Prompt gamma-ray imaging for particle beam therapy using nuclear emulsion

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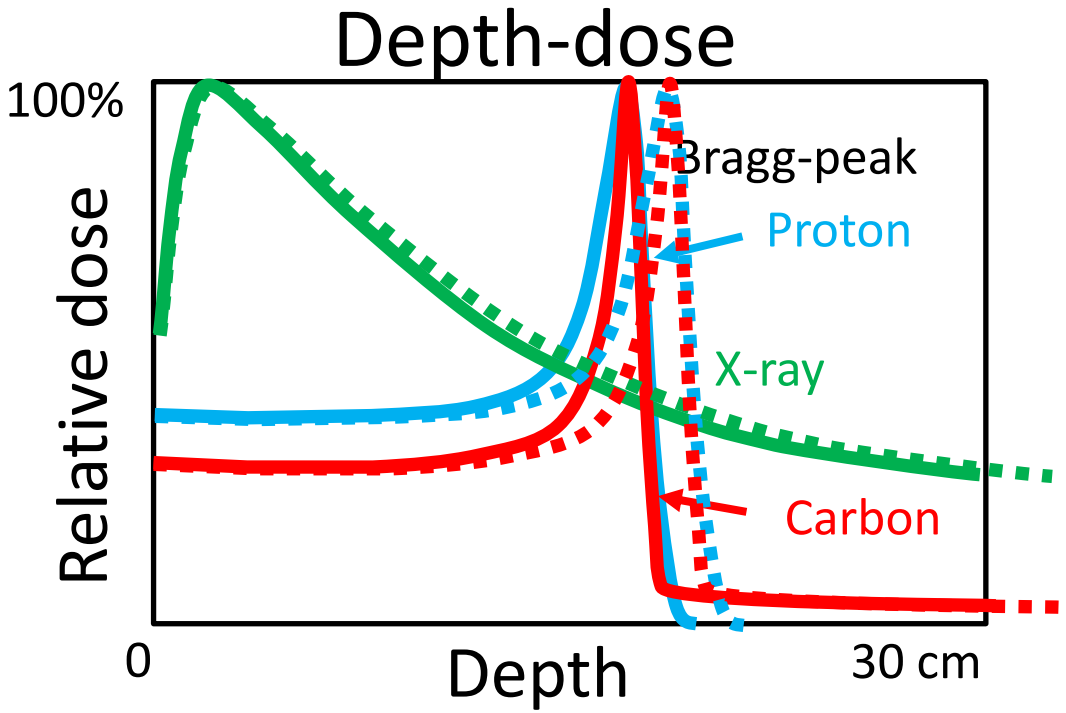
Nagoya Proton Therapy Center

Particle therapy



Particle therapy is much more sensitive to the range uncertainty !

In Japan

00 patients/year
radiotherapy

Proton	13	21000	Pediatric
Carbon	5	15000	Bone and soft tissue

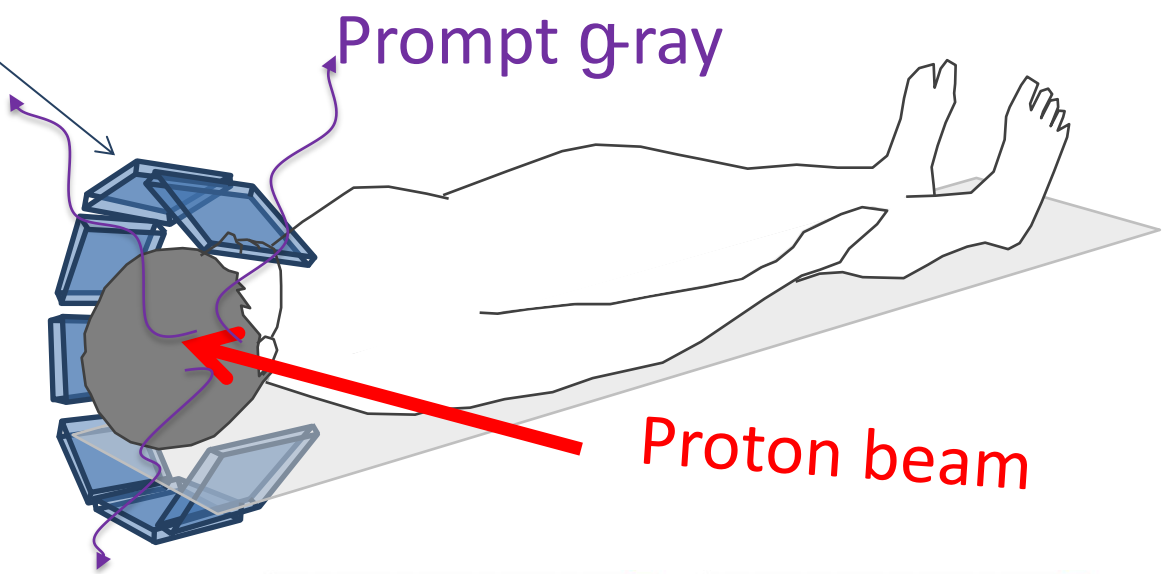
In the world proton 60, carbon 10

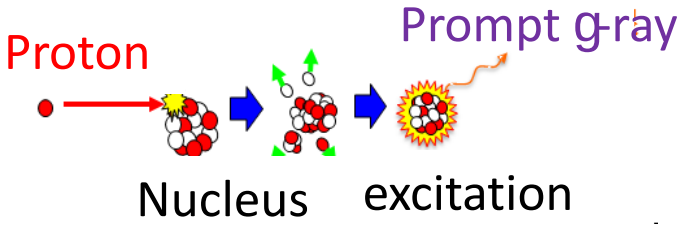
Range uncertainty

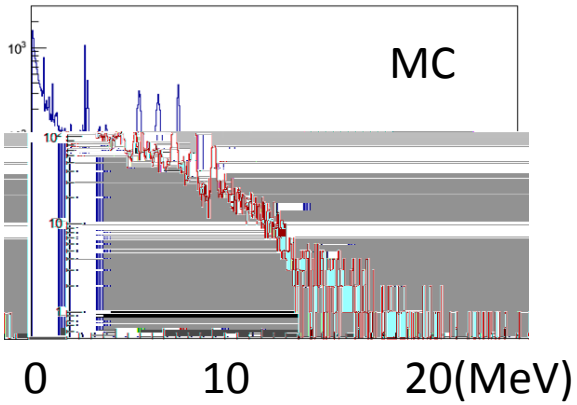
- Calculation
  - CT-value to material conv. ~3%
- Machine
  - Beam energy ~1 mm
- Patient setup
- Internal motion
  - respiration
  - Anatomical change

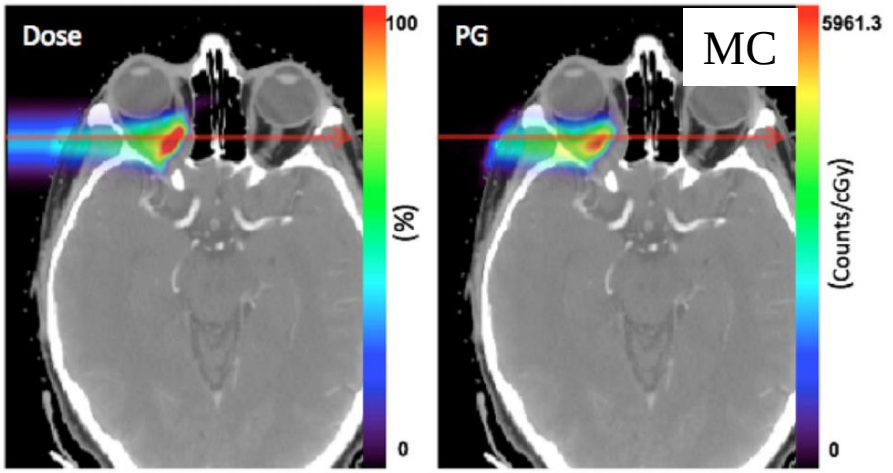
Prompt gamma-ray imaging - principle

Gamma camera SPECT(single photon emission computed tomography)



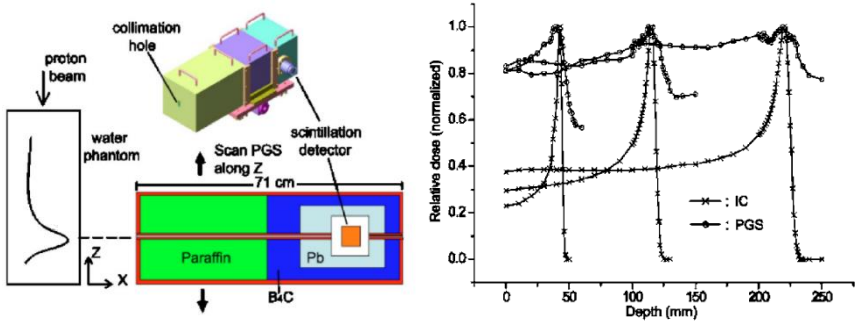




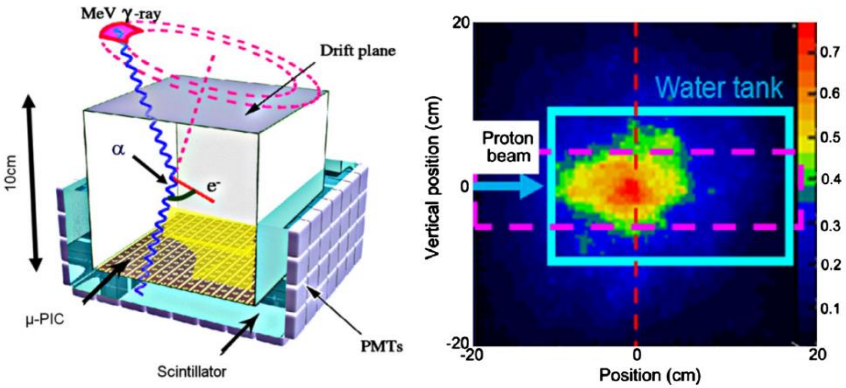


Moteabbed Phys. Med. Biol. 56 1063 (2011)

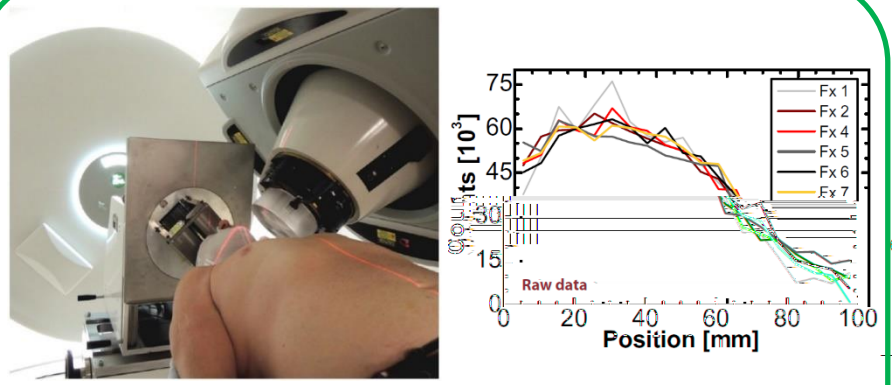
Prompt gamma-ray imaging – experimental history



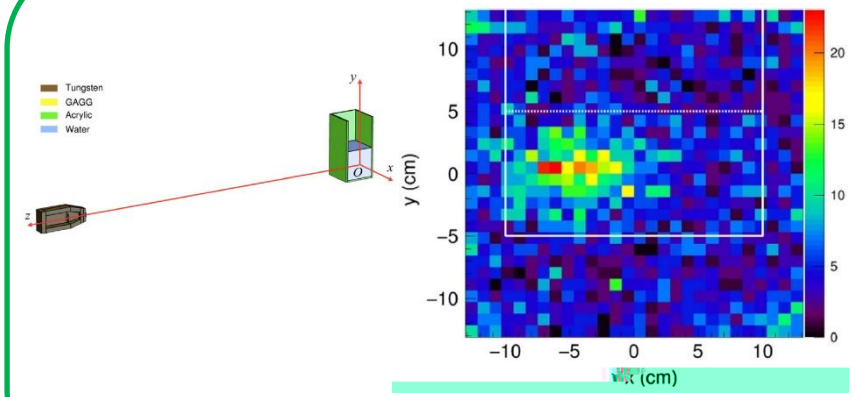
Min Appl Phys Lett 89 183517 2006



Kurosawa Current Appl Phys 12 364 2012



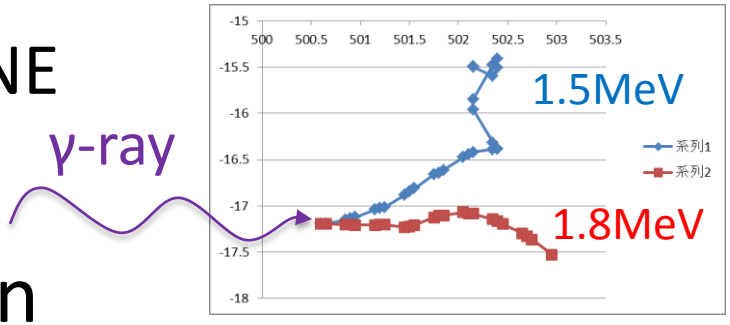
Richter Radio Oncol 118 232 2016



Yamaguchi NIM A 833 199 2016

Prompt gamma-ray imaging using nuclear emulsion

- Detect $\gamma \rightarrow e^+e^-$ conversion below 10 MeV
  - Low energy extension of GRAINE



MC in stack of 10 OPERA-films

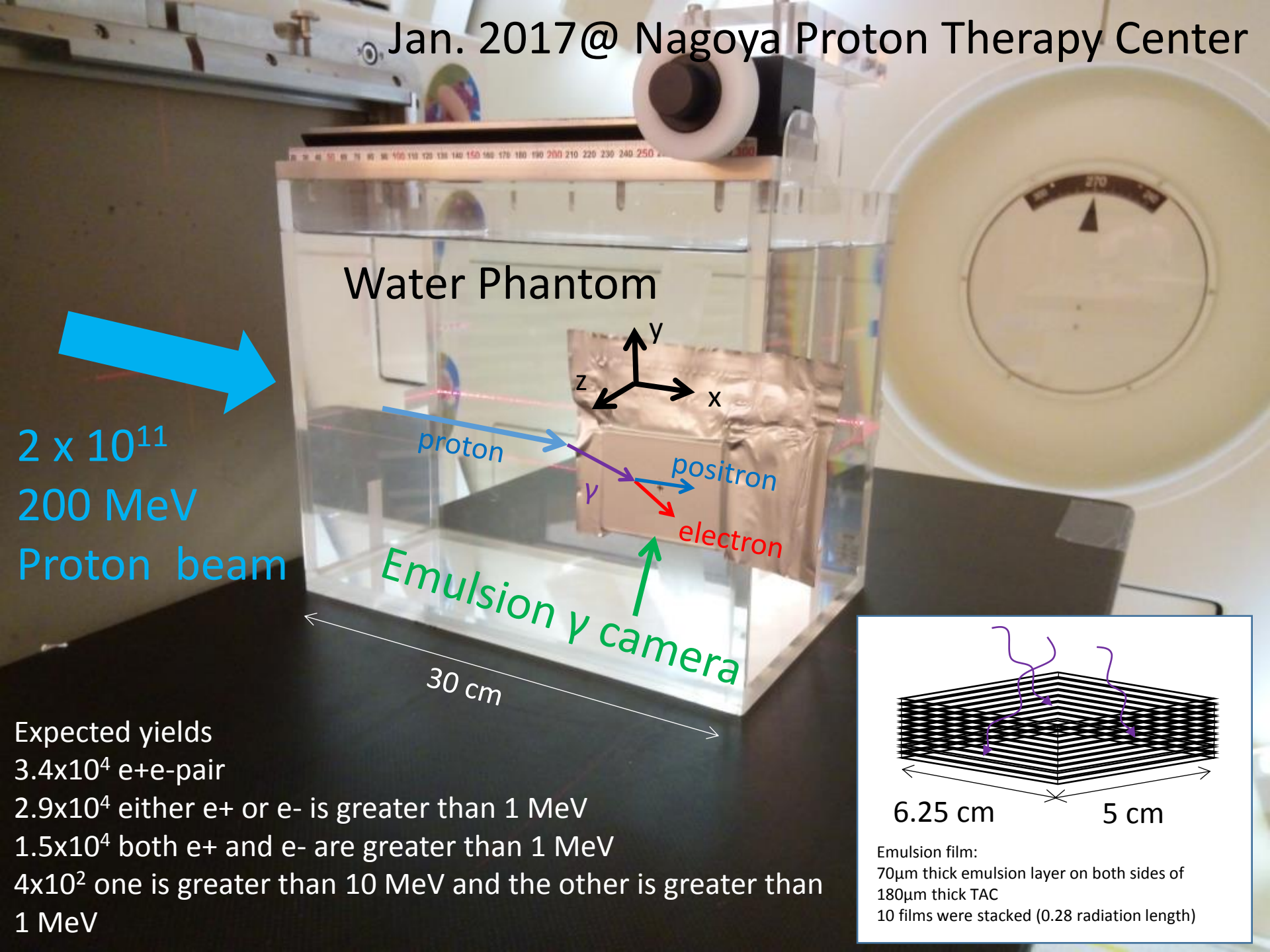
- Superior background rejection
- No pile-up, No dead-time
  - All events can be recorded

- Limited angular resolution

Experiments for proof-of-principle

- Dec. 2016, Jan. 2017 6.25 cm x 5 cm x 10 films
- Aug. 2017 12.5 cm x 10 cm x 10 films

Jan. 2017@ Nagoya Proton Therapy Center



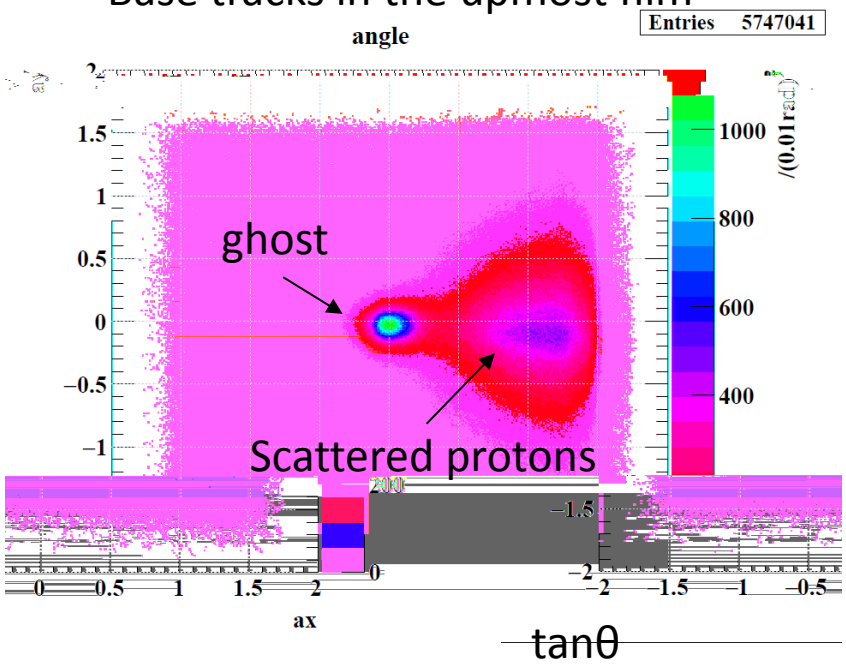
Expected yields
3.4×10^4 e+e-pair
2.9×10^4 either e+ or e- is greater than 1 MeV
1.5×10^4 both e+ and e- are greater than 1 MeV
4×10^2 one is greater than 10 MeV and the other is greater than 1 MeV

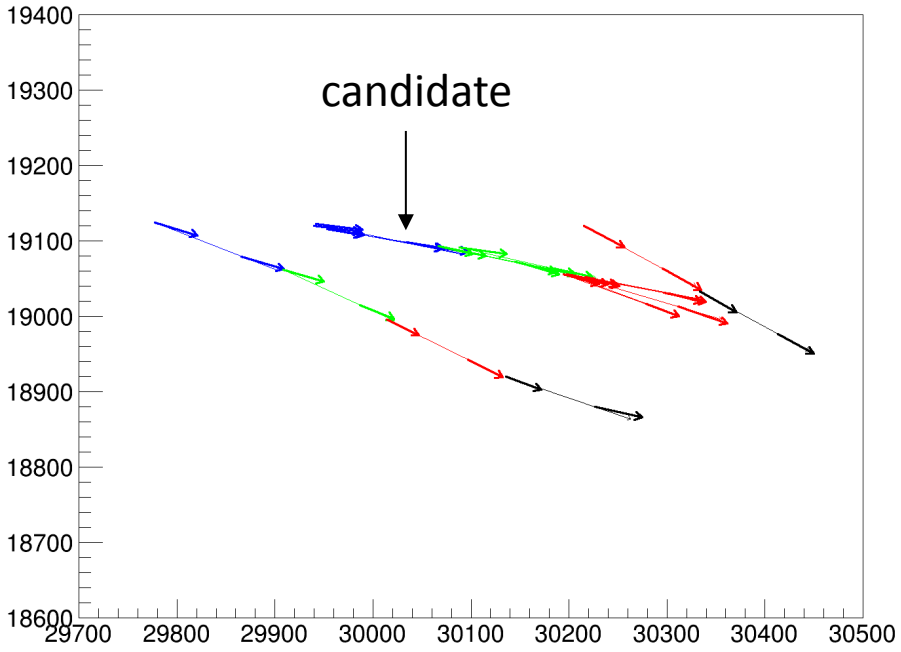
Emulsion film:
70μm thick emulsion layer on both sides of 180μm thick TAC
10 films were stacked (0.28 radiation length)

Pilot analysis

4 cm x 4 cm in both sides of all emulsion films were scanned by using HTS.
7 x 10^7 tracks / film were detected as micro tracks.
5 x 10^6 tracks / film were reconstructed as base tracks.

Base tracks in the upmost film





Summary

- Prompt gamma-ray imaging is expected to be useful to visualize dose in the patient.
- Challenging is tracking of low energy electrons/positrons.
- We are testing prototype nuclear emulsion gamma-ray camera systems for proof-of-principle.