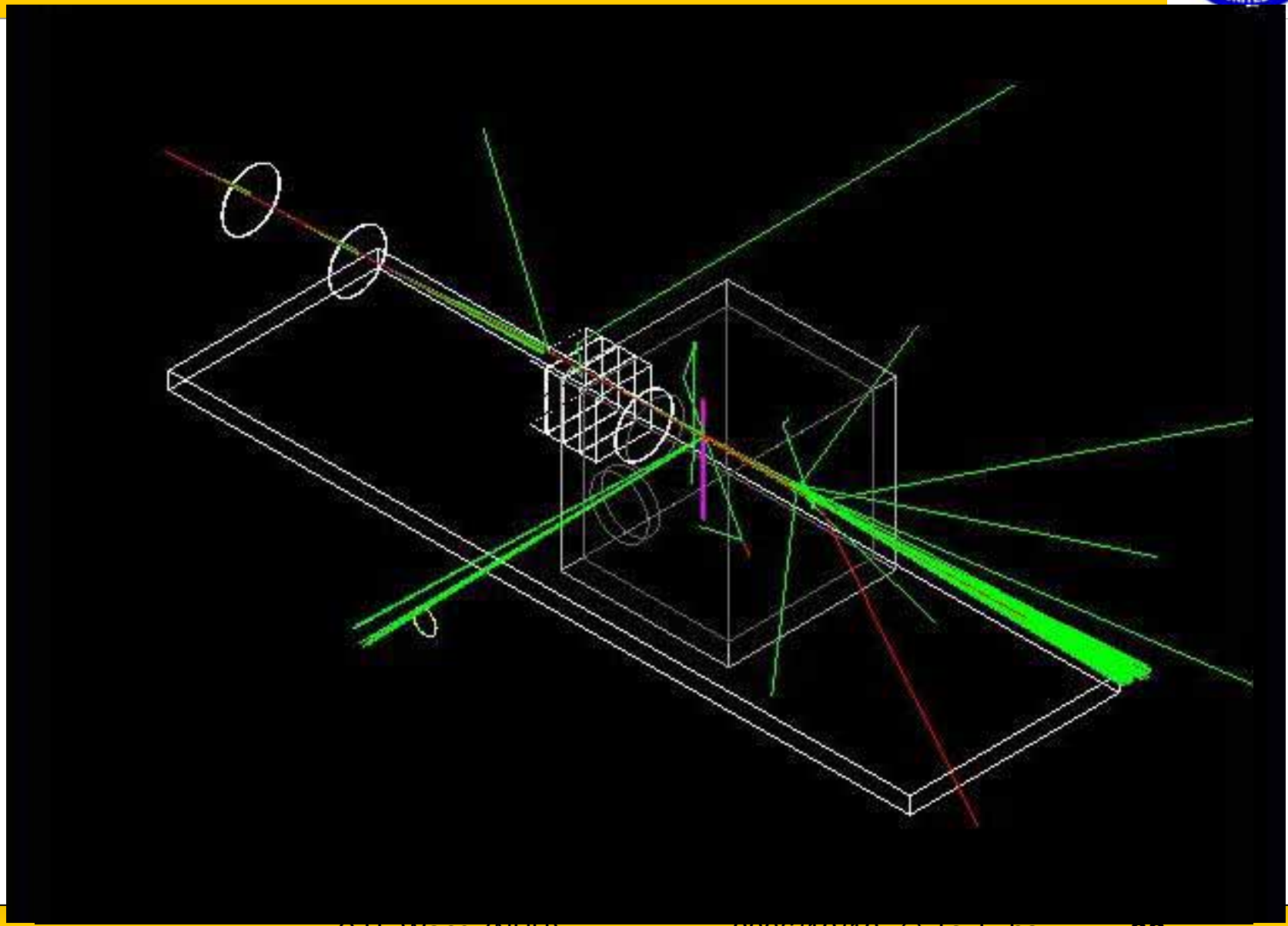
GEANT4 environment parameter

- GEANT4 version: geant4.8.0.p01
- OS: Scientific Linux 4.2.1.6
- libCLHEP-1.9.2.2
- G4ELASTIC1.1
- G4EMLOW3.0
- G4NDL3.7
- PhotonEvaporation2.0
- RadiativeDecay3.0

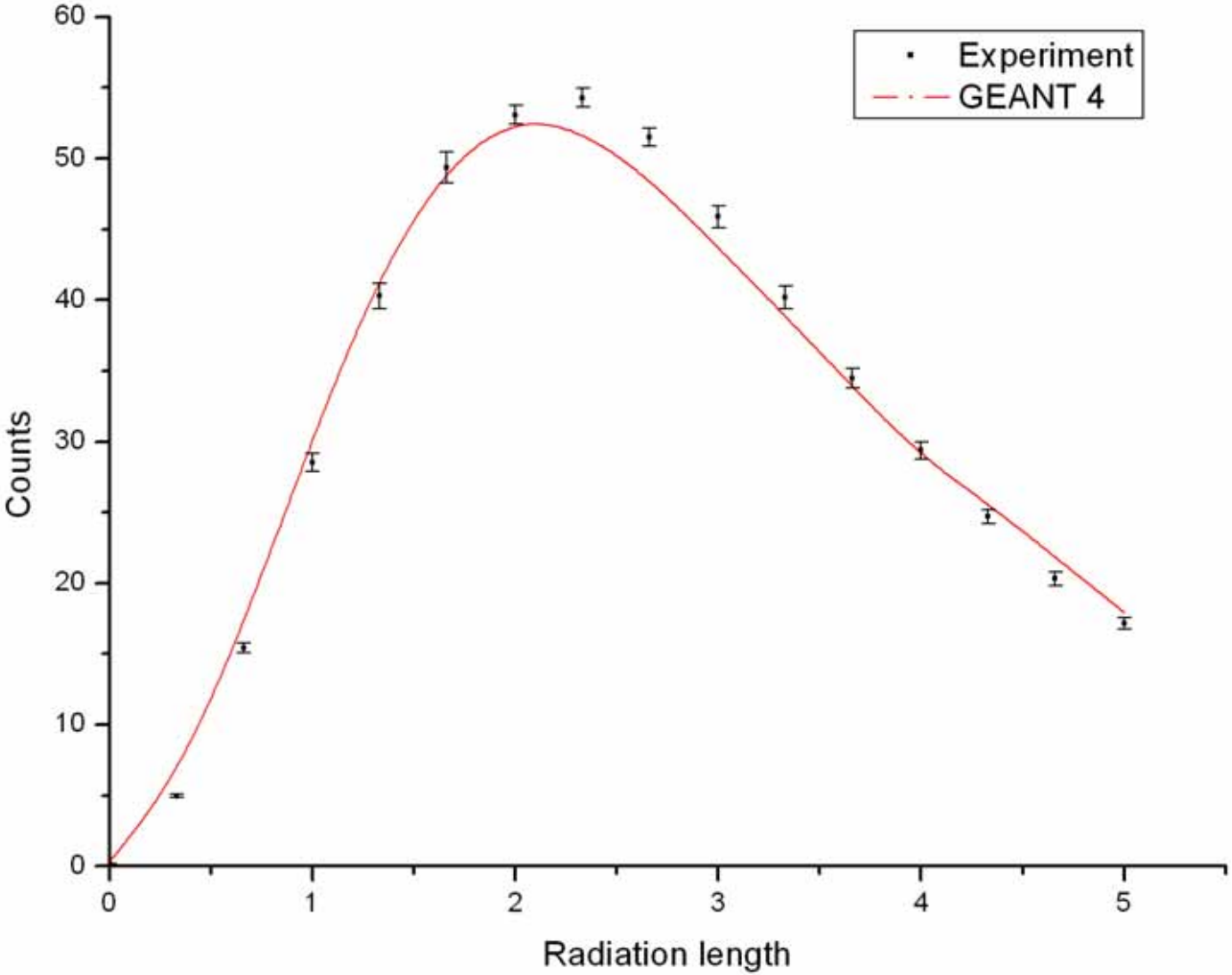
GEANT 4 physics process List

Geant4 simulates the generation of particle in Al
  - Compton scatting
  - Bremsstrahung
  - ionization
  - decay
  - photoelectric effect etc.
Geant4 simulates the generation of Cherenkov light in air
  - Cherenkov light process
  - scintillation yields
  - Rayleigh scatting etc.
The photon detection efficiencies of CCD and the light transmission efficiencies of windows have been put in the simulation for data comparison.

GEANT 4 Detector construction



Now!!!
Cherenkov light profile



Summary

- A experiment on shower profiles from a electron beam has been performed.
- GEANT4 can simulate the results of Cherenkov light yields well.
- Need to compare the shower widths next!

- 29th International Cosmic Ray Conference Pune (2005)
- From Colliders to Cosmic Rays (C2CR) ,Prague, Czech Republic (2005), Poster http://www.particle.cz/conferences/c2cr2005/
- Origin, Propagation and Interaction of Energetic Particles KASI-APCTP Joint Workshop (KAW4),Daejeon (2006) ,Poster http://sirius.cnu.ac.kr/kaw4/