質子治療-質子束流監測設計與開發

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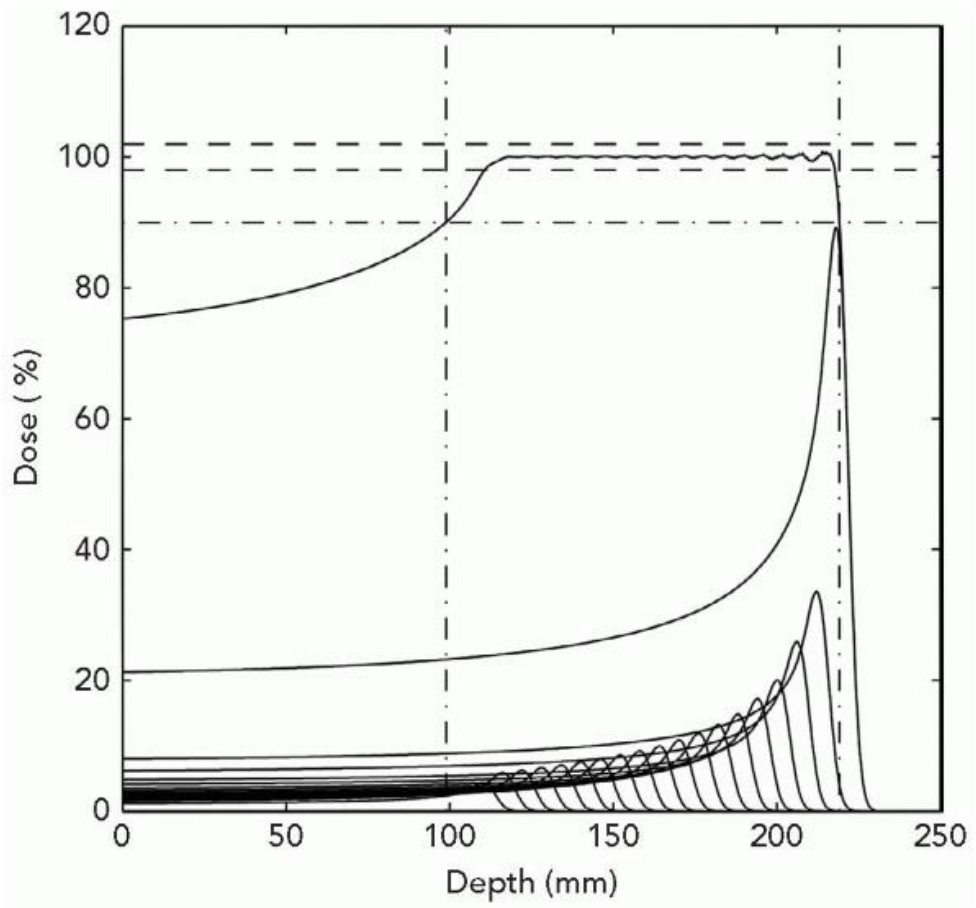
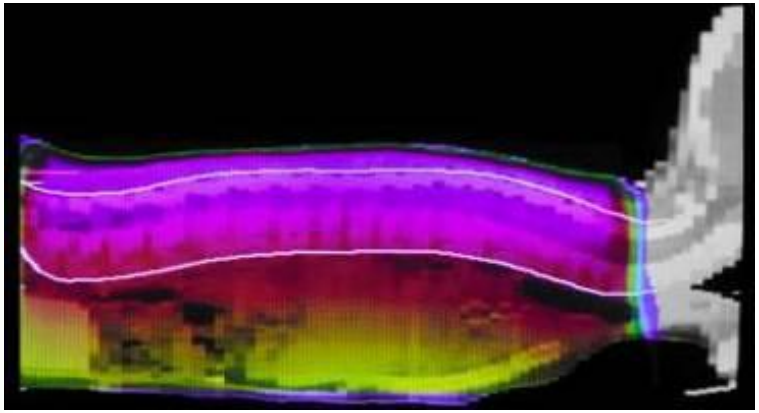
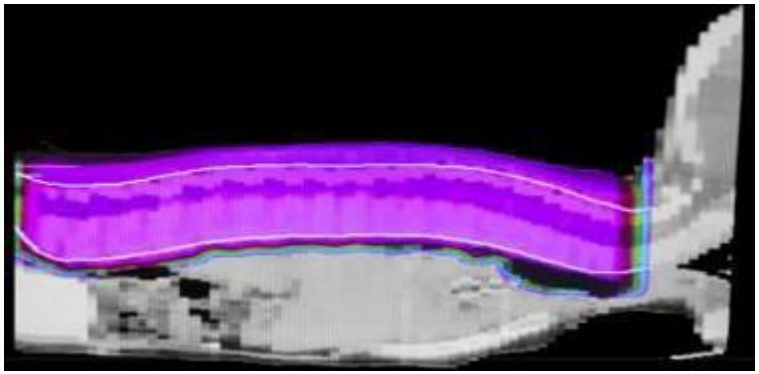
Why Particle Therapy?

- Bragg Peak of Proton beam

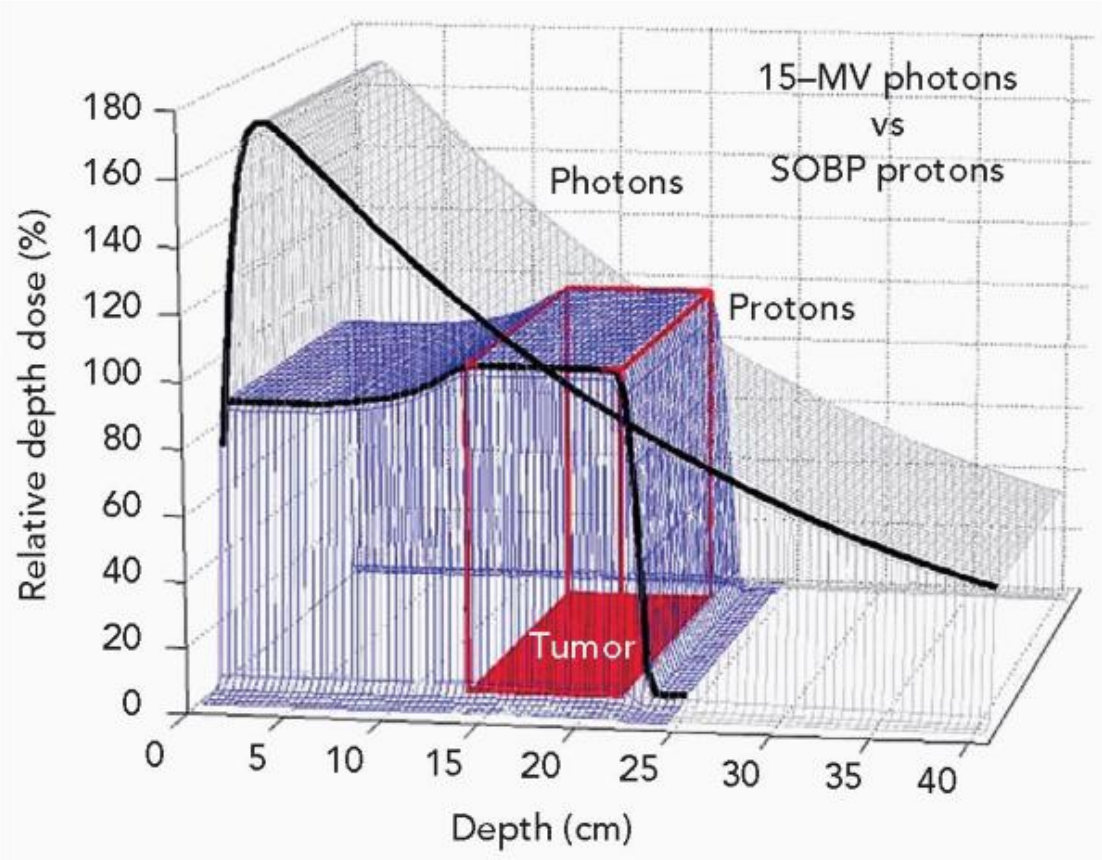




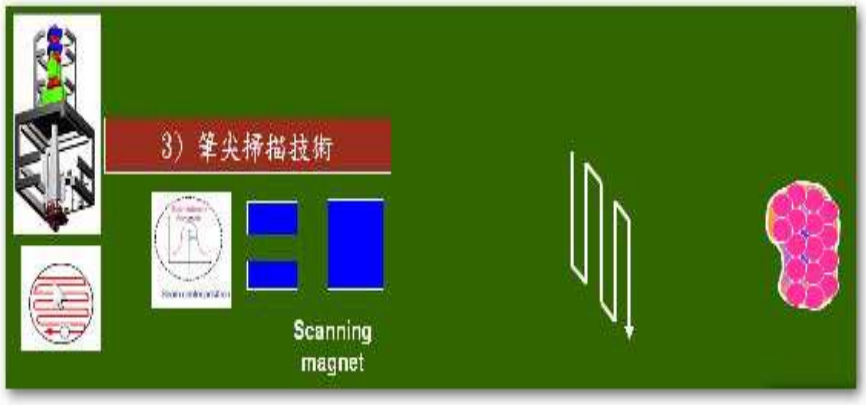


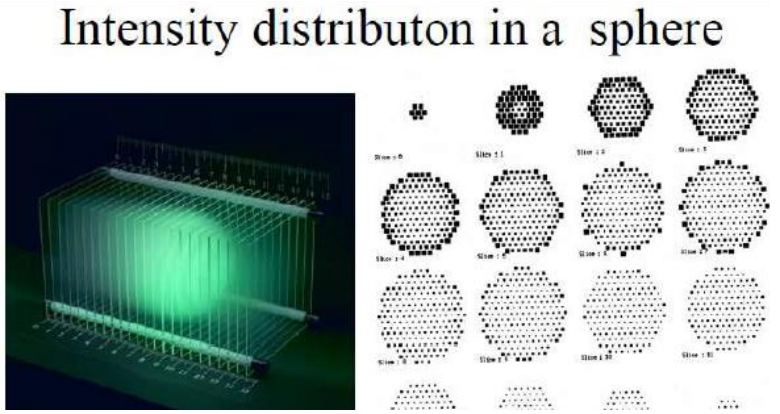
Why Particle Therapy?

- X-ray radiotherapy vs. Proton therapy



Pencil Beam Scanning





圖一: 取材於林口長庚醫院網站。左側為PBS系統的示意圖。右側為質子束在不同深度的強度模擬圖。由圖中可以看出，質子治療和傳統的x-ray治療很不一樣。

X-ray因為是電磁波，所以強度一開始最大，然後呈現指數衰減。因此對癌症前方的組織，傷害極大。
參考: https://www.youtube.com/watch?v=iEKqv8q16rw，和 https://www.youtube.com/watch?v=OTd5dv3VDws (在1分50秒處有清楚動畫說明)

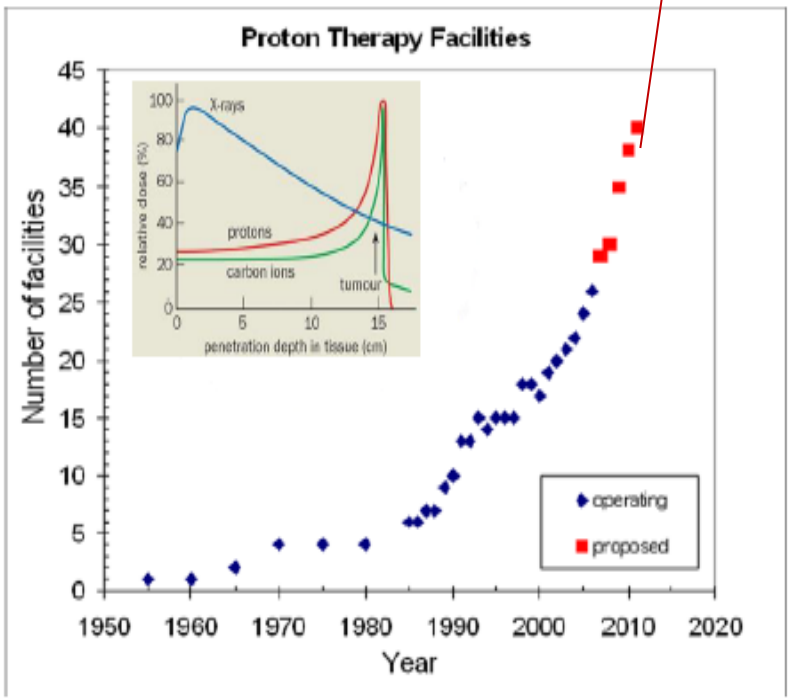
History

- 1919 yr: Ernest Rutherford demonstrated the existence of the proton.
- 1946 yr: Robert Wilson proposed the possibility for clinic use of the proton beam.
- 1985 yr: First hospital based facility (Loma Lida)
- 2001 yr: Second hospital based (MGH), IBA produced
- 2008 yr: First scanning beam treatment
- 2015 yr: First proton facility settled in Taiwan (CGMH)

現狀與未來

全球質子治療中心數目正快速增加，其中筆尖式掃瞄技術(Pencil Beam Scan)最為看好，現今市場無快速且精確之品保系統(包括治療儀及病患劑量)。

PTCOG統計到2020年全球約有90中心運行(不含國內規劃中8座)



~ 90 (by 2020)

57 in operation
33 in progress
17 planning
PTCOG
(2015.04)

國內放射醫療設備現況

500 億

Facility & members

Radiology----------192 facilities

712 Physicians

Nuclear Medicine-----55 facilities

160 Physicians

Radiation Oncology—64 facilities

168 Physicians

Radiology Equipments

X-ray Machine---2,578 units/1,548 facilities

Dental X-ray---9,069 units/6,537 facilities

Mobile X-ray---1,158 units/365 facilities

Mammography—198 units/177 facilities

CT---440 units/240 facilities

醫學影像

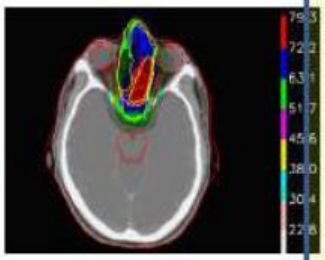
GPS主導

100 億

Nuclear Medicine Equipments

PET/CT---33 units/26 facilities

Cyclotron---10 units/10 facilities



400 億

Radiation Oncology Equipment

Linear Accelerators---120 units

Tele/Brachy---46 units

Gamma knife---7 units

Cyberknife---6 units

Tomotherapy---8 units

Proton -- 1 units

放射治療輔助儀器

PTW/ IBA

競爭較小

現狀品保(QA)儀器

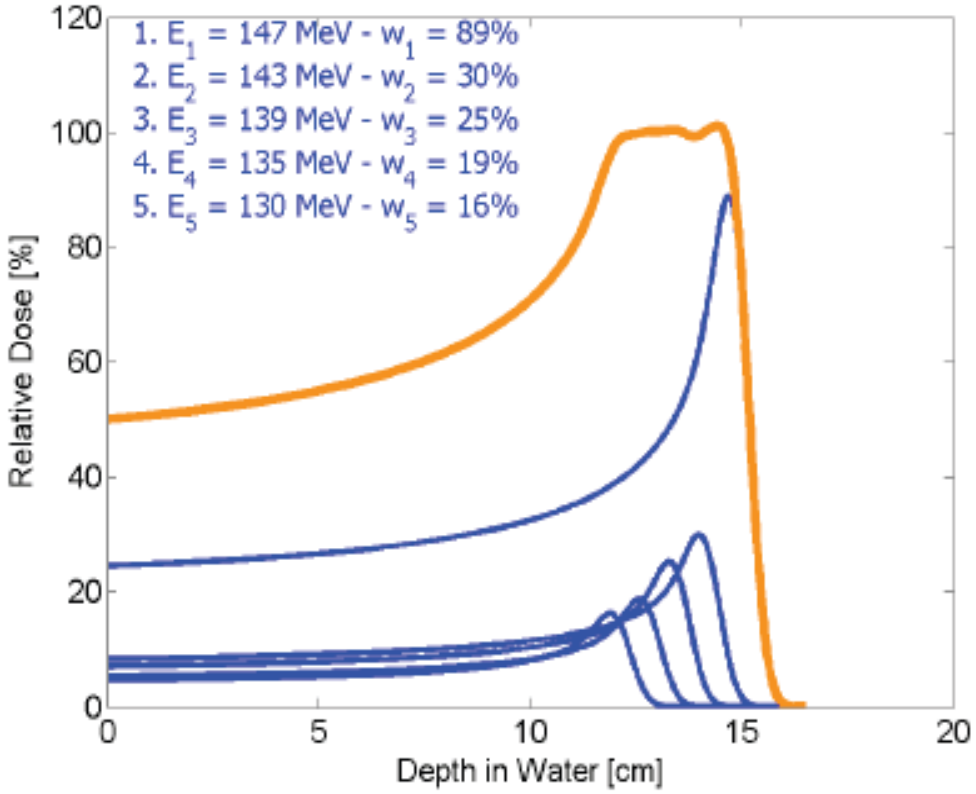
現今只有IBA公司之DigiPhant可提供質子治療之病患劑量品保，但耗時過長，不易為醫院接受。
每套售價台幣一千萬左右。

此計畫擬以八層測量平面加上多層游離室，同時完成劑量深度及腫瘤平面劑量分布，預期可大幅縮短時程，且提供較高空間解析度。

計畫產出具有獨特的市場競爭力。

IBA DigiPhant 系統

現狀品保的問題點



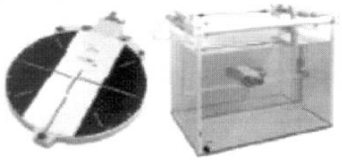
此例為3cm大小腫瘤以5層布拉格峰疊加成延展布拉格峰(SOBP)施以治療劑量。DigiPhant每掃瞄一次布拉格峰須20分鐘才能完成，3cm腫瘤就耗時100分鐘，這是醫院無法接受的。

這就是快速質子治療之精確劑量品保系統的商機

QA Workflow

Dedicated PBS Dosimetry Solutions

Commissioning



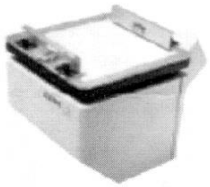
Bragg Peaks
- StingRay
- Blue Phantom²

Gold standard.

Bragg Peaks
- Giraffe

Spot Characteristics
- Lynx

Machine QA



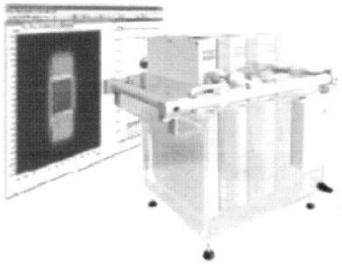
Spot Characteristics
- Lynx

Bragg Peaks
- Giraffe

Spread Out Bragg Peaks
- Zebra

PDD only.

Patient QA



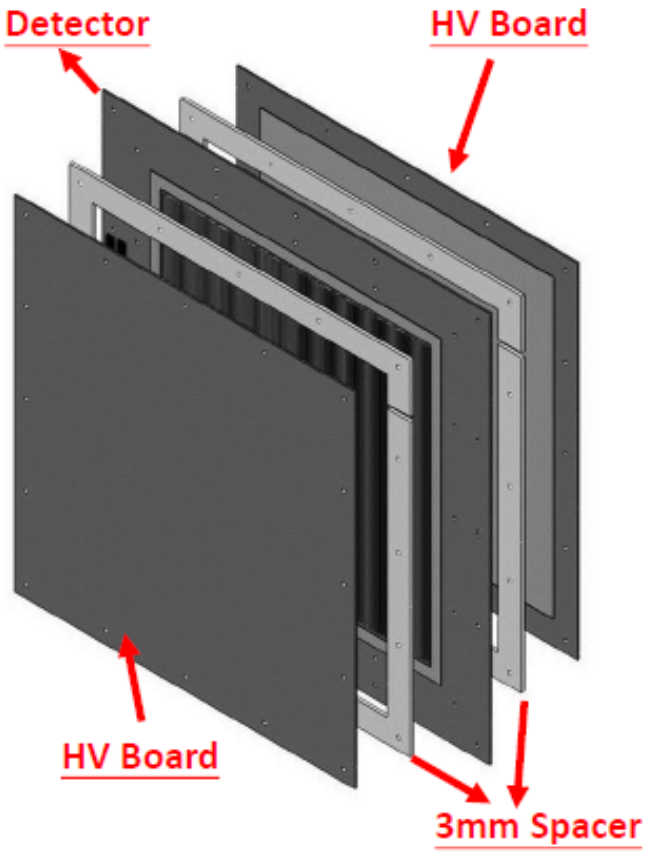
Patient Plan Verification
- DigiPhant PT – Water Phantom system with motorized MatriXX PT detector

*逐层扫描得到3D dose distribution, one layer at a time.

Need of a tool can measure 3D dose distribution directly, and provide a software can evaluate the discriptance between Tx. planning and measurement based on the Gamma evaluation method.

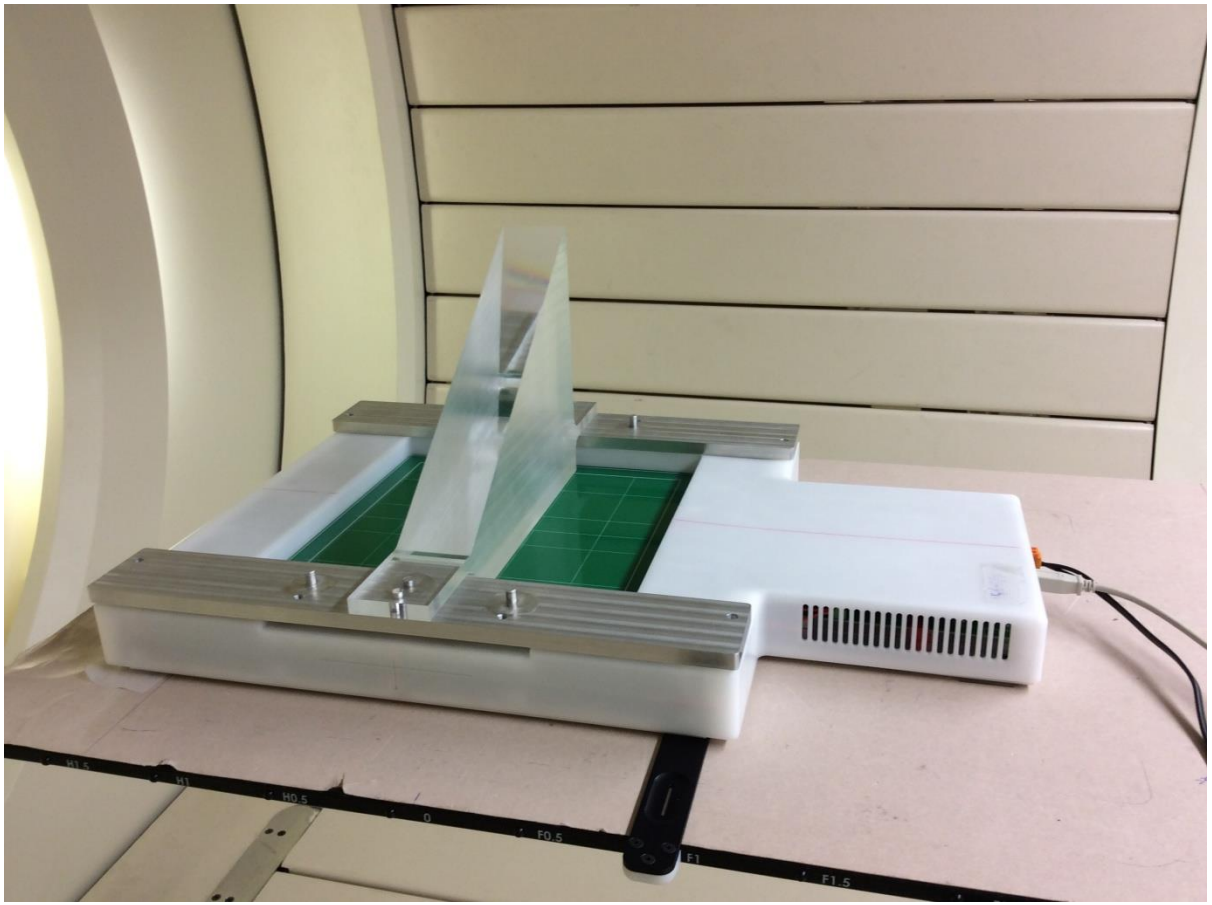
X-Y Strip Ionization Chamber

Specifications	
Number of channels:	254
Active area:	254 x 254 mm
Sensor layout:	127+127 (X direction + Y direction)
Pitch:	2 mm channel to channel
Chamber type:	Strip of Parallel Plate Ionization Chambers
Sensor size:	254(l) x 1.88(w) mm /Ch.
Application:	Proton & X-Ray Beam monitor
Positioning:	nozzle mount (holder optional) or patient table
Maximum DAQ Rate	20 kHz

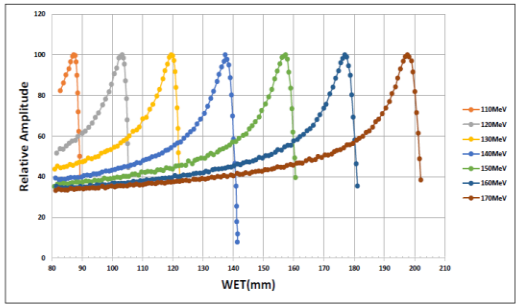


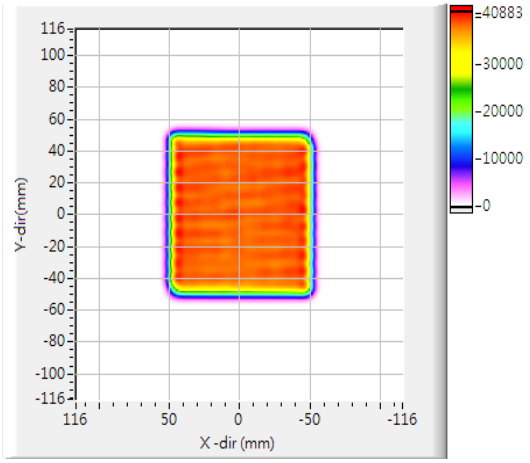
質子治療之相關探測器研製3年計畫產出

此產品獲得第十二屆國家臨床新創獎

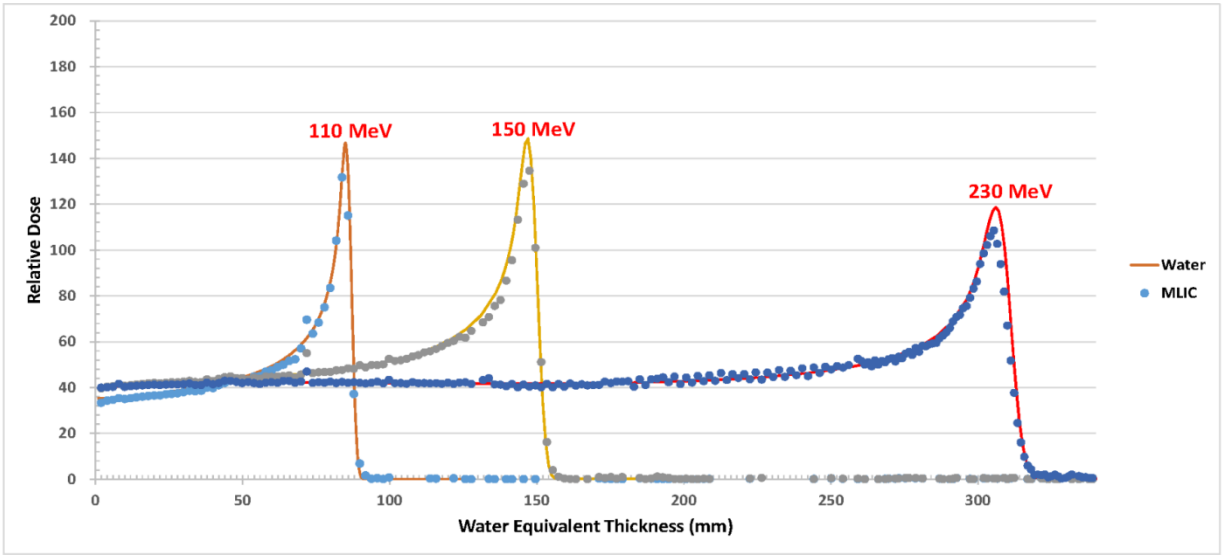


X-Y Strip Ionization Chamber:
Bragg curve measurement

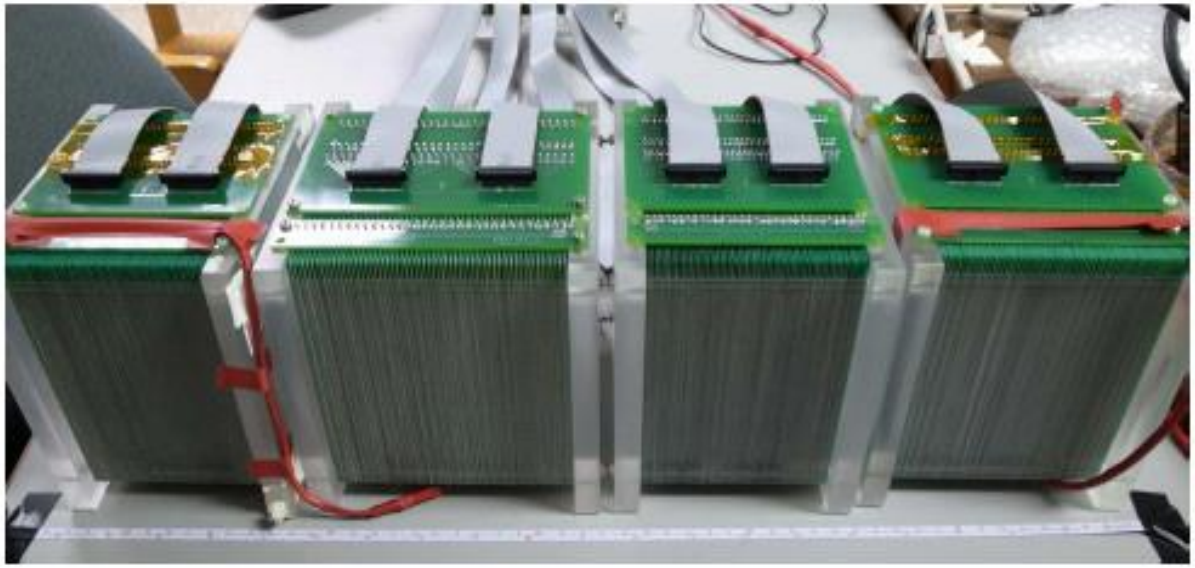




以多層游離室同時完成劑量深度量測

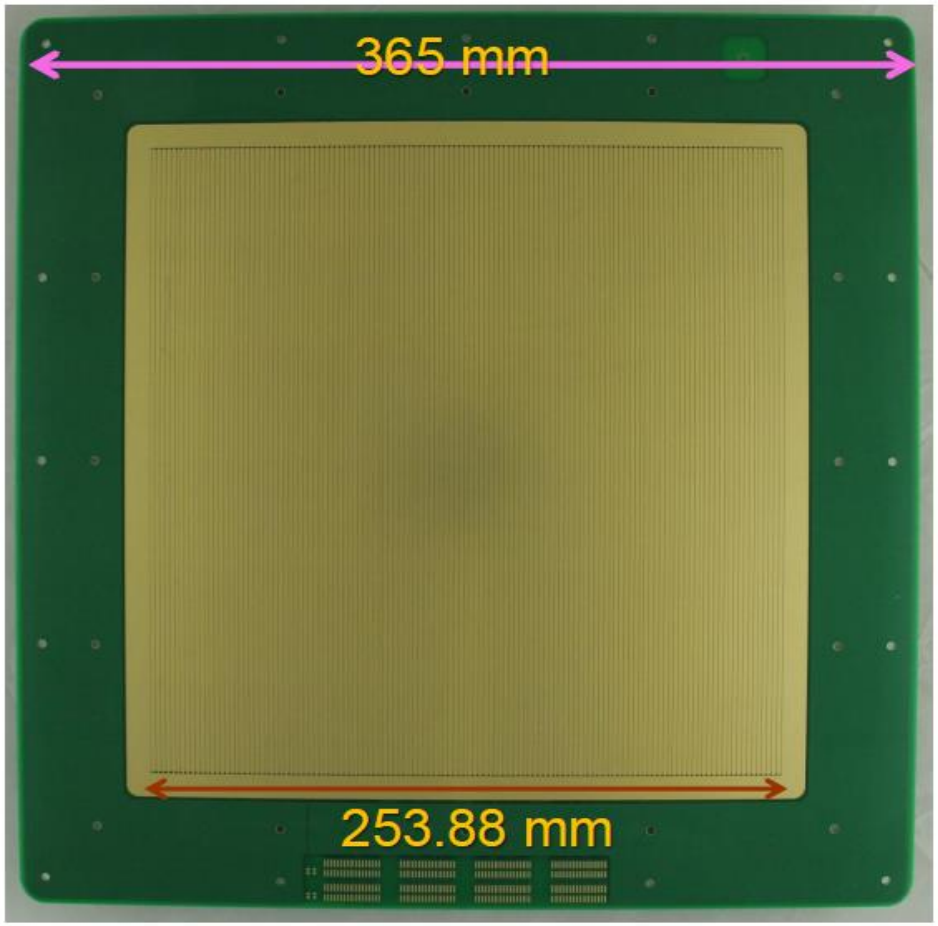


IBA Zebra



自製MLIC

For PBS



PCB Board size

365mm*365mm

strip dimension

254 mm*1.88 mm

strip gap

0.12 mm

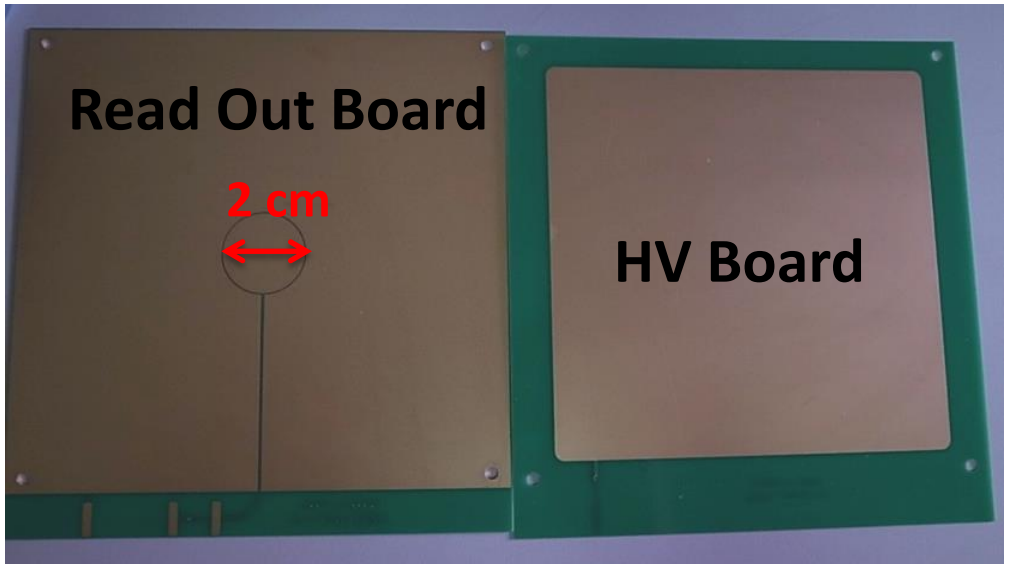
total strip

127+127

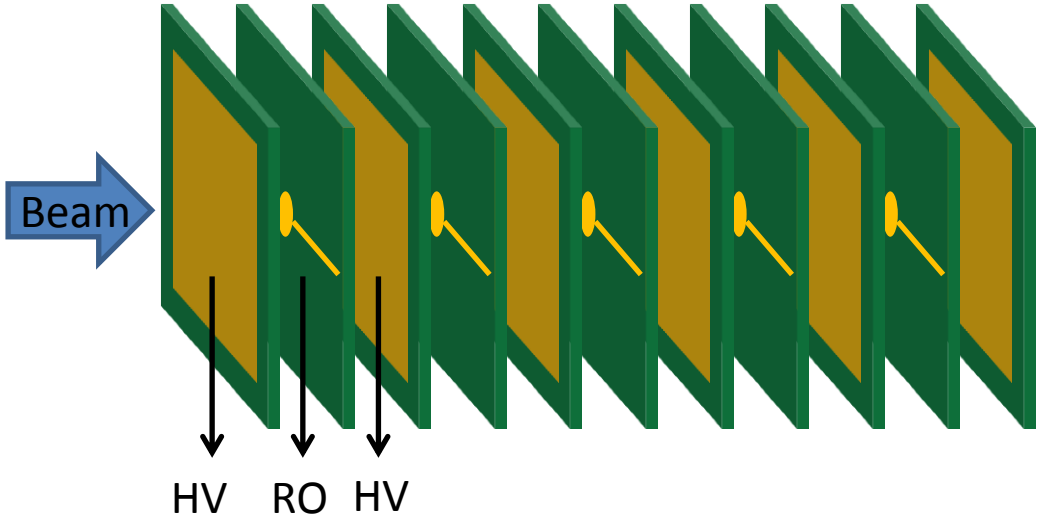
total strip area

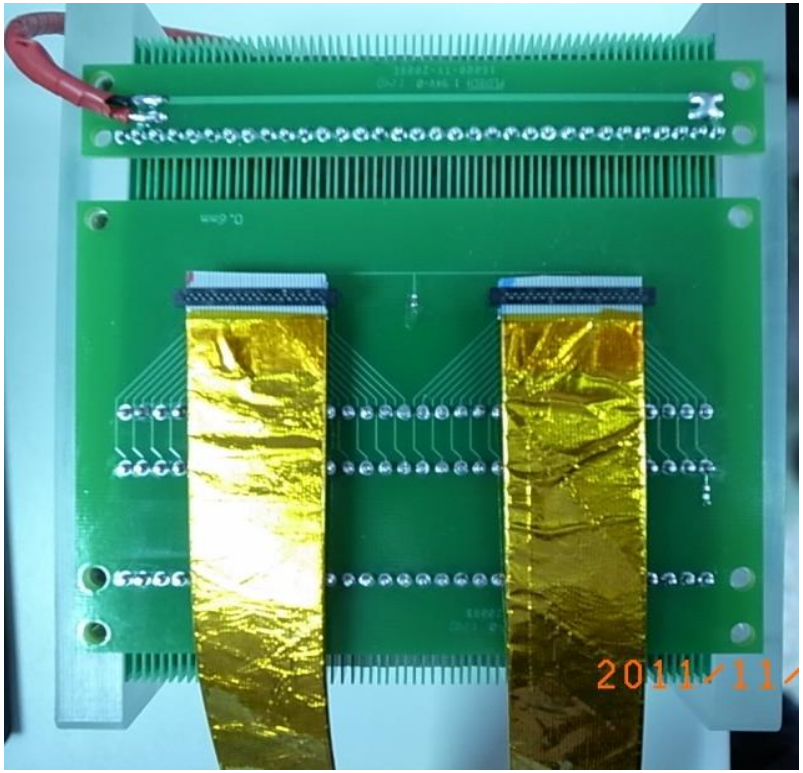
254 mm*254 mm

Multi-Layer Ionization Chamber



A multi-layer ionization chamber (MLIC) consists of a stack of parallel plate-type ionization chambers can measure depth dose distributions at one time.





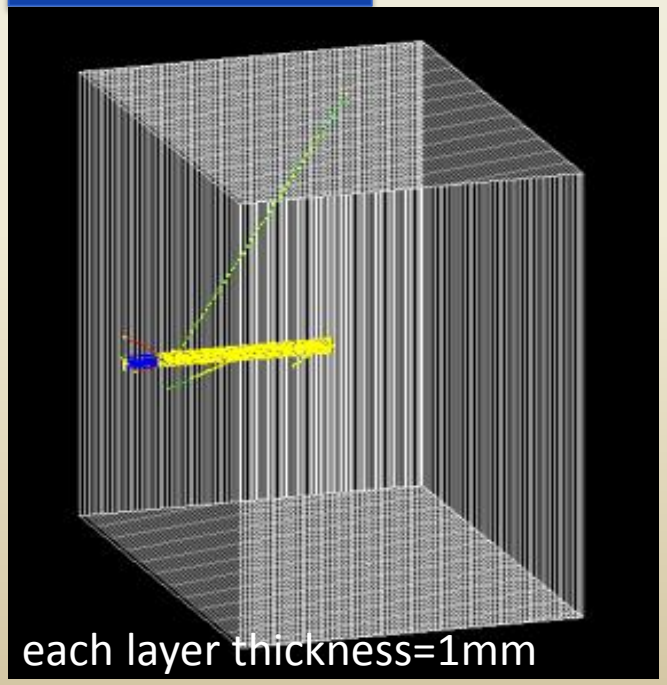
Geant4 Estimated the Depth Dose Distribution

- Geant4 simulation parameter

  Energy=100/200MeV (smear=0.5%)

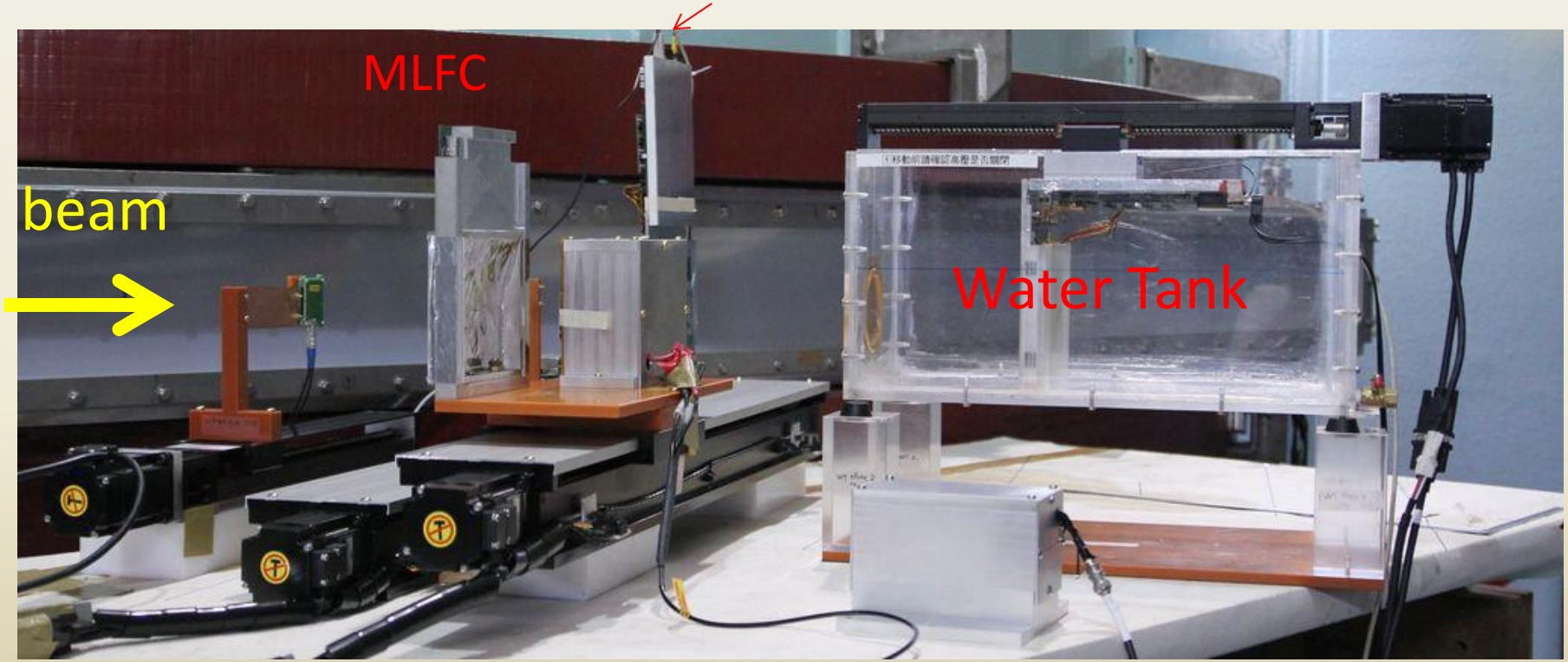
Cut off step:10um

Water tank



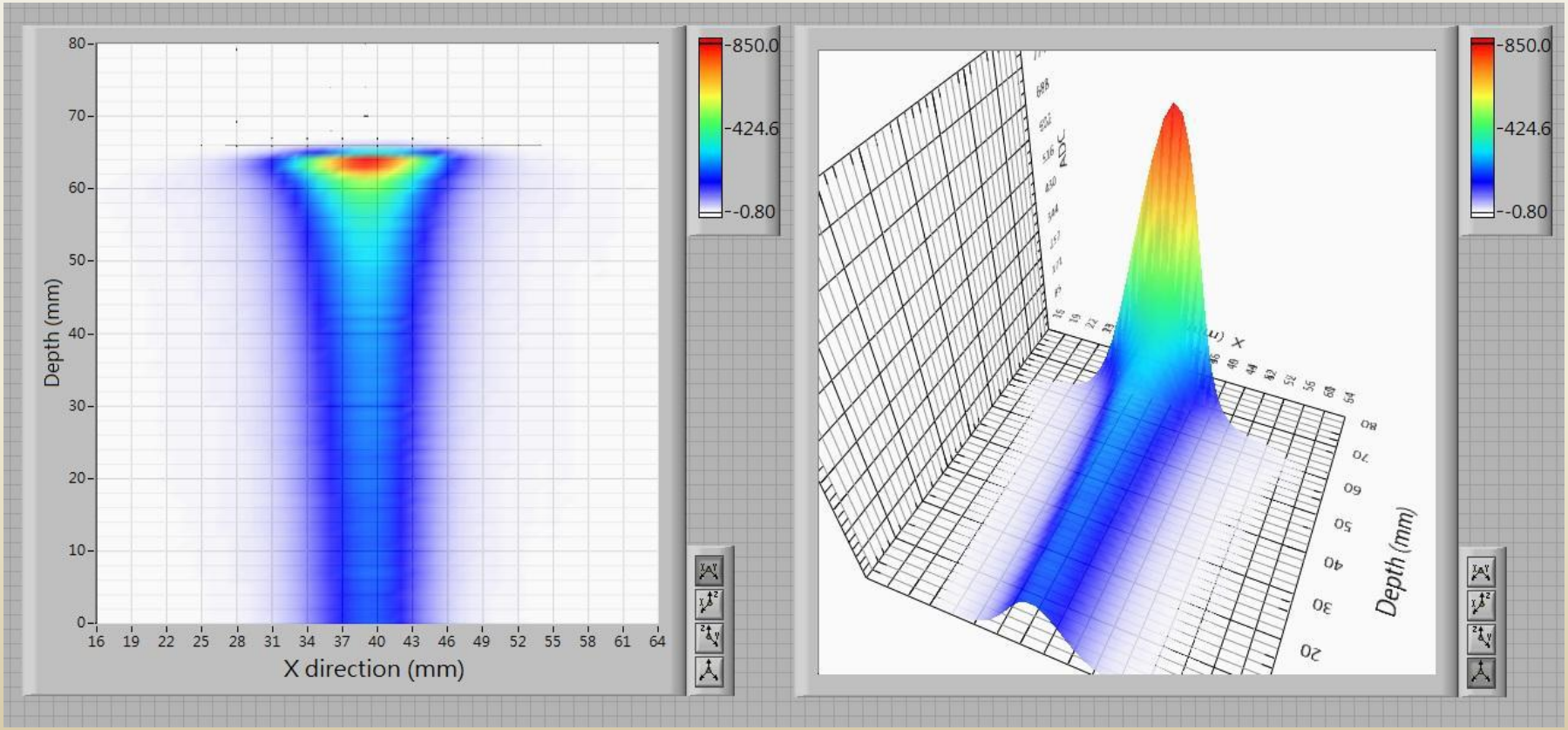
Proton beam
2mm(FWHM)
100,000

Experiment Setup-Water Tank



Depth Dose Distribution (Experiment)

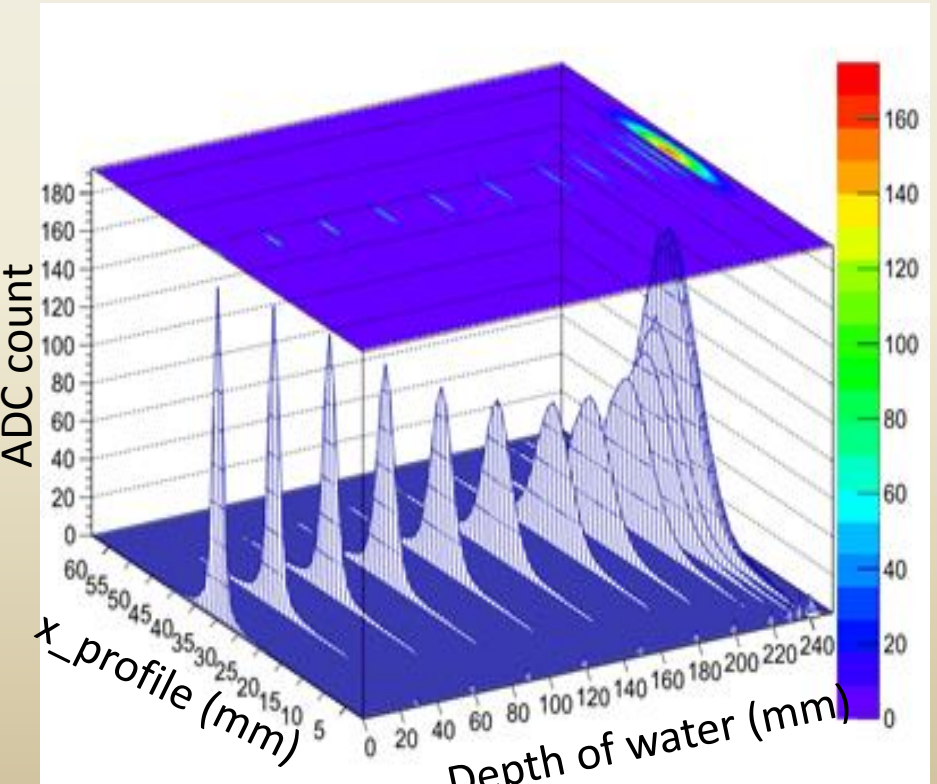
- 100MeV Proton beam in water tank.



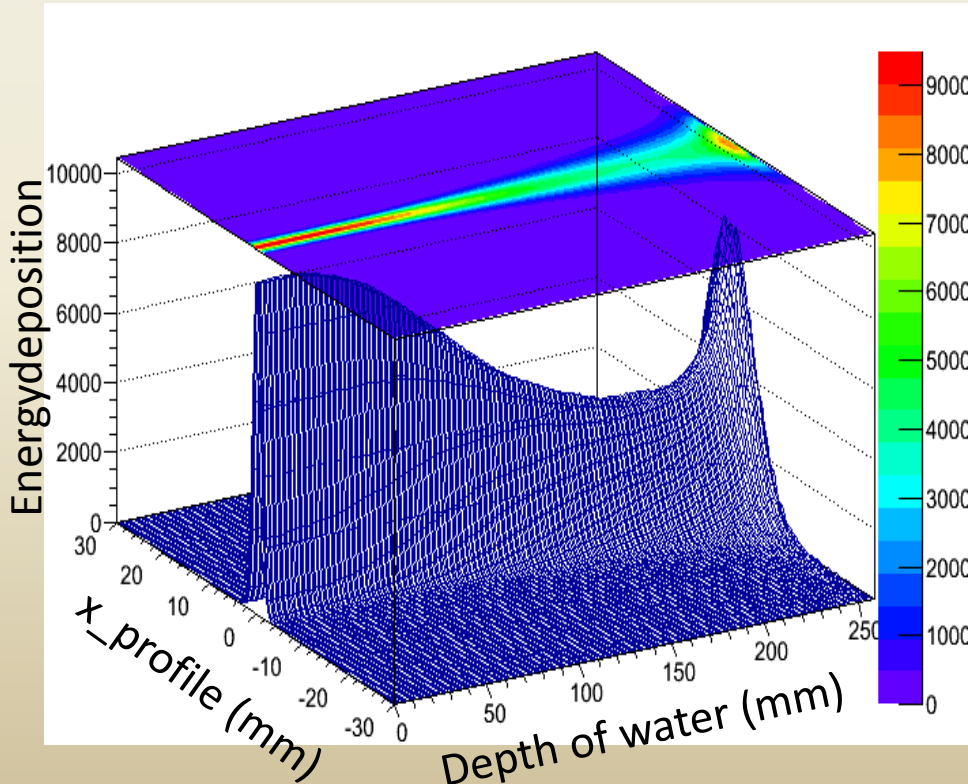
Depth Dose Distribution- Experiment vs. Simulation

200MeV_2mm(FWHM)

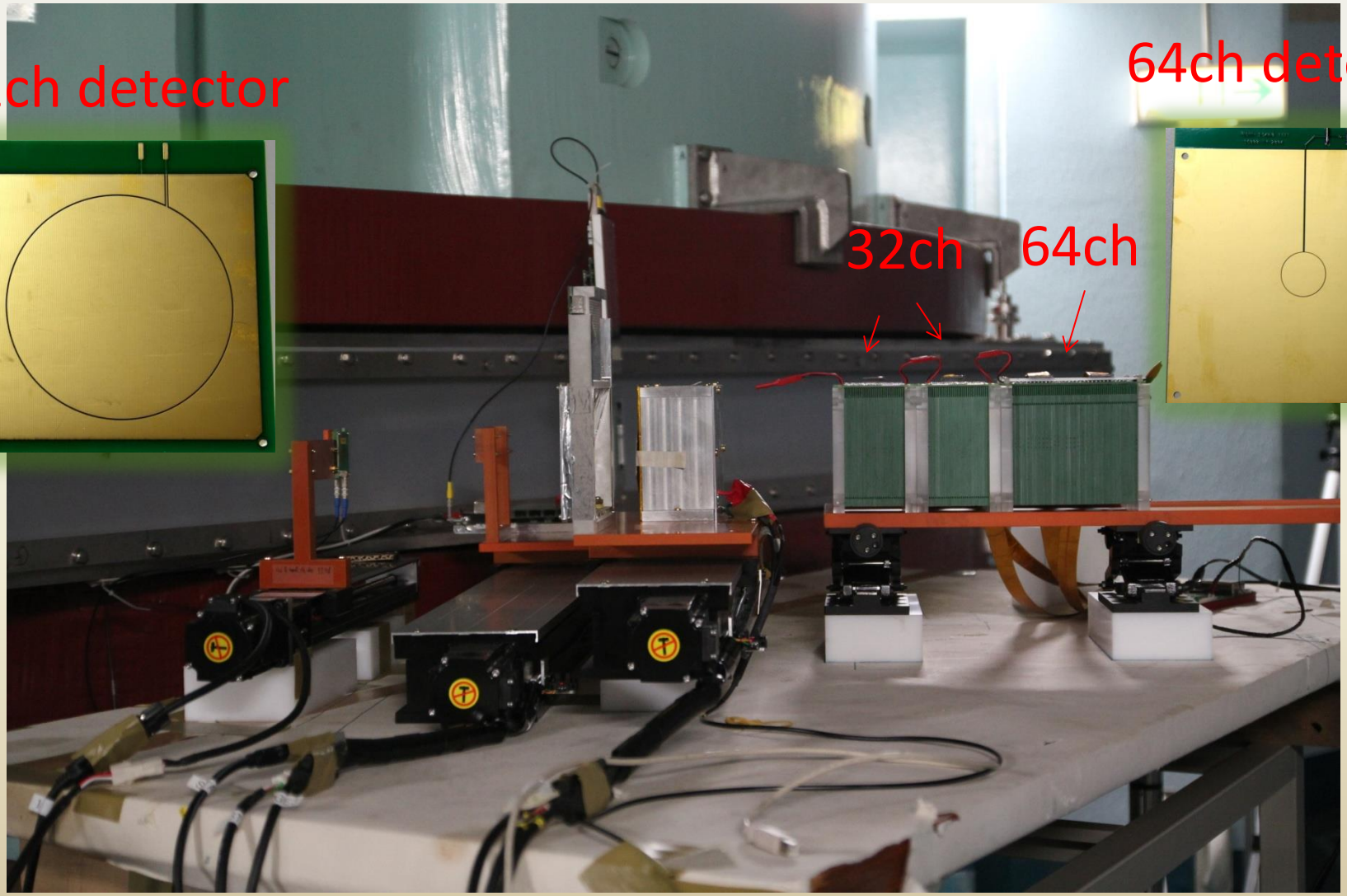
Experiment

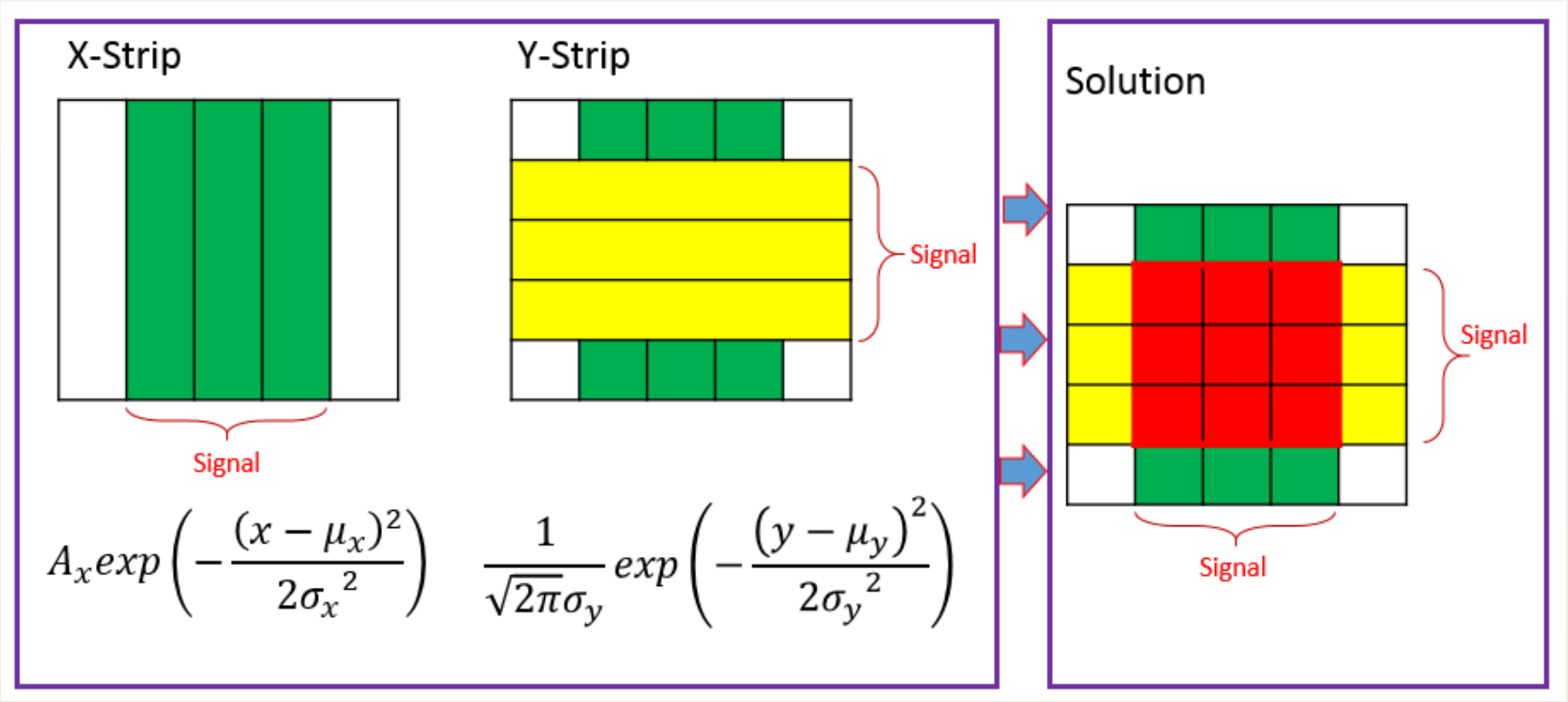


Simulation



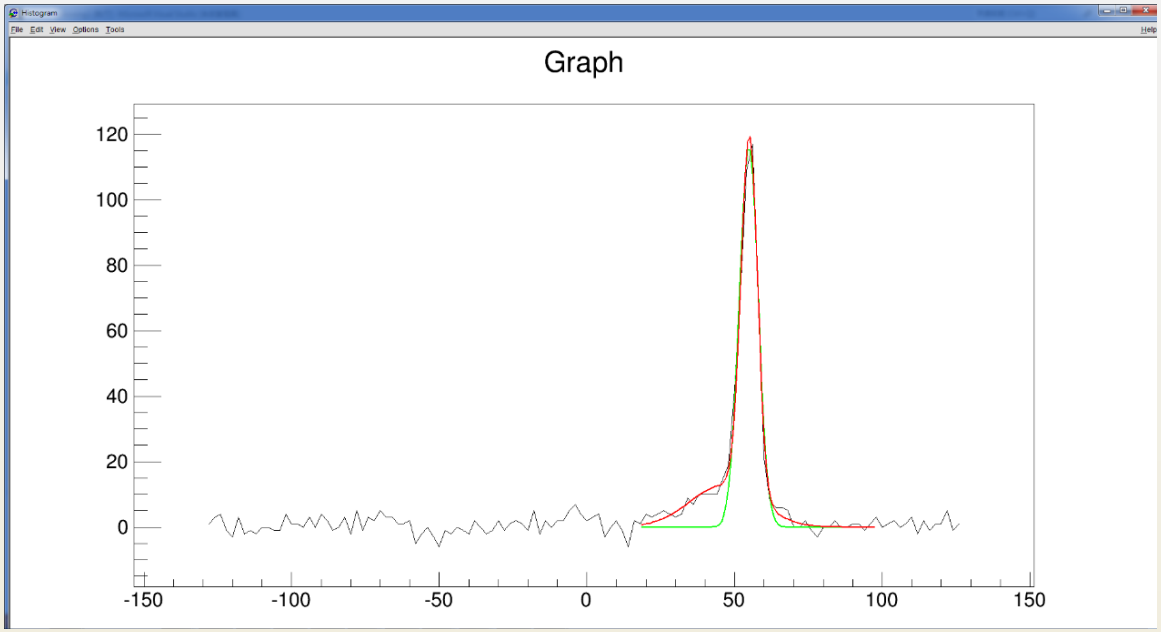
MLIC Experiment Setup





$$f(x,y) = A_x exp\left(-\frac{(x-\mu_x)^2}{2\sigma_x{}^2}\right) \frac{1}{\sqrt{2\pi}\sigma_y} exp\left(-\frac{(y-\mu_y)^2}{2\sigma_y{}^2}\right)$$

$$f(x,y) = A_y exp\left(-\frac{(y-\mu_y)^2}{2\sigma_y{}^2}\right) \frac{1}{\sqrt{2\pi}\sigma_x} exp\left(-\frac{(x-\mu_x)^2}{2\sigma_x{}^2}\right)$$



$$f_{G1\_x}(x,y) = A_{G1\_x} exp\left(-\frac{(x-\mu_{G1\_x})^2}{2\sigma_{G1\_x}{}^2}\right) \frac{1}{\sqrt{2\pi}\sigma_{G1\_y}} exp\left(-\frac{(y-\mu_{G1\_y})^2}{2\sigma_{G1\_y}{}^2}\right)$$

$$f_{G2\_x}(x,y) = A_{G2\_x} exp\left(-\frac{(x-\mu_{G2\_x})^2}{2\sigma_{G2\_x}{}^2}\right) \frac{1}{\sqrt{2\pi}\sigma_{G2\_y}} exp\left(-\frac{(y-\mu_{G2\_y})^2}{2\sigma_{G2\_y}{}^2}\right)$$

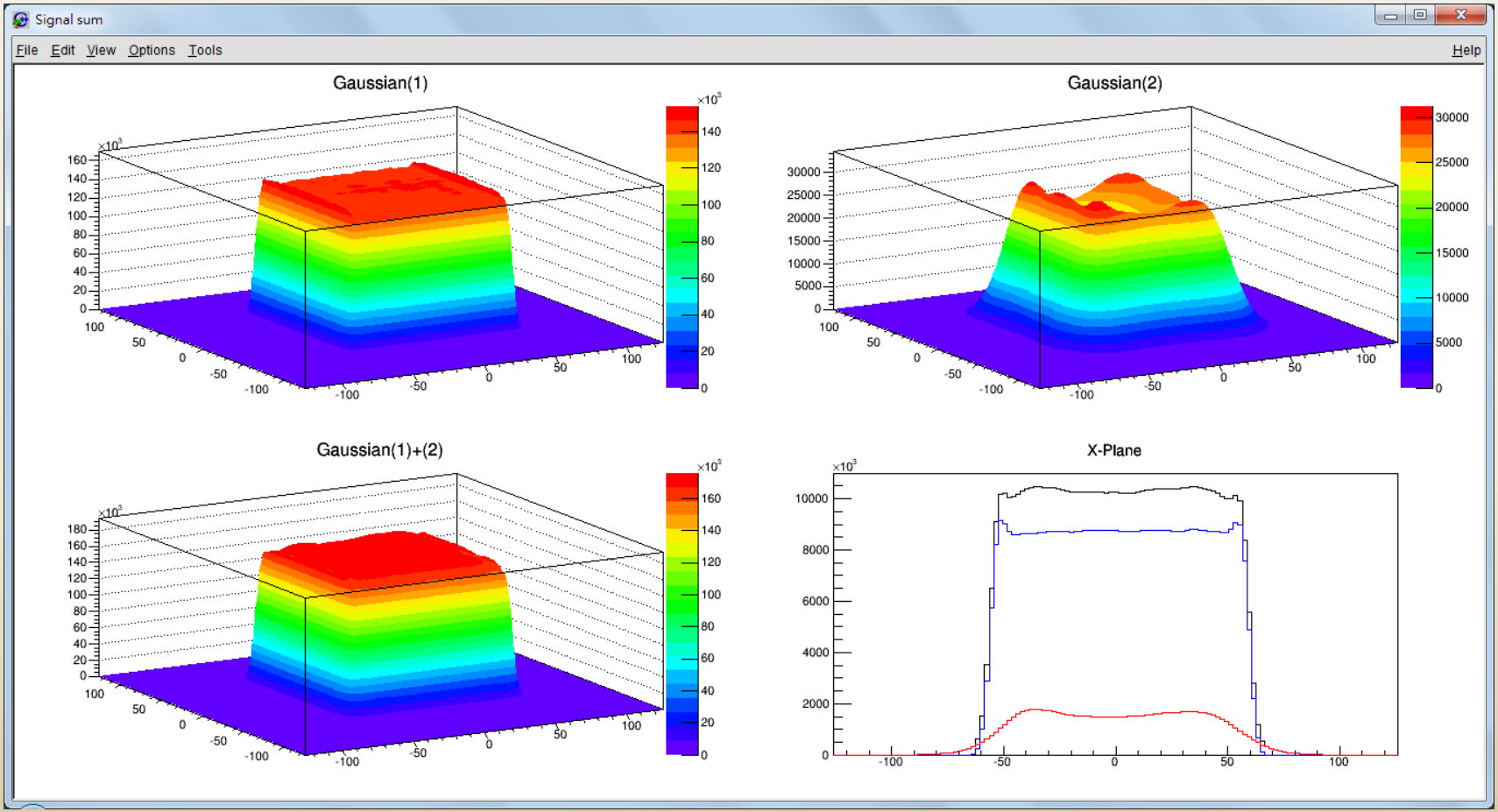
$$f_{Total\_x}(x,y) = f_{G1\_x}(x,y) + f_{G2\_x}(x,y)$$

$$f_{G1\_y}(x,y) = A_{G1\_y} exp\left(-\frac{(y-\mu_{G1\_y})^2}{2\sigma_{G1\_y}{}^2}\right) \frac{1}{\sqrt{2\pi}\sigma_{G1\_x}} exp\left(-\frac{(x-\mu_{G1\_x})^2}{2\sigma_{G1\_x}{}^2}\right)$$

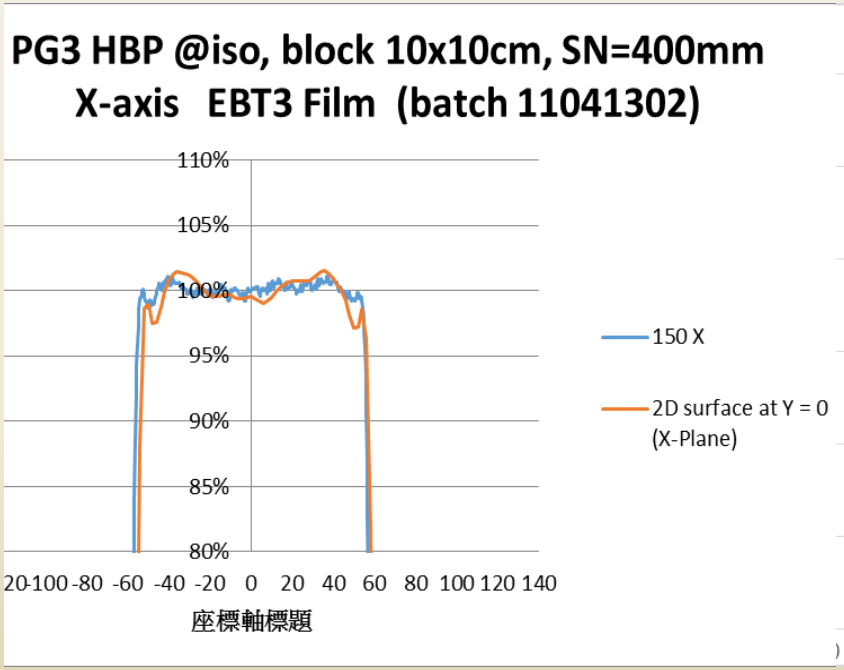
$$f_{G2\_y}(x,y) = A_{G2\_y} exp\left(-\frac{(y-\mu_{G2\_y})^2}{2\sigma_{G2\_y}{}^2}\right) \frac{1}{\sqrt{2\pi}\sigma_{G1\_x}} exp\left(-\frac{(x-\mu_{G2\_x})^2}{2\sigma_{G2\_x}{}^2}\right)$$

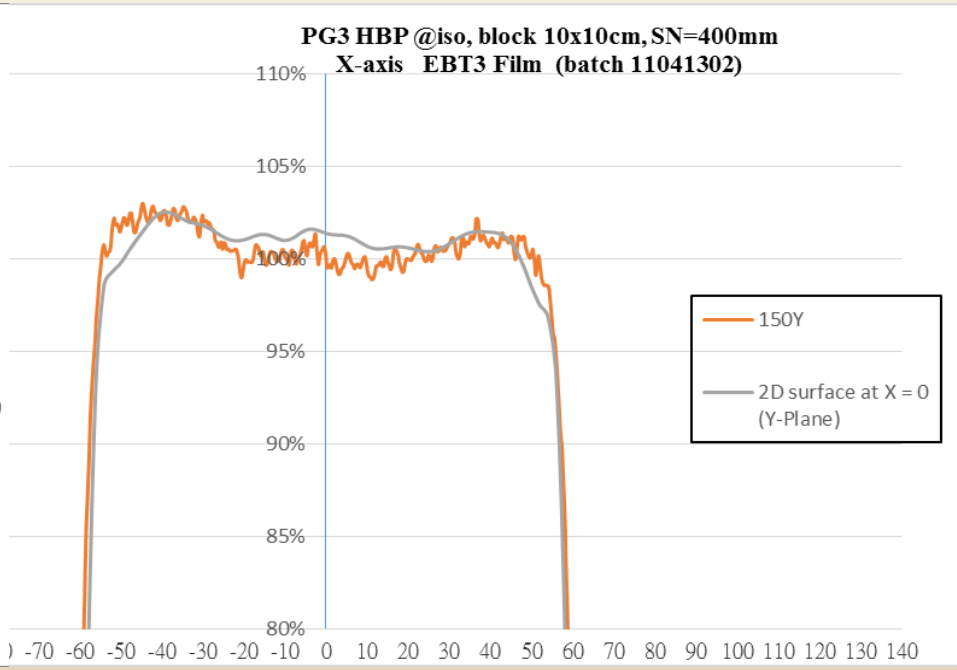
$$f_{Total\_y}(x,y) = f_{G1\_y}(x,y) + f_{G2\_y}(x,y)$$

訊號重建


Signal sum
File Edit View Options Tools
Help
Gaussian(1)
Gaussian(2)
Gaussian(1)+(2)
X-Plane

膠片驗證


PG3 HBP @iso, block 10x10cm, SN=400mm
X-axis EBT3 Film (batch 11041302)
110%
105%
100%
95%
90%
85%
80%
20 -100 -80 -60 -40 -20 0 20 40 60 80 100 120 140
座標軸標題
150 X
2D surface at Y = 0
(X-Plane)


PG3 HBP @iso, block 10x10cm, SN=400mm
X-axis EBT3 Film (batch 11041302)
110%
105%
100%
95%
90%
85%
80%
-70 -60 -50 -40 -30 -20 -10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140
150Y
2D surface at X = 0
(Y-Plane)

Thank you!

謝謝您的聆聽!