Proton Beam Therapy. Applications of PP detector technologies

PPAP Community Meeting
RAL
21-Jul-2017

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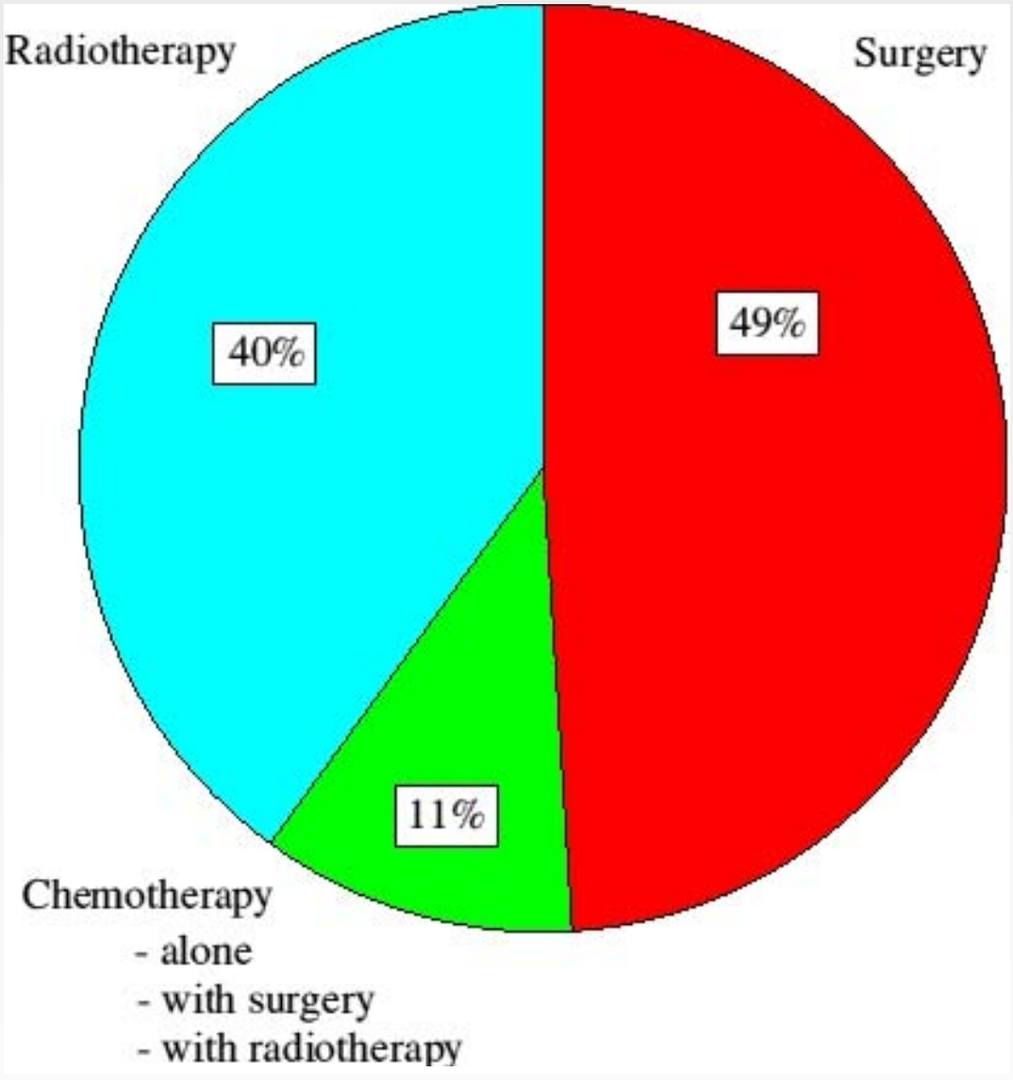
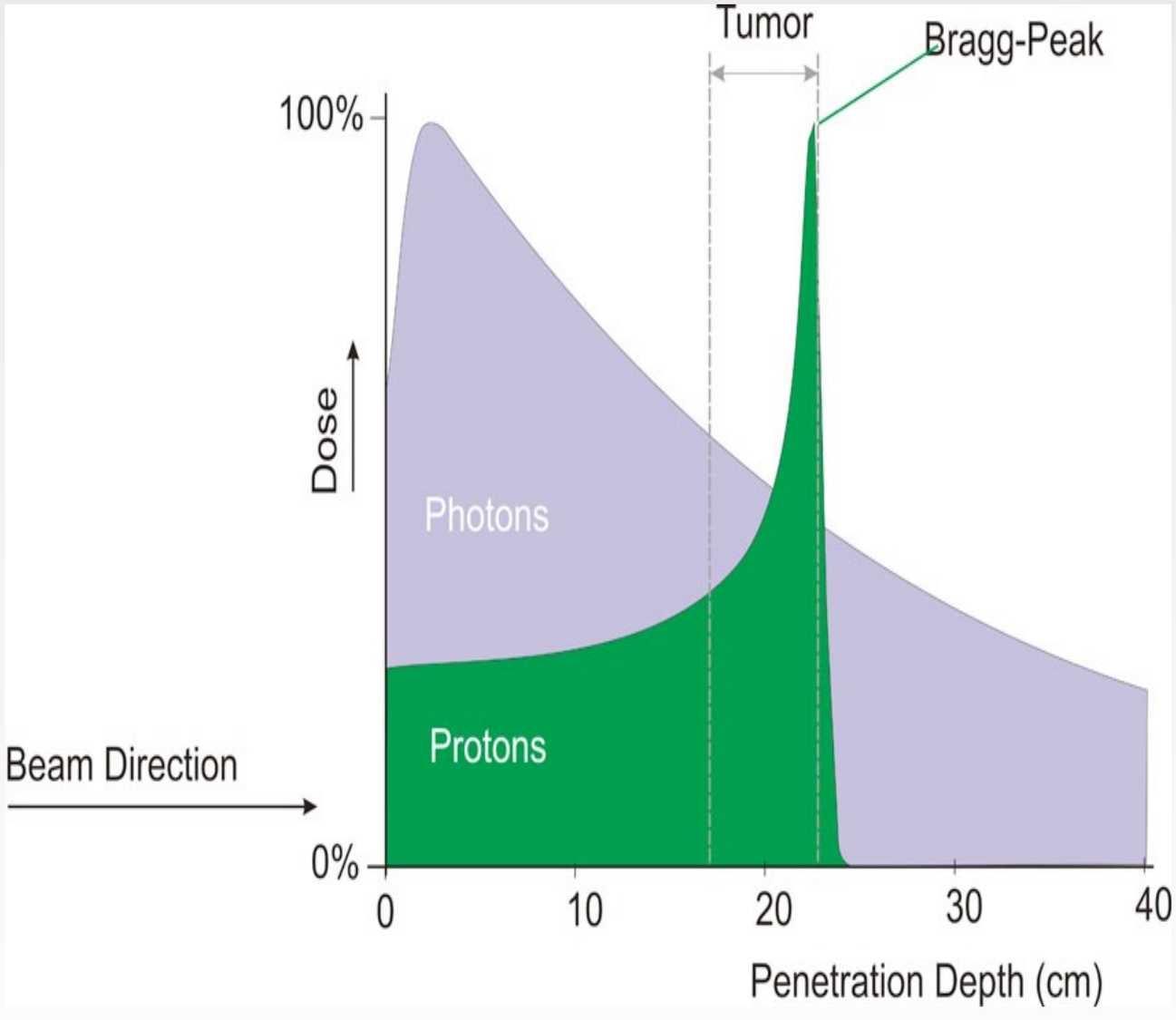
Outline

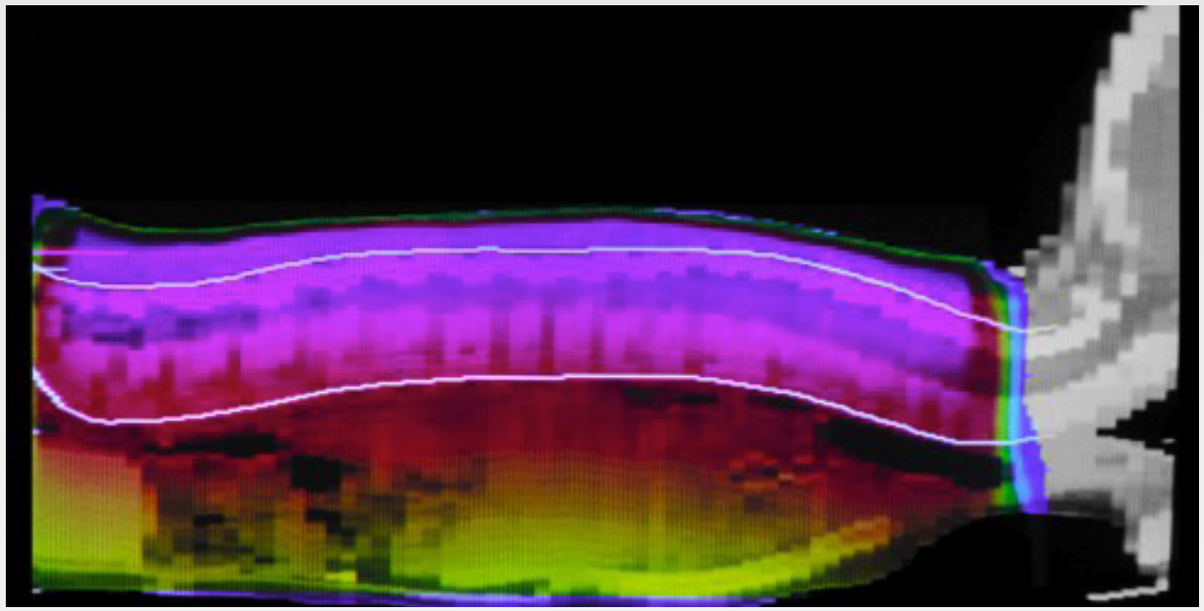
- Proton Beam Therapy in UK
- Detector development
  - QA in PBT
  - Proton Computed Tomography - pCT
- SuperNEMO calorimeter and ATLAS Si-tracker
- Results so far
- Prospects and Plans

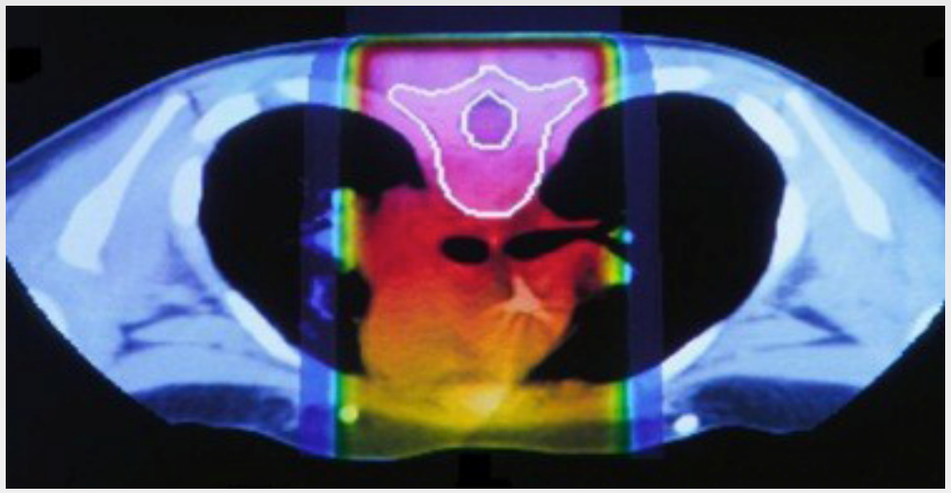
Proton Beam Therapy (PBT)





Medulloblastoma: Protons Vs. Photons





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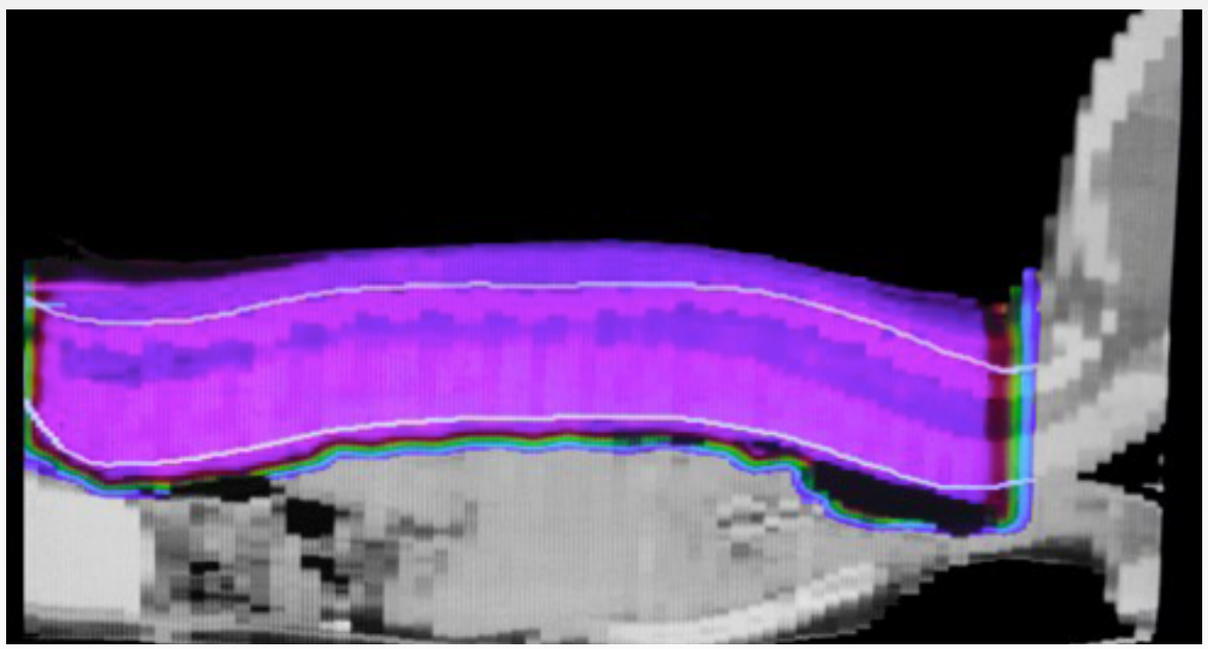

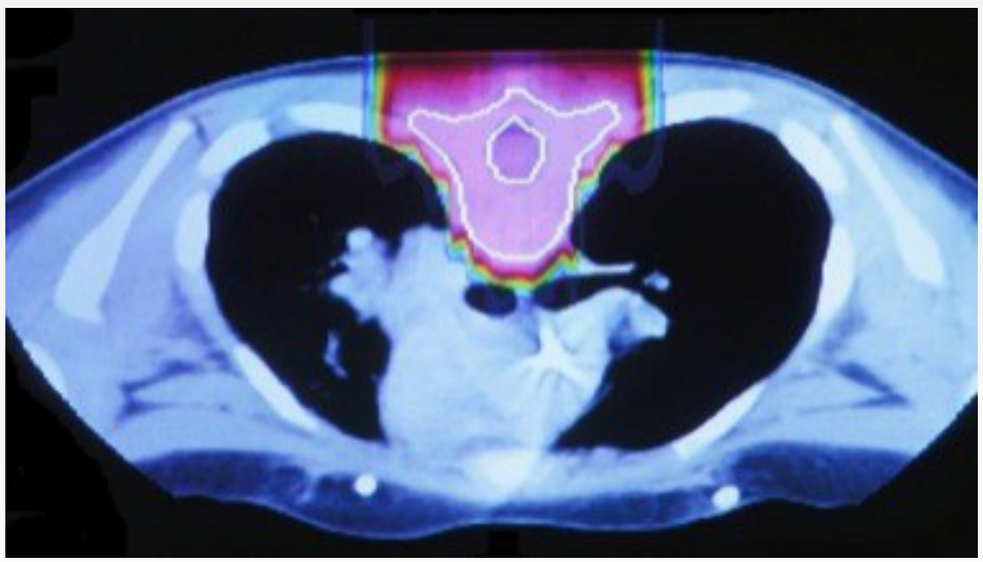

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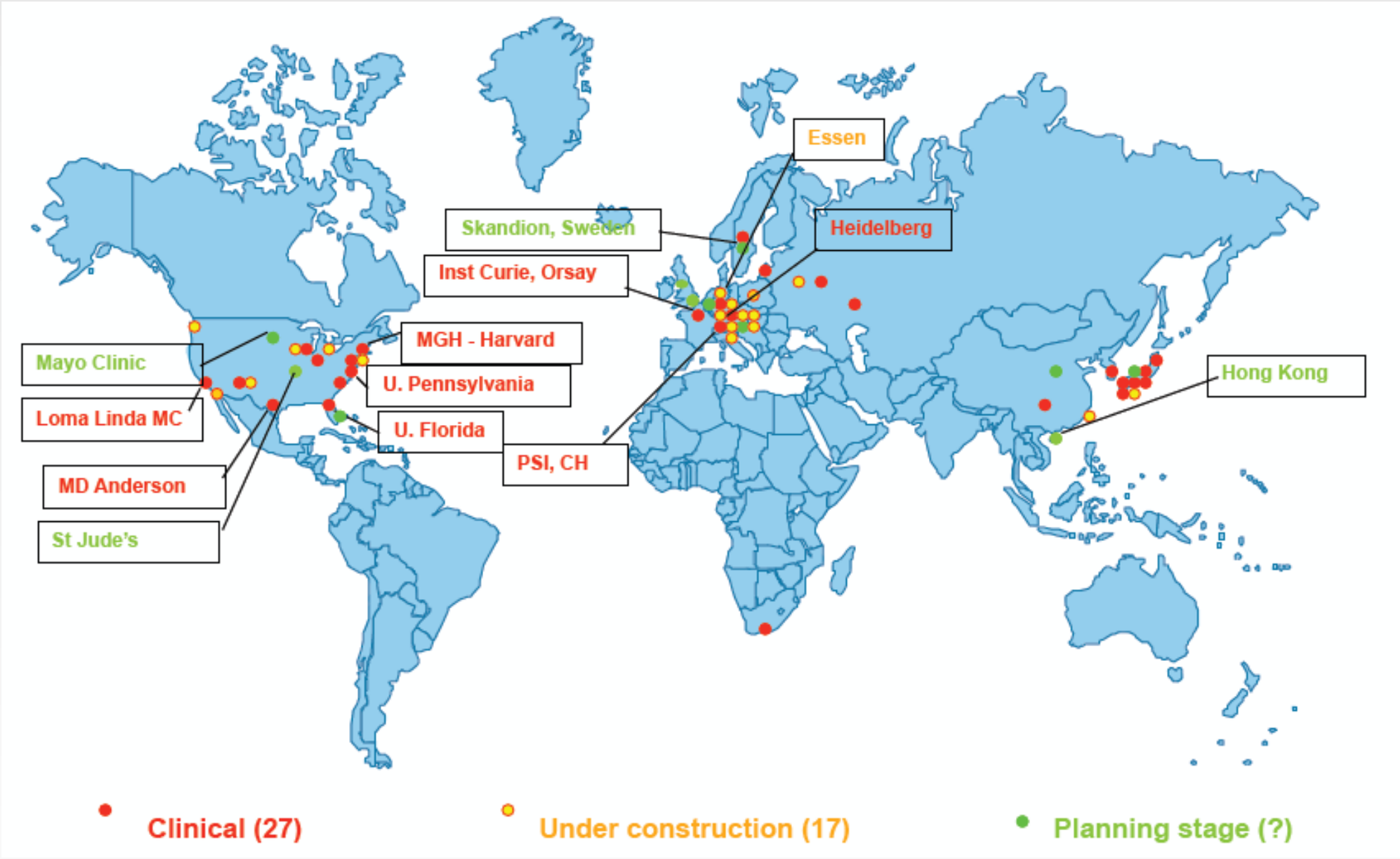
PBT Facilities



At current rate, number of centres worldwide doubles every 3 yr

UK

- **Clatterbridge** — 60 MeV cyclotron (ocular melanoma). **Only** UK operating facility **so far**.
- **Two new centres**. 250 MeV cyclotron (brain, spine, head&neck). £250M funding in 2012
  - UCLH and Manchester/Christie
  - Opens in 2018/19

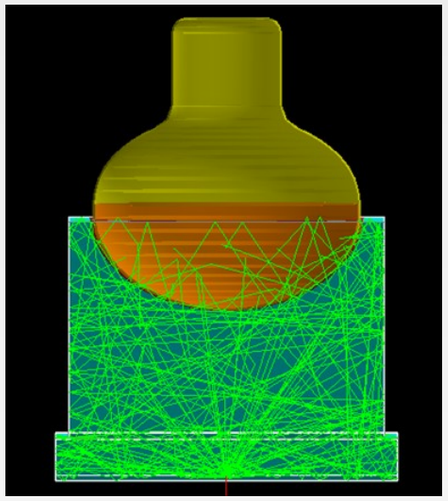
Challenges in Proton Therapy and PP Detector Development

- **Daily Quality Assurance** (QA). Need to know "water equivalent" proton range to < 1%

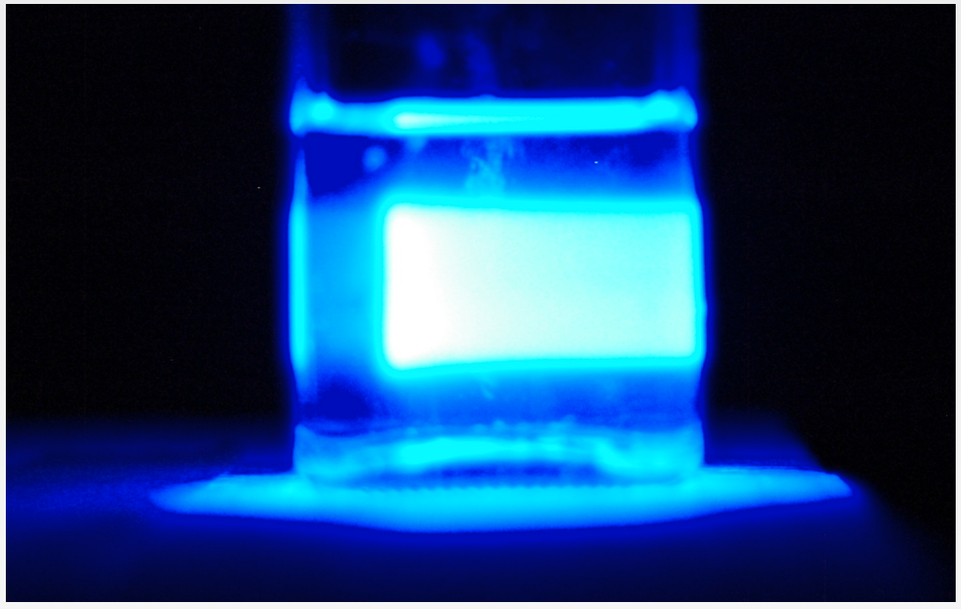
  Currently use commercial setups based ionisation chambers

  - **Expensive (> £200k)**
  - **Long setting up and QA times**

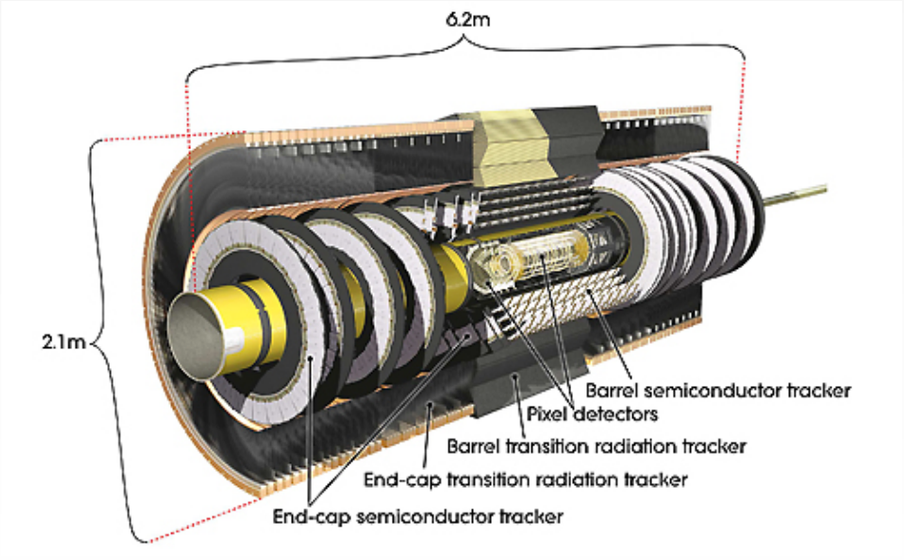
SuperNEMO Calorimeter
1,000 p.e./MeV

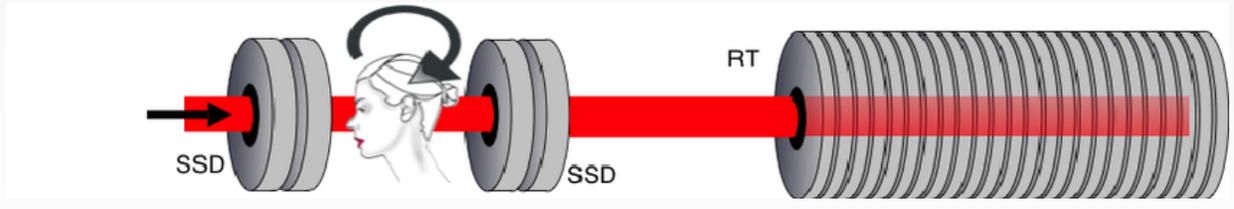


R&D at UCL to adopt SuperNEMO fast, ultra-bright scintillator detector for proton energy/ range verification



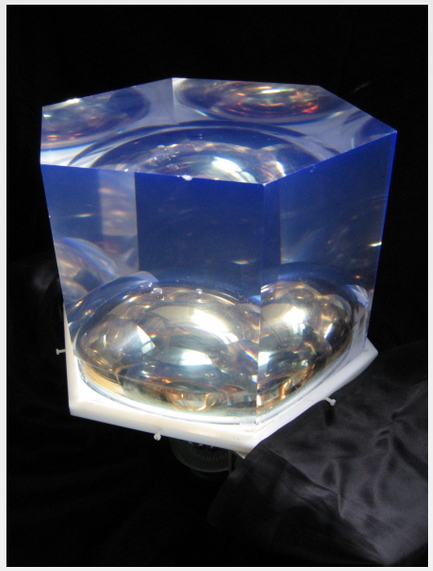
- **Proton Computed Tomography**, pCT, to reduce uncertainty in treatment plan from X-ray CT





ATLAS Si tracker for imaging with protons

QA for PBT: R&D based on SuperNEMO optical module

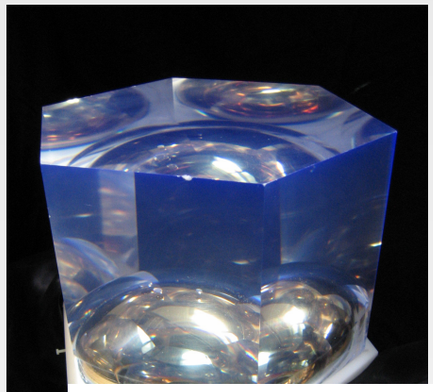


Measure energy —> range

Sufficient light output (1000 p.e./MeV) for < 1% proton energy measurement

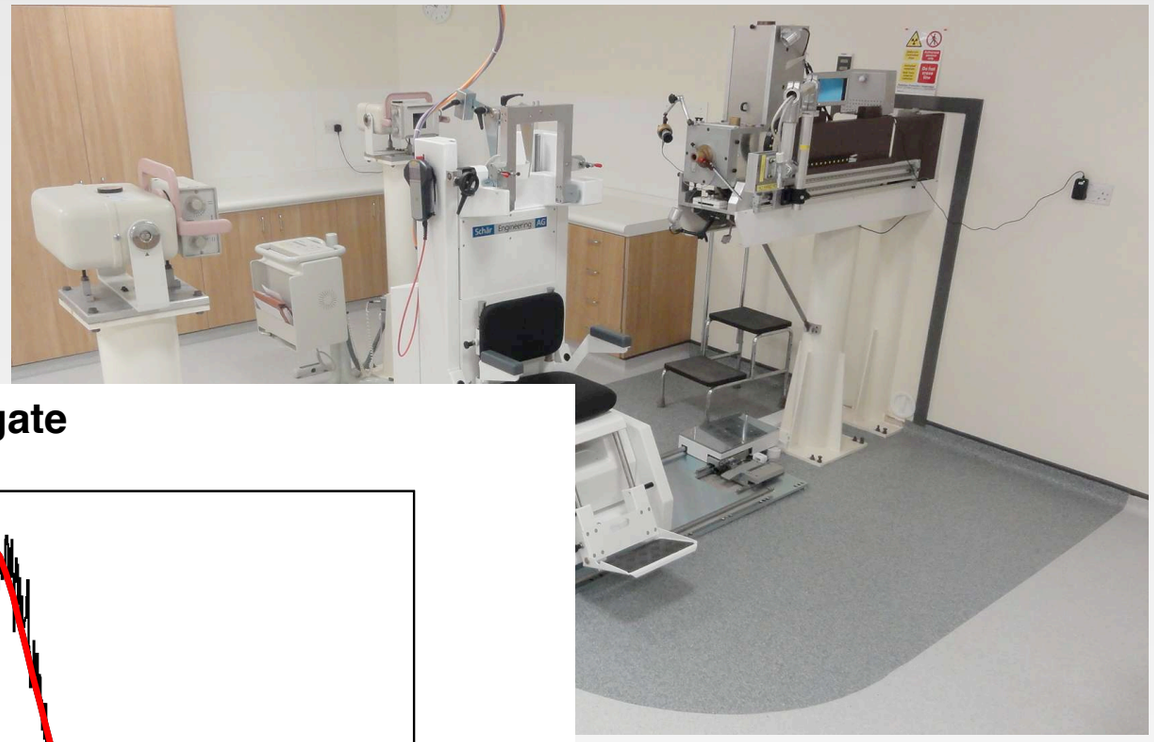
Series of test at Clatterbridge PBT Centre

QA for PBT: R&D based on SuperNEMO optical module

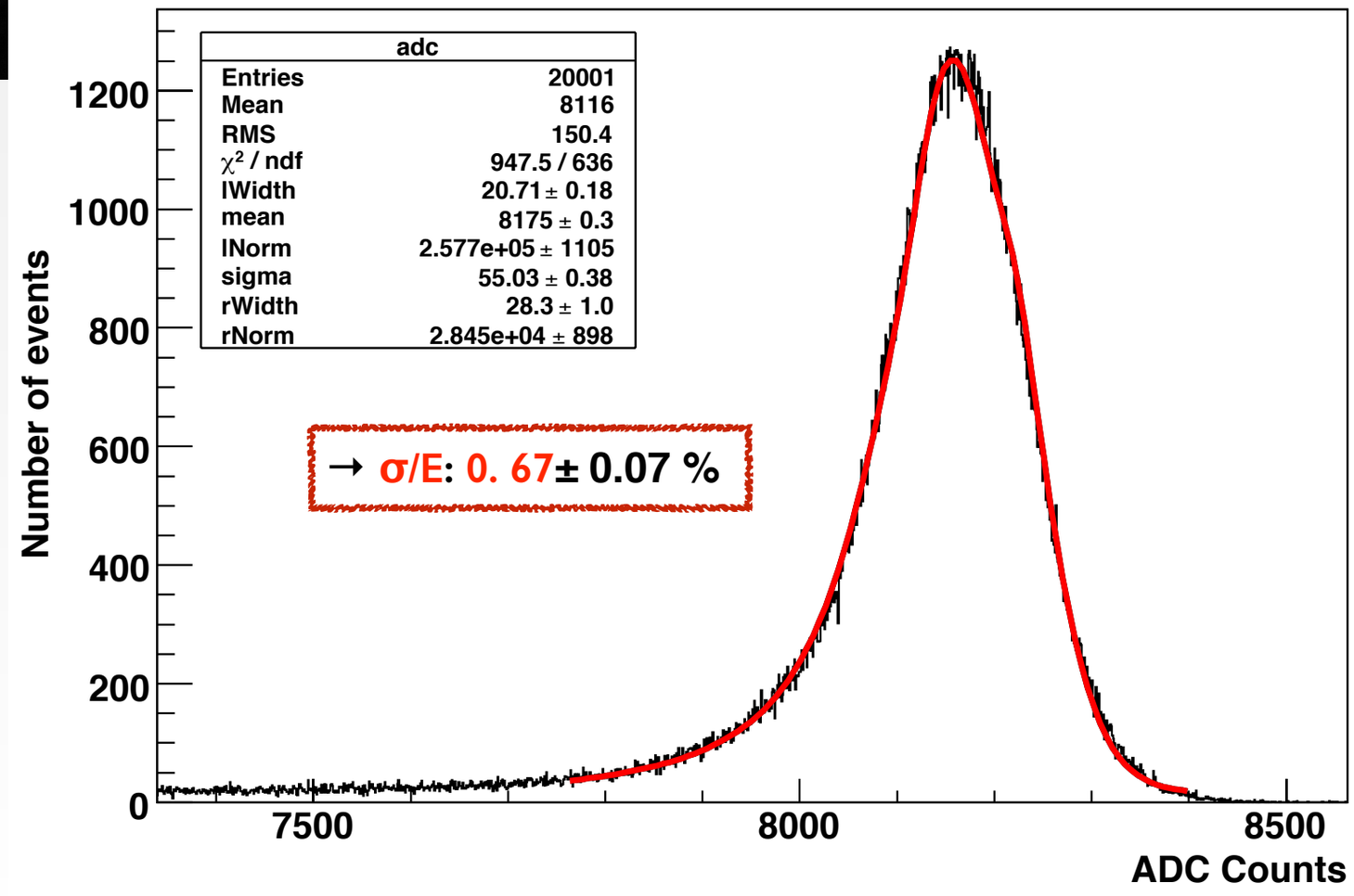


Measure energy —> range

Series of test at Clatterbridge PBT Centre



ADC Distribution: 800V, 2 mm collimator, 100ns gate

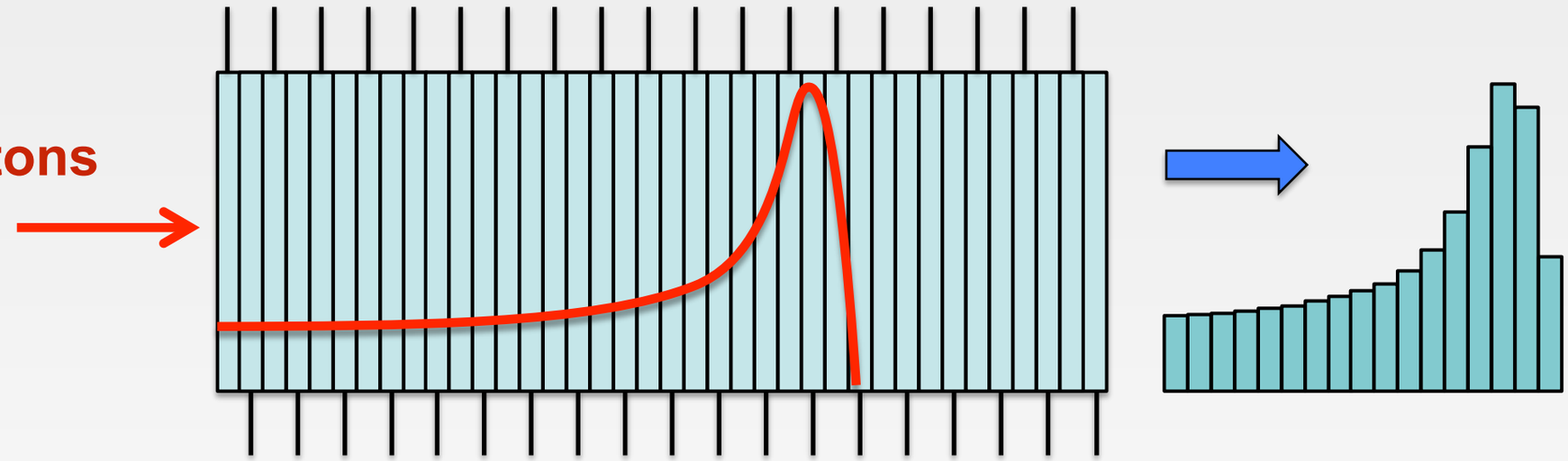


Target < 1% resolution reached at ~200 kHz rates!

QA for PBT: Current and Future

Two key **challenges** remain:

- Maintain < 1% resolution performance at **clinical rates** (10^9-10^{10} protons/sec)
- Direct **range verification**

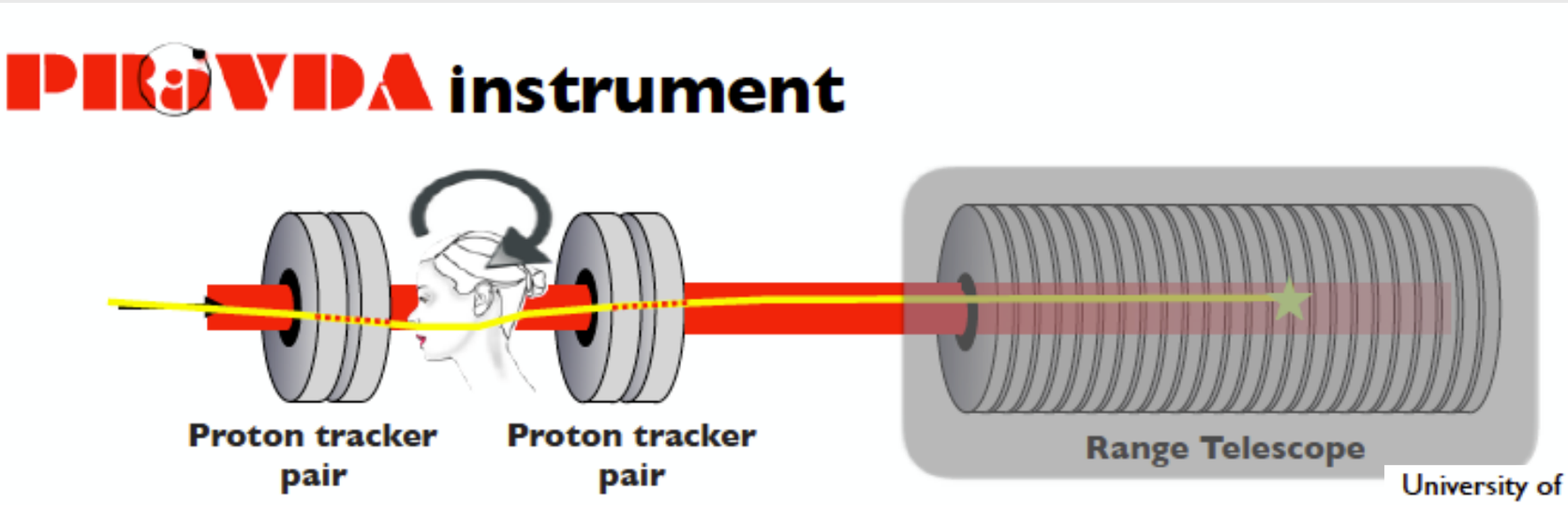


- Segmented Calorimeter — "**Range** Telescope"
- **Integrate** signals from many protons, up to **10^{10} protons/sec**
- Direct **range** measurement — plastic scintillator is "**water equivalent**"
- **Industrial partnerships** — NUVIA (scintillator)
- Close collaboration with Hamamatsu on **photodetectors**

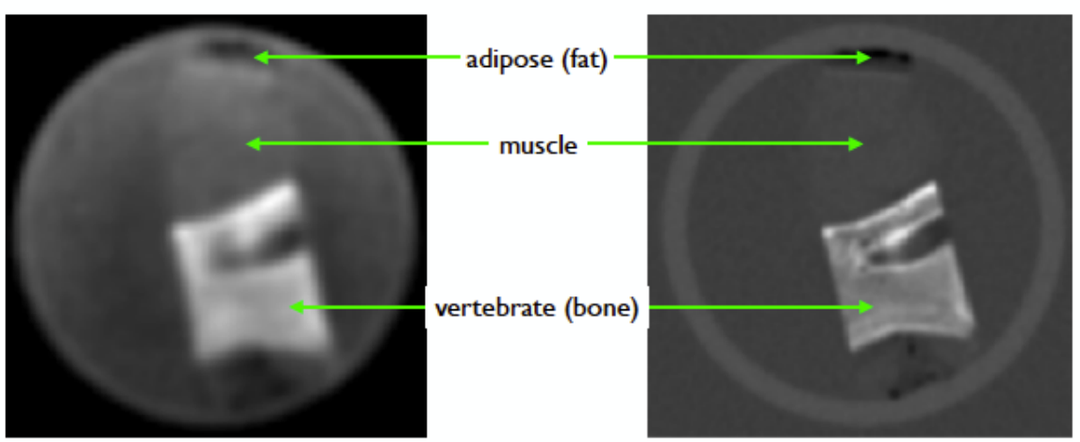
If successful, clear path to clinical trials and commercial prototypes

→ faster and cheaper

Proton Radiotherapy Verification and Dosimetry Applications



Discussions to replace Si range telescope with fast SuperNEMO-like scintillator calorimeter




Lamb chop in agar

University of Lincoln

University of Birmingham

University of Liverpool

University of Surrey

University of Warwick

Karolinska University Hospital, Sweden

University of Cape Town

University Hospital Birmingham NHS Foundation Trust

The Christie NHS Foundation Trust

University Hospital Coventry and Warwickshire NHS Trust

iThemba LABS, SA

ISDI

aSpect

Funded by wellcome trust

STFC Angle and other funding

- STFC Global Challenge
  - Initial R&D based on SuperNEMO Optical Module
- MiniIPS
  - Optimised module with <1% demonstrated at clinical facility
- IPS (current)
  - Segmented calorimeter to address clinical rates and direct range verification
- Other
  - EU Optimisation of Medical Accelerators (OMA)
    - UCL studentship to work on QA etc
  - STFC Network+ in Advanced Radiotherapy
    - Fast treatment plan verification

Concluding Remarks

- **Significant** progress over **short** period of time (~2 years)
- Energy resolution **< 1%** required for proton QA **reached** with compact , cheap system
- Modest STFC funding produced significant **impact**
  - Made possible due to **previous** serious **investment** in R&D, e.g. on SuperNEMO calorimeter
- Significant **interest** from **PBT** centres **worldwide** (UK, Europe, USA)
- **Short-term** plans (1-2 yr, partially funded)
  - Achieve <1% for single block with **1-10MHz imaging** rates ⇒ proton-CT
  - Direct **water equivalent** proton **range** with segmented calorimeter at **clinical rates**, up to 10^{10} p/sec
- **Longer-term** plans (not funded)
  - **Clinical** trials of QA device and path to commercialisation
  - **Integrating** UCL proton calorimeter with PRAvDA Si trackers — **pCT**, fast treatment plan verification

BACKUP

Plastic scintillator — “water equivalent” standard

Proton Beam Energy, MeV	Mean stopping distance, SCINT (mm)	Mean stopping distance, WATER (mm)	σ stopping distance, SCINT (mm)	σ stopping distance, WATER (mm)
60	30.21	30.54	0.33	0.33
200	255.4	257.1	2.48	2.44
300	505.9	509.9	4.64	4.78