HARPO: Measurement of polarised gamma rays (1.7 to 74MeV) with the HARPO TPC

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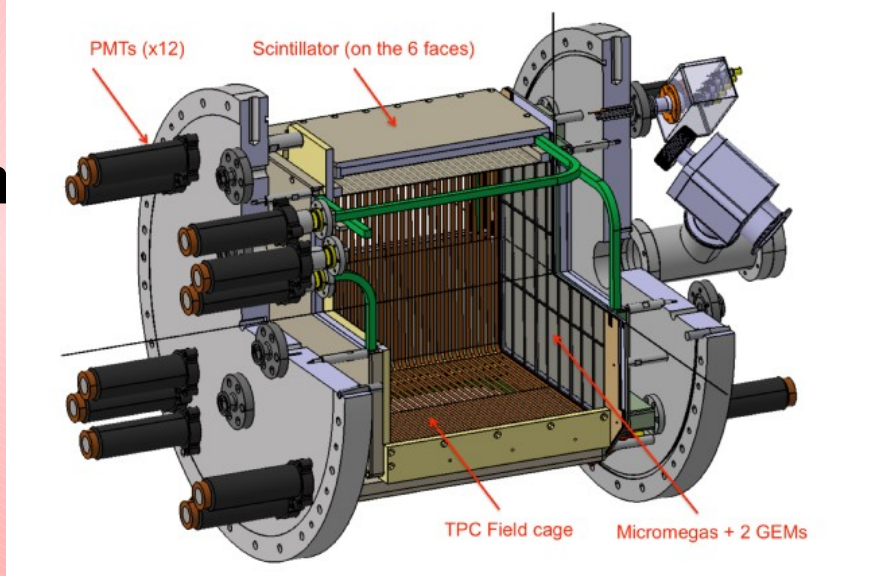
for the HARPO collaboration

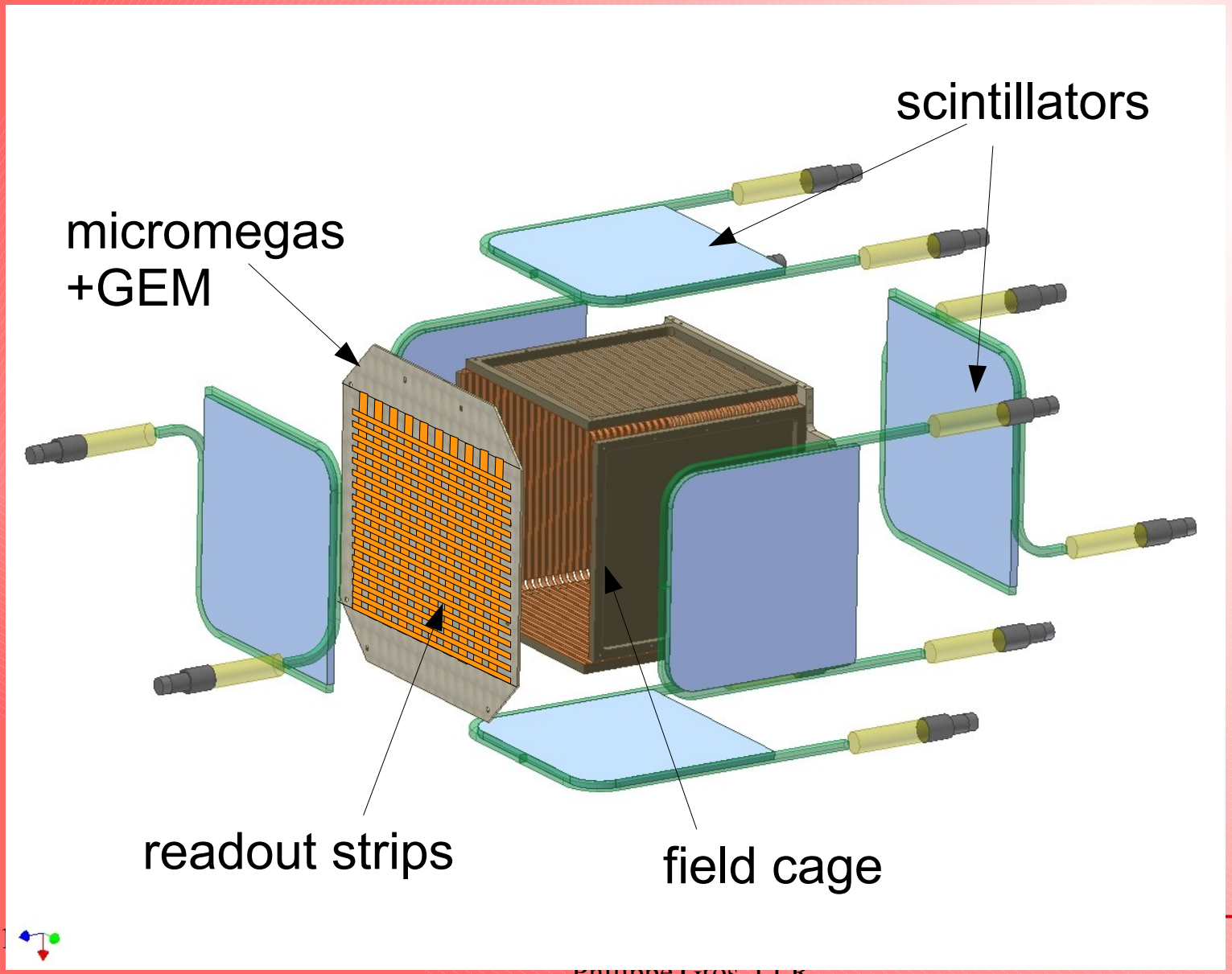
- The HARPO project
- Setup at the NewSUBARU photon beam
- Trigger design and efficiency
- Challenges for a balloon/space mission
- Conclusion and perspectives

HARPO Demonstrator

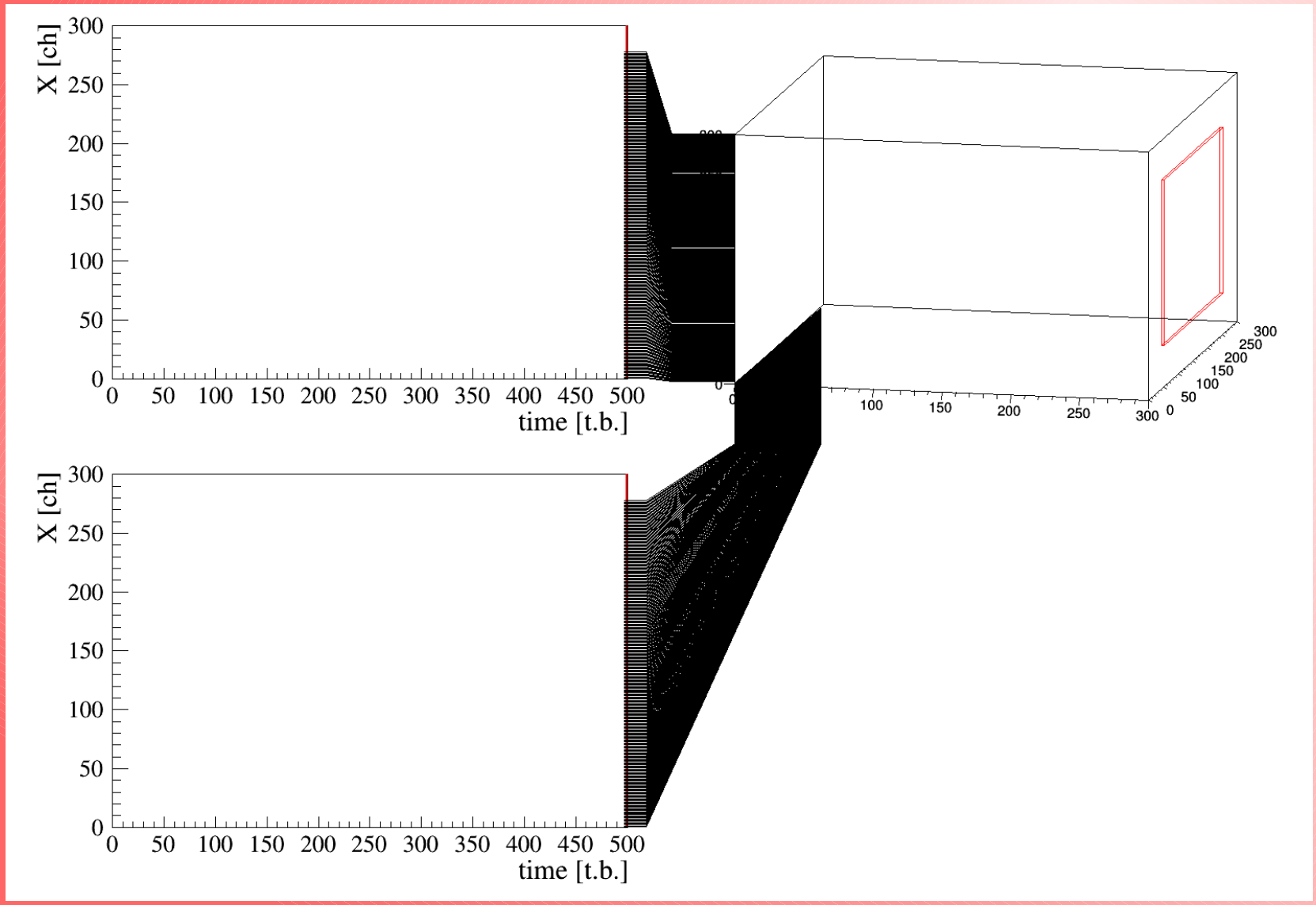
- Purpose
  - Assess challenges
  - Demonstrate performance in beam
- Realisation
  - 30cm cubic TPC
  - Ar/iC_4H_{10} 95/5 up to 5bar
  - micromegas+2GEM amplification
  - 2x288 strips readout (x&y), 1mm pitch
  - AFTER readout electronics, 511 time bins, up to 100MHz (33 used)



HARPO Demonstrator



Event Geometry

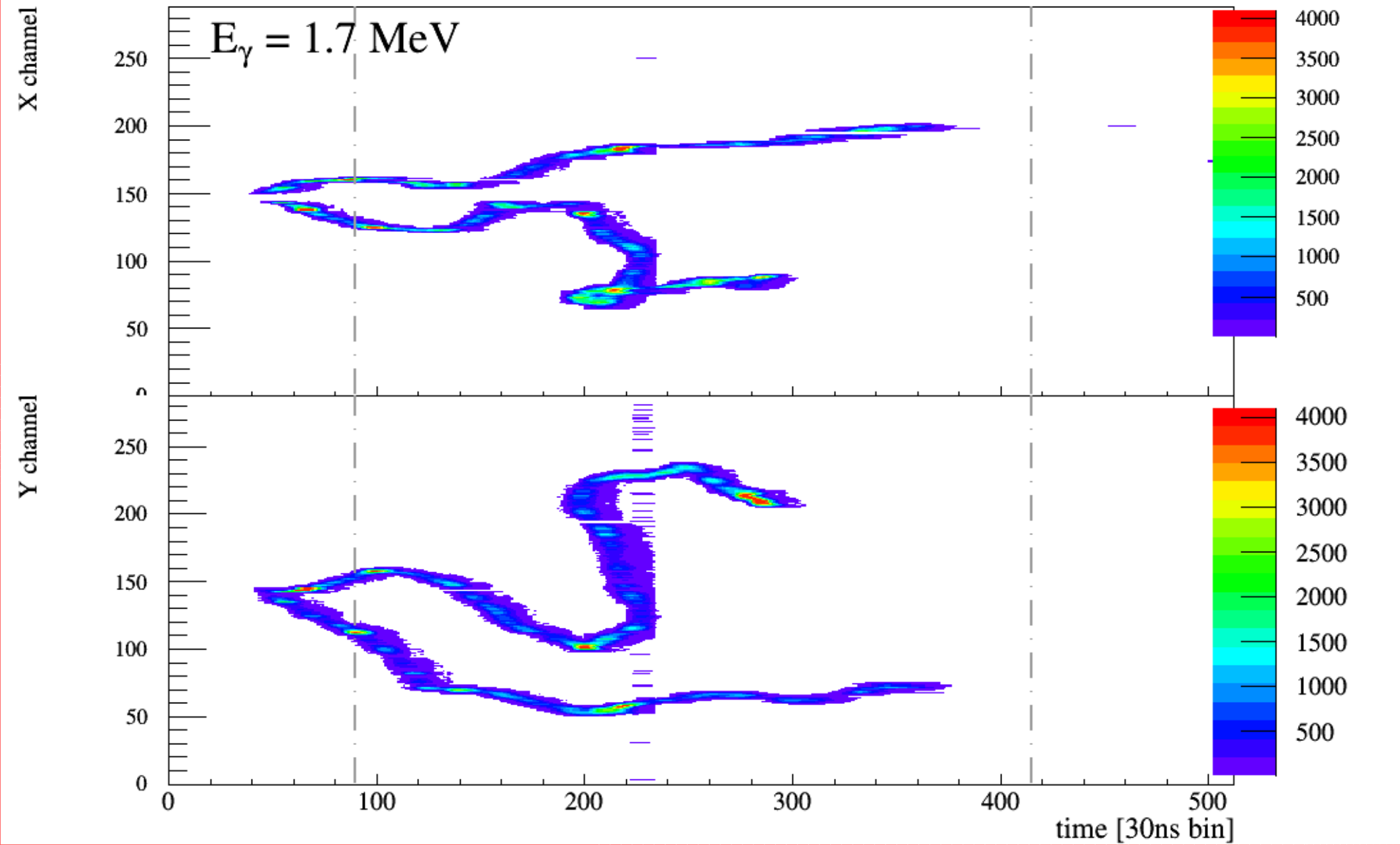


NewSUBARU photon beam

- Polarised gamma ray beam
  - Inverse Compton Scattering
  - electron beam 0.6, 1., 1.2 or 1.5 GeV
  - laser Nd (1ω or 2ω), Er or CO_2

  => polarised photons 1.71 to 74MeV
- Pulsed mode
  - Nd: 20kHz, Er:200kHz, CO_2: continuous
- Operated by LASTI, U. of Hyôgô, Japan

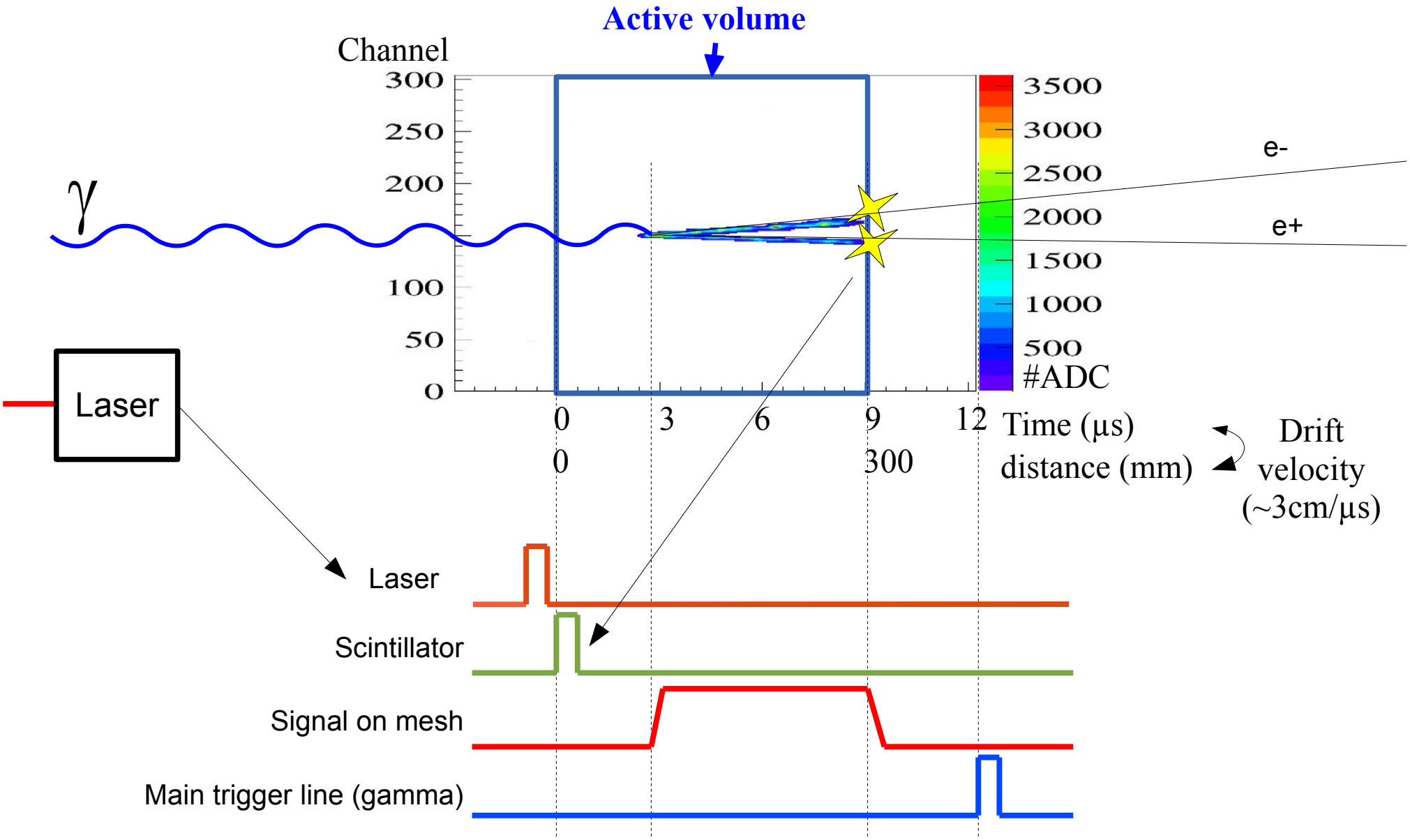
Conversion events



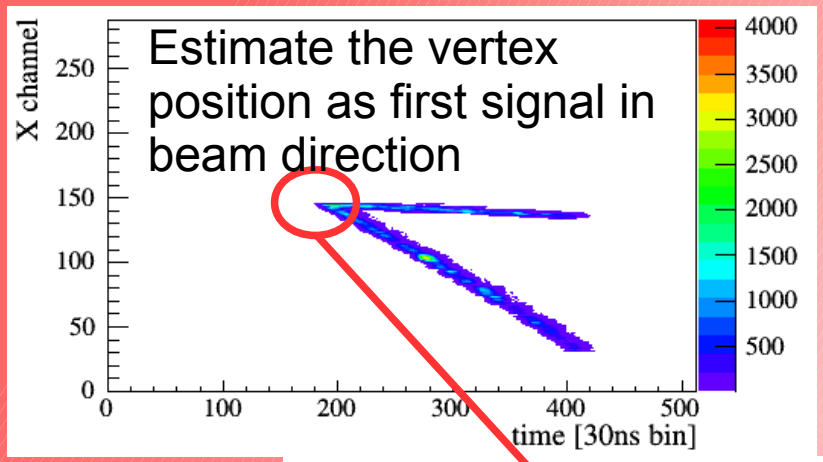
Trigger in beam

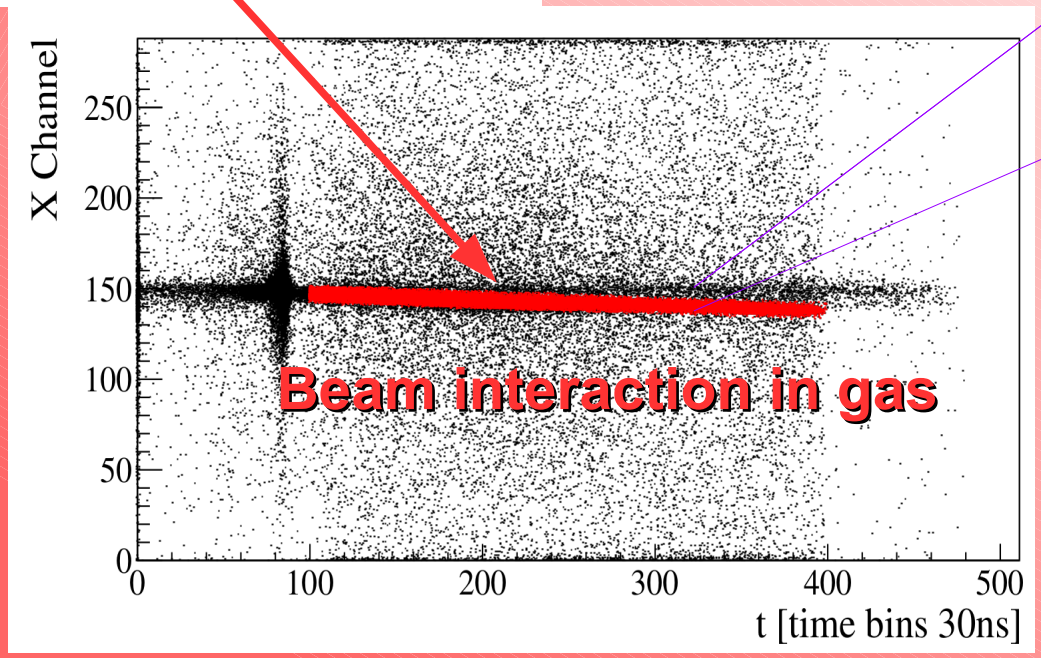
- Several kHz events in TPC
- DAQ max acquisition rate <600Hz
- Dominated by background
  - beam interaction in upstream material
  - >20x larger than signal
- Efficient BG suppression needed
- Signal rate important, not efficiency

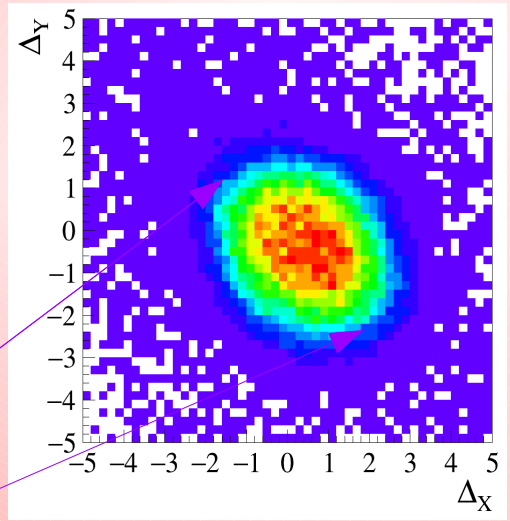
Trigger building



Preliminary event selection

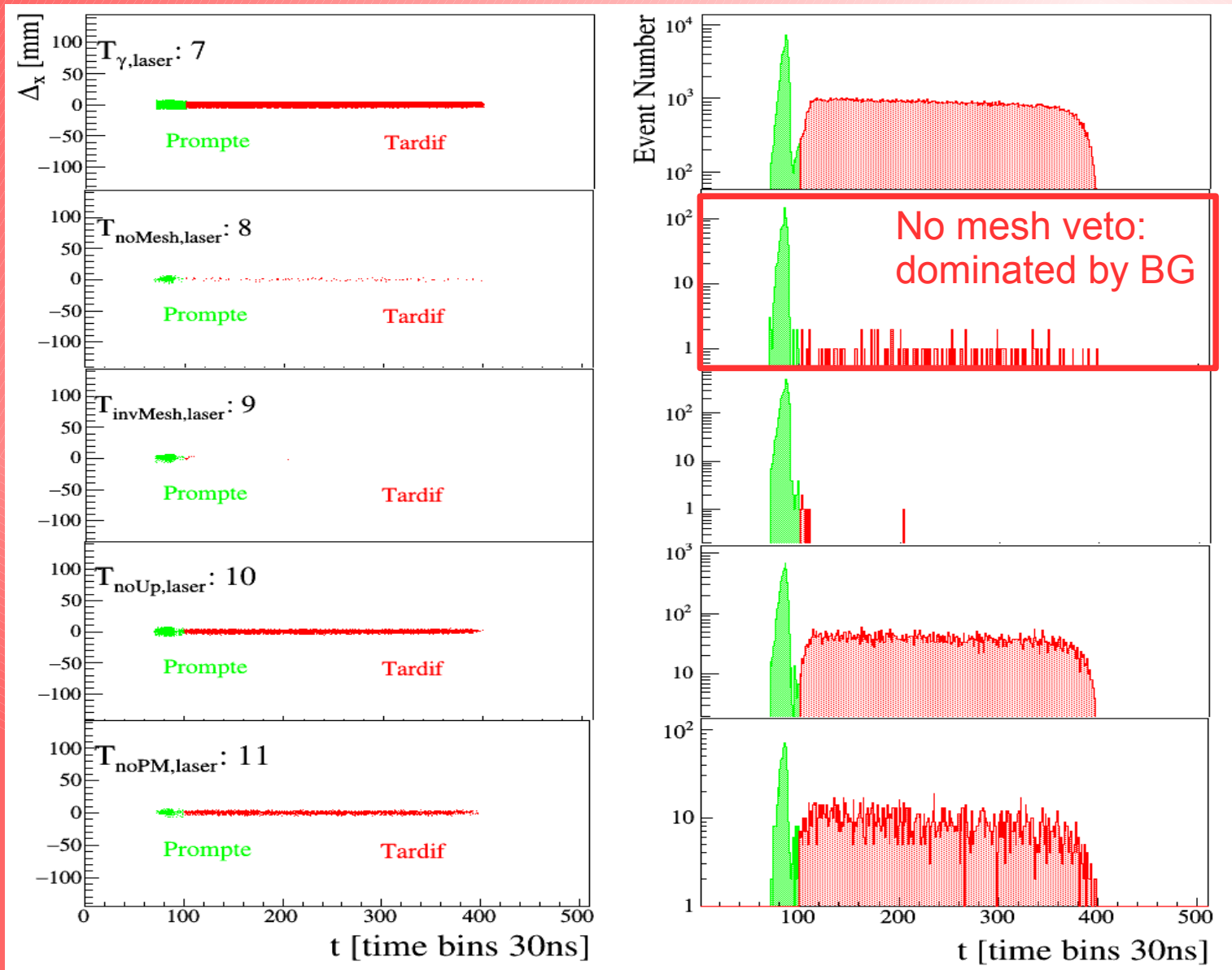






The vertexes are located on a region corresponding to the 4mm circular beam collimator

Signal/BG selection different trigger lines



Event rates

- 5 trigger lines for efficiency studies
- Rates for **signal** and **BG**
  - from vertex position selection

7	$T_{\gamma,laser}$	$N_{\overline{S}_{up}\cap O\cap M_{slow}\cap L,p}$	197 822	$\tau_{\overline{S}_{up}\cap O\cap M_{slow}\cap L,p}$	13 (1 ± 0.002) Hz
Main trigger		$N_{\overline{S}_{up}\cap O\cap M_{slow}\cap L,t}$	785 837	$\tau_{\overline{S}_{up}\cap O\cap M_{slow}\cap L,t}$	52 (1 ± 0.001) Hz
8	$T_{noMesh,laser}$	$N_{\overline{S}_{up}\cap O\cap L,p}$	2 698	$\tau_{\overline{S}_{up}\cap O\cap L,p}$	589 (1 ± 0.019) Hz
		$N_{\overline{S}_{up}\cap O\cap L,t}$	321	$\tau_{\overline{S}_{up}\cap O\cap L,t}$	70 (1 ± 0.056) Hz
9	$T_{invMesh,laser}$	$N_{\overline{S}_{up}\cap O\cap M_{quick}\cap L,p}$	9 958	$\tau_{\overline{S}_{up}\cap O\cap M_{quick}\cap L,p}$	506 (1 ± 0.010) Hz
		$N_{\overline{S}_{up}\cap O\cap M_{quick}\cap L,t}$	25	$\tau_{\overline{S}_{up}\cap O\cap M_{quick}\cap L,t}$	1.3 (1 ± 0.020) Hz
10	$T_{noUp,laser}$	$N_{O\cap M_{slow}\cap L,p}$	18 427	$\tau_{O\cap M_{slow}\cap L,p}$	29 (1 ± 0.007) Hz
		$N_{O\cap M_{slow}\cap L,t}$	34 311	$\tau_{O\cap M_{slow}\cap L,t}$	54 (1 ± 0.005) Hz
11	$T_{noPM,laser}$	$N_{\overline{S}_{up}\cap M_{slow}\cap L,p}$	2 136	$\tau_{\overline{S}_{up}\cap M_{slow}\cap L,p}$	18 (1 ± 0.022) Hz
		$N_{\overline{S}_{up}\cap M_{slow}\cap L,t}$	8 862	$\tau_{\overline{S}_{up}\cap M_{slow}\cap L,t}$	73 (1 ± 0.011) Hz

Trigger efficiency

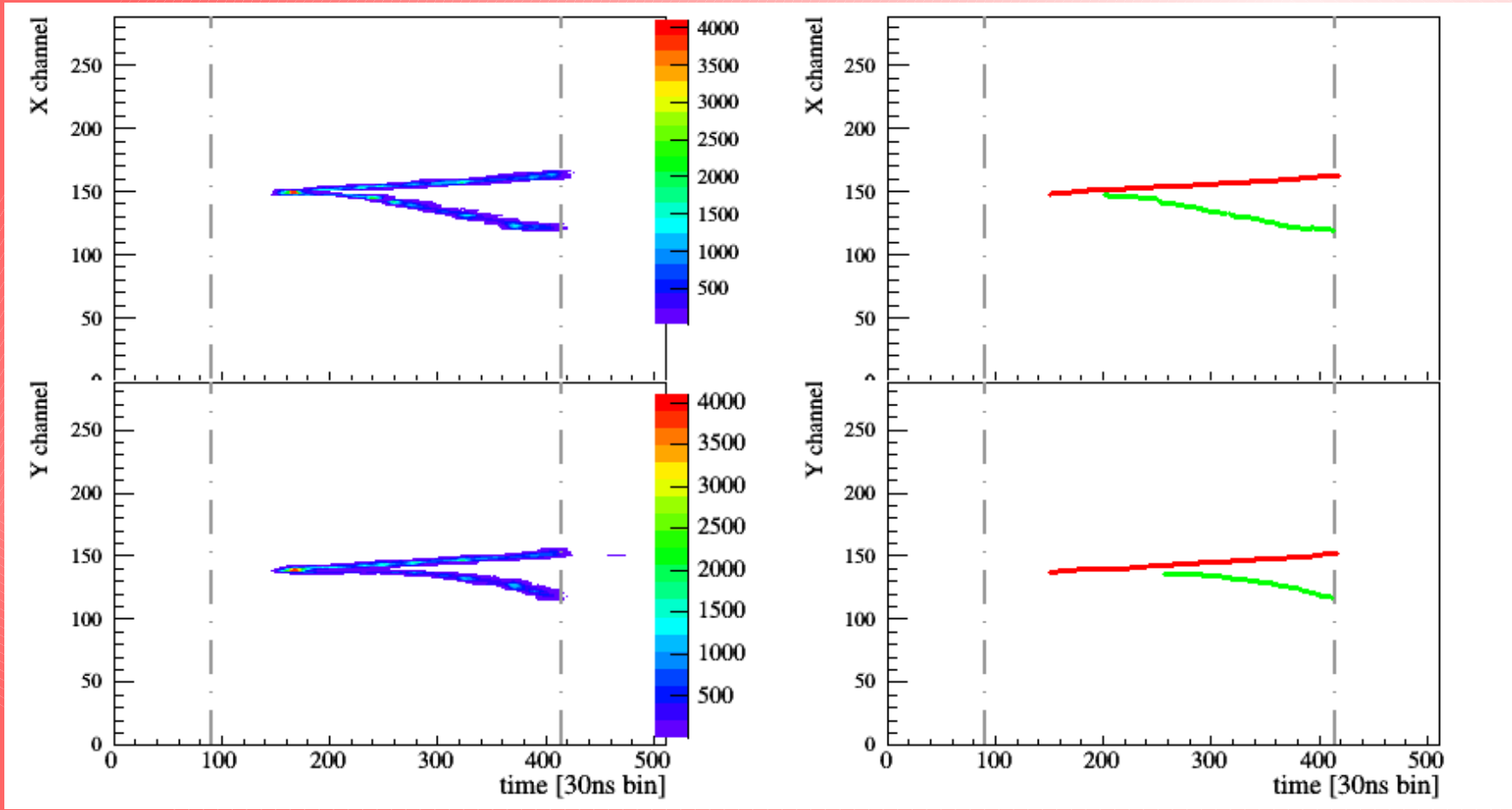
- We can estimate accurately the rate of events corresponding to
  - Signal: conversion on beam in the gas
  - Background: mostly conversion in upstream material
- This allows to measure the trigger efficiency:
  - **>99%** BG rejection
  - **>50%** Signal selection efficiency

Reconstruction efficiency not included

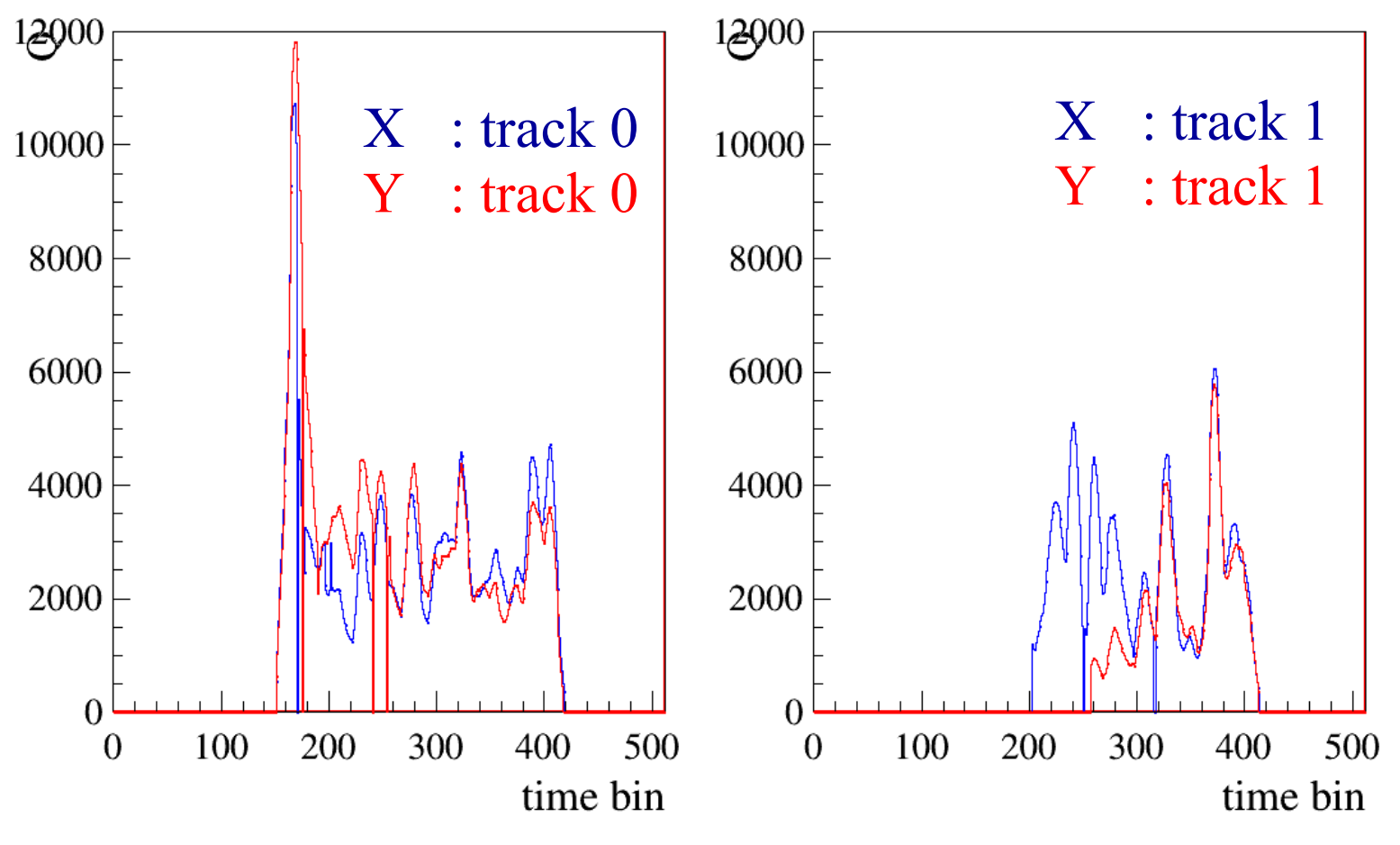
Reconstruction challenges

- Intrinsic challenges
  - matching X-Z and Y-Z tracks
  - multiple scattering
  - non directionality
  - delta electrons
- Extra challenges
  - electronics saturation
  - cross-talk

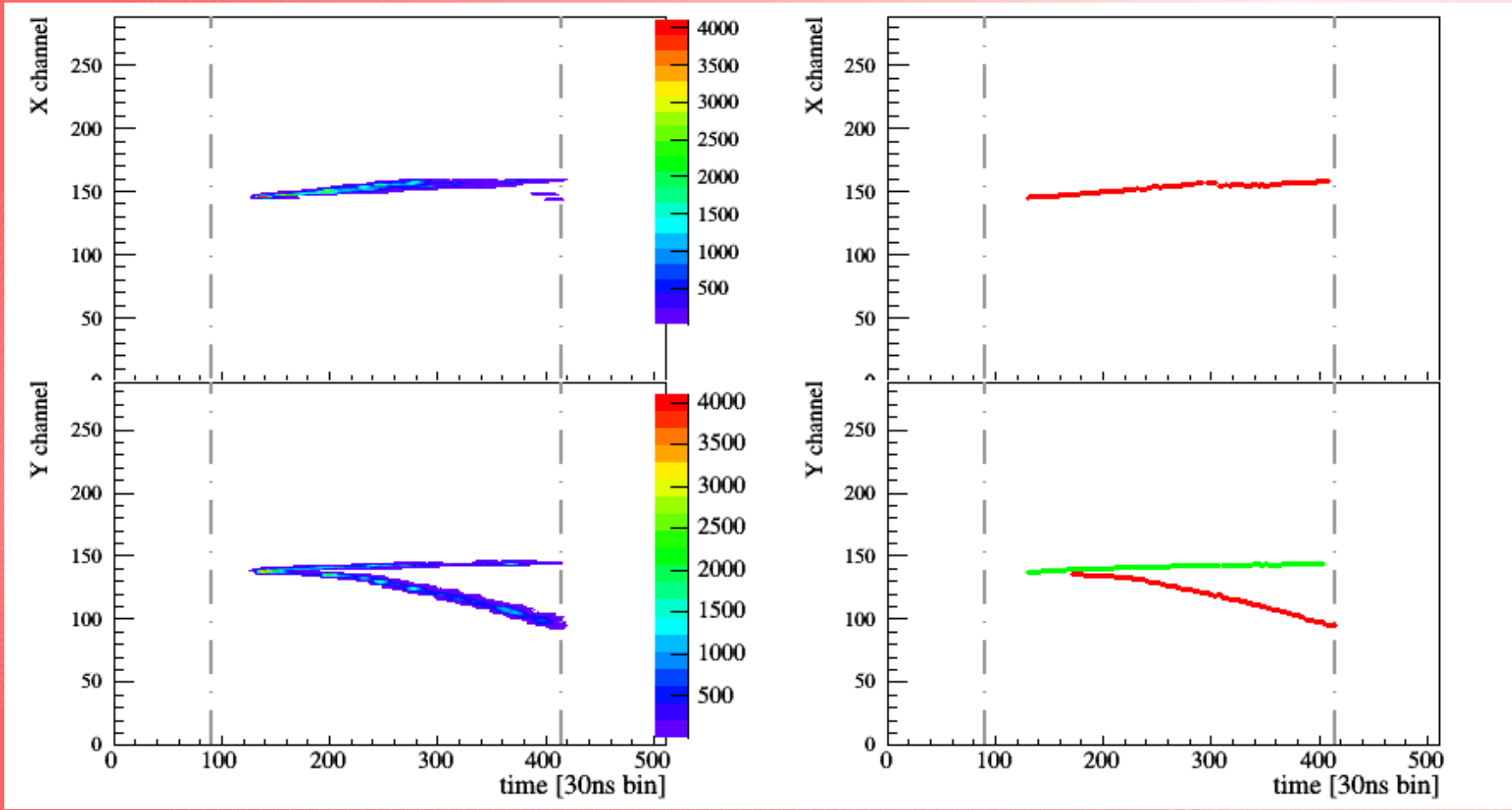
Sometimes it is easy



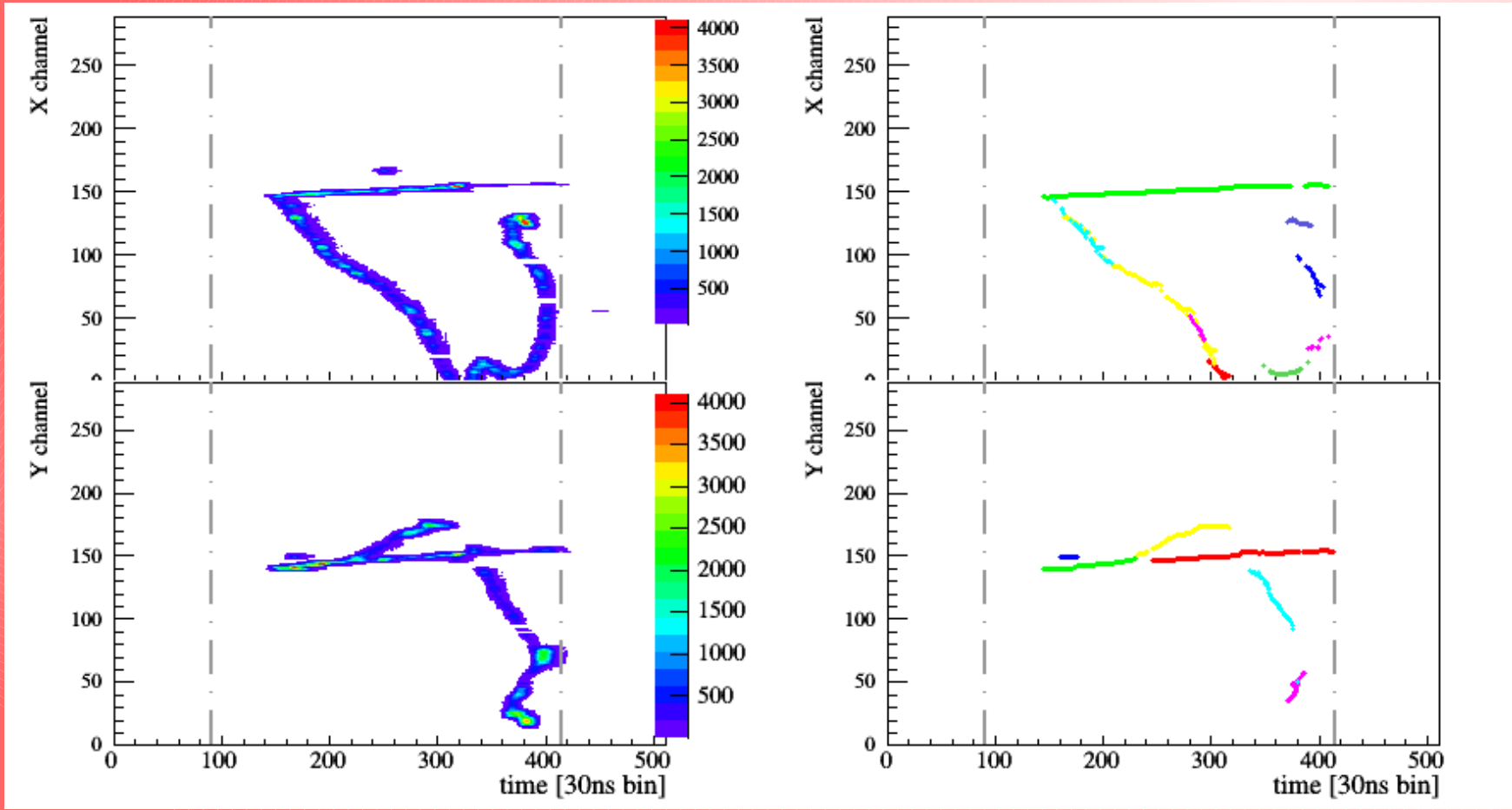
Matching X and Y charge profiles



More difficults



Or very tricky



Challenges in space

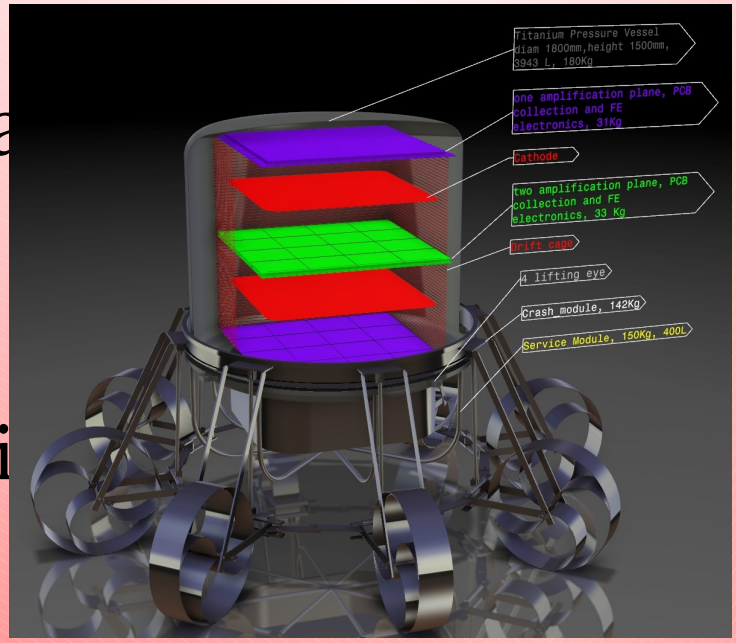
- Readout electronics
  - low power => strips instead of pads
  - radiation hardness
- Adapted trigger
  - standalone TPC (minimize extra material)
  - high selection efficiency
  - self-triggered electronics

Challenges in space

- Gas stability
  - minimise outgassing
  - purification
- High pressure
  - optimise pressure: sensitivity, scattering, mechanical & HV constraints
  - small gap micromegas?

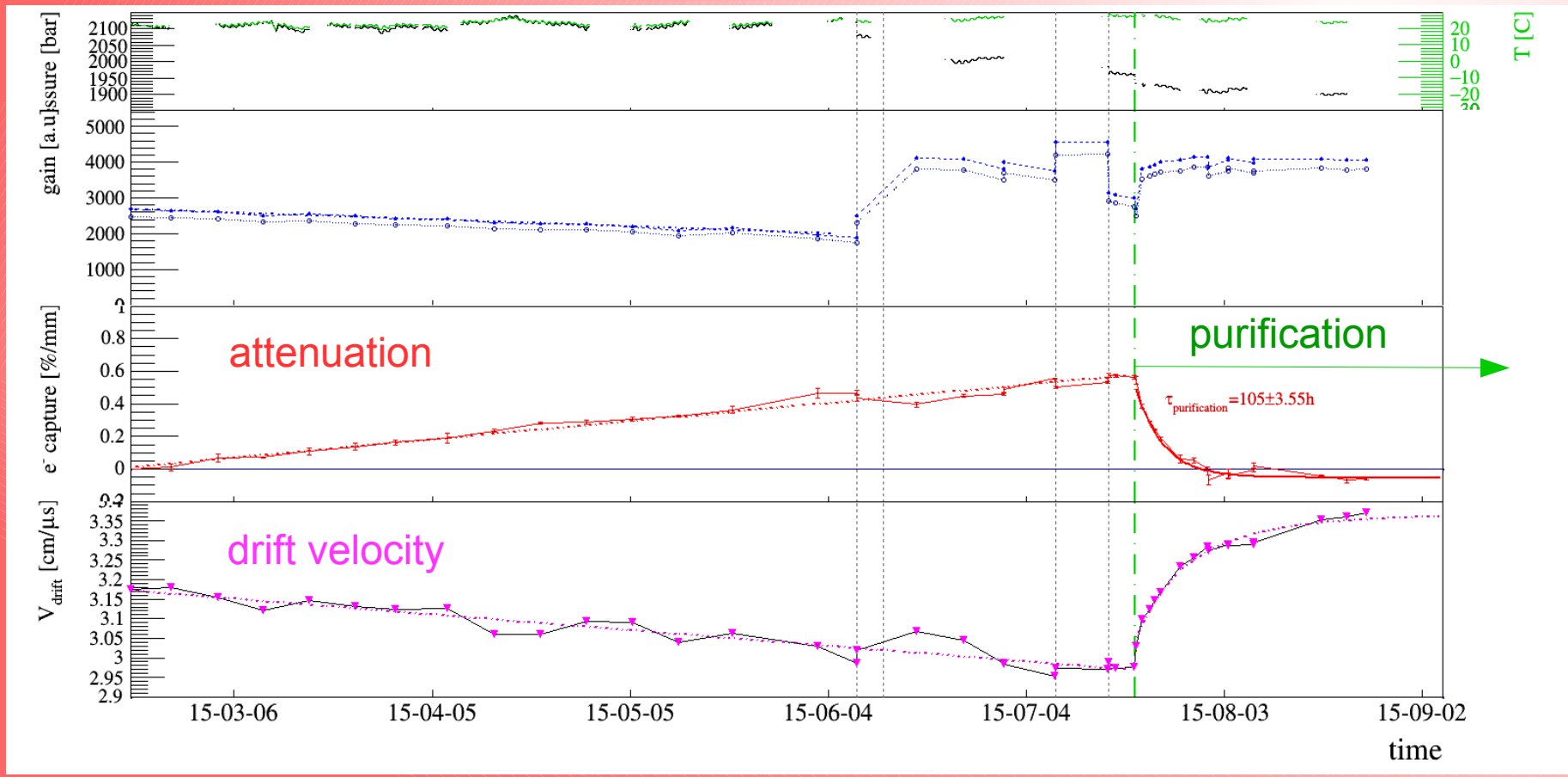
Conclusion and outlook

- Successful beam campaign with gamma rays
  - Good trigger performance
  - Challenging reconstruction
- Developments towards spatialisa
  - gas purification in sealed mode demonstrated
  - starting work on radiation hardeni of AGET
  - trigger development (simulation)
  - ~1m³ balloon module design (4x4x4xHARPO)



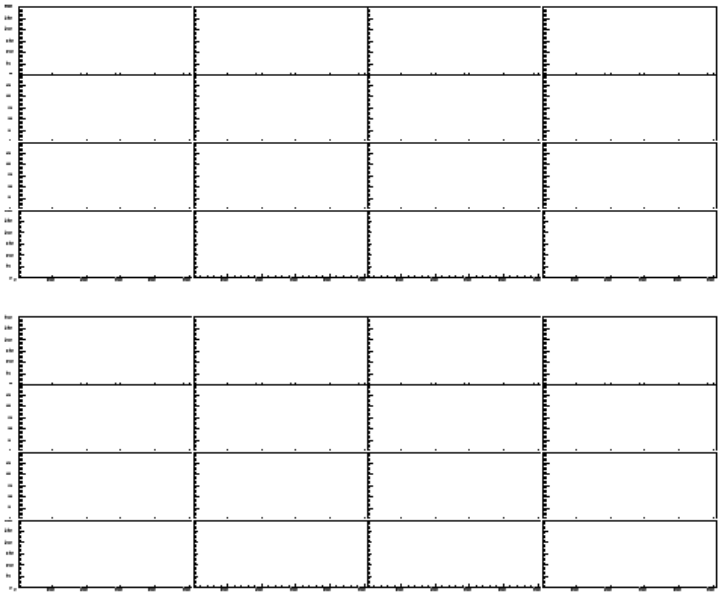
Advertisement

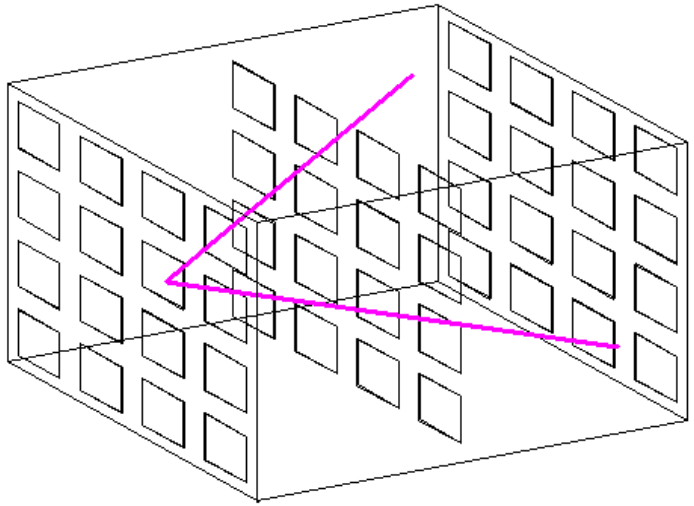
- Poster #2 on gas circulation and purification

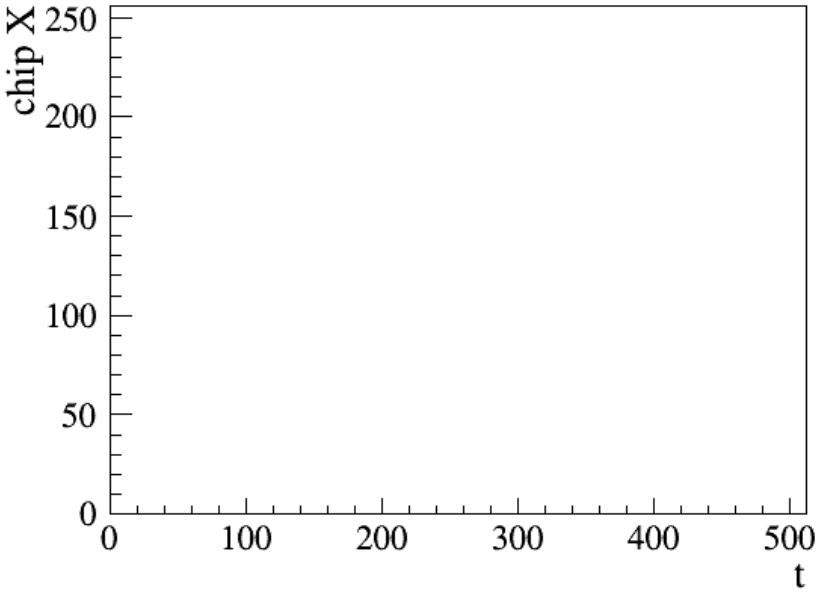


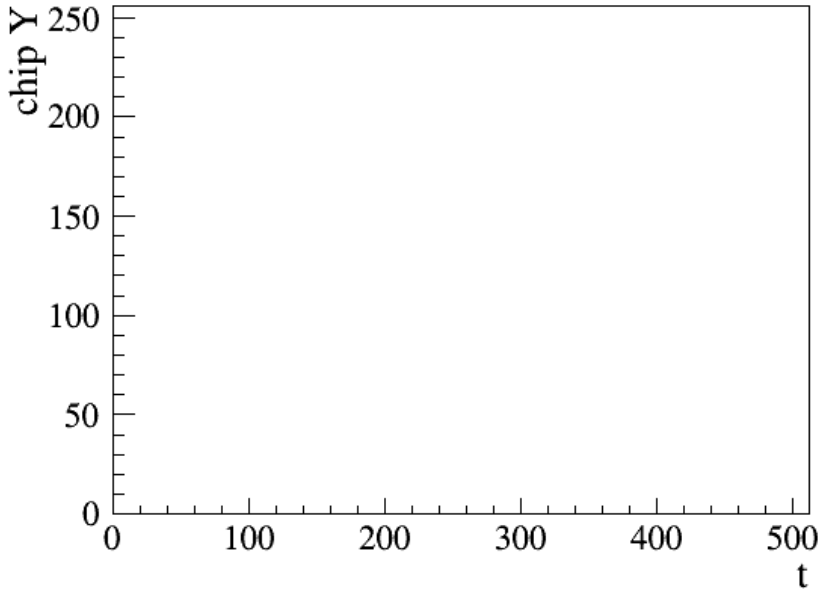
Backup

1 m3 module trigger







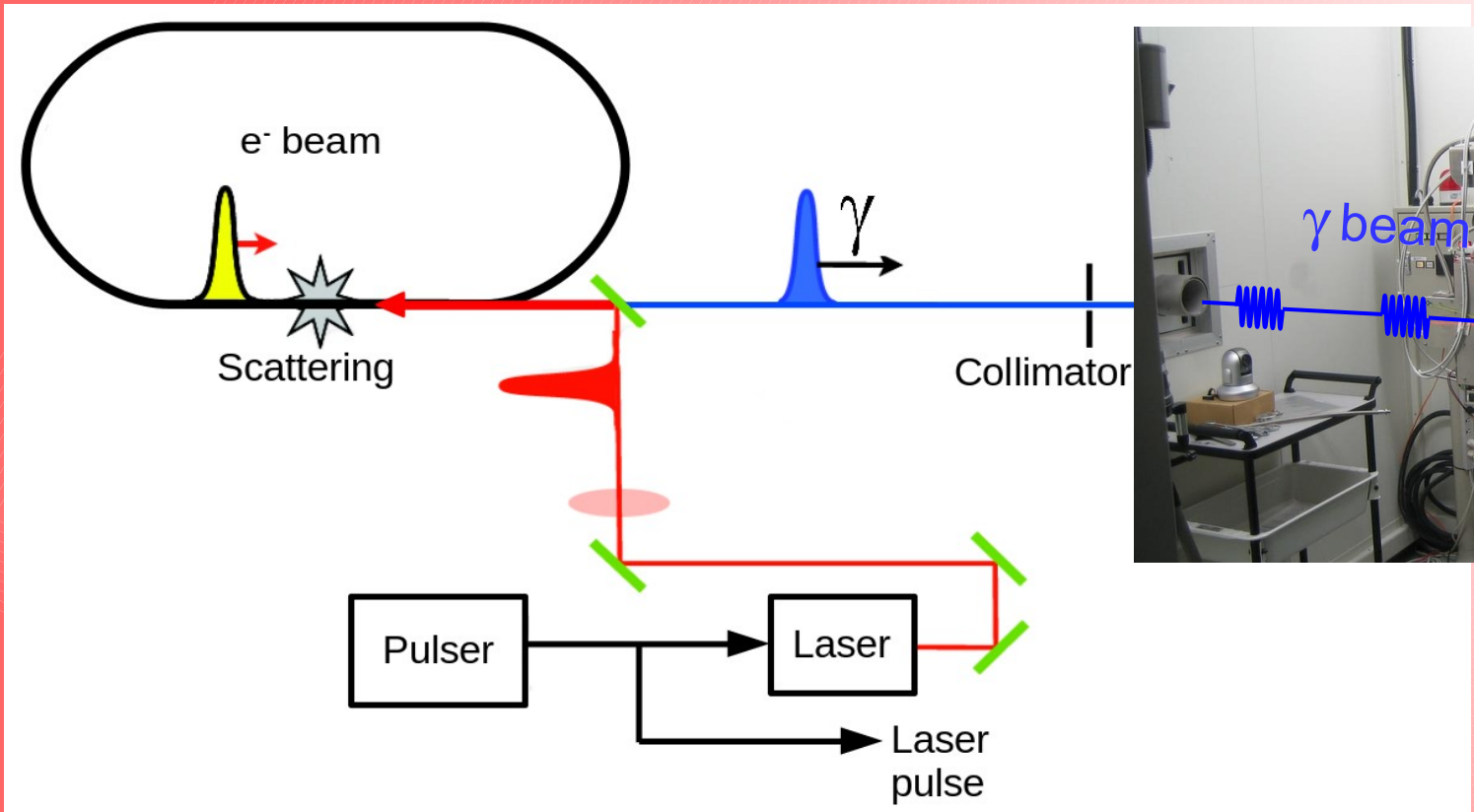


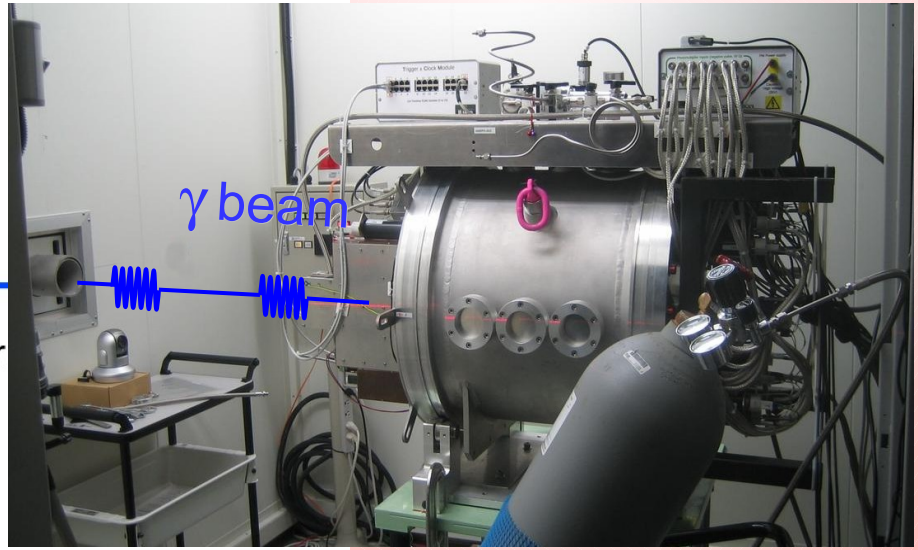
Pressure scan

- One day dedicated to pressure scan
  - "Clean" gas at 1, 1.5, 2, 3 and 4 bar
  - Signal amplitude (dE/dx x gain) ~fixed (Adjusted on the fly)
  - At high pressure, cathode voltage was limited
- Good running condition at all pressures
- Increasing micromegas current spikes at high pressure
  - matching GEM over current => physics?

HARPO

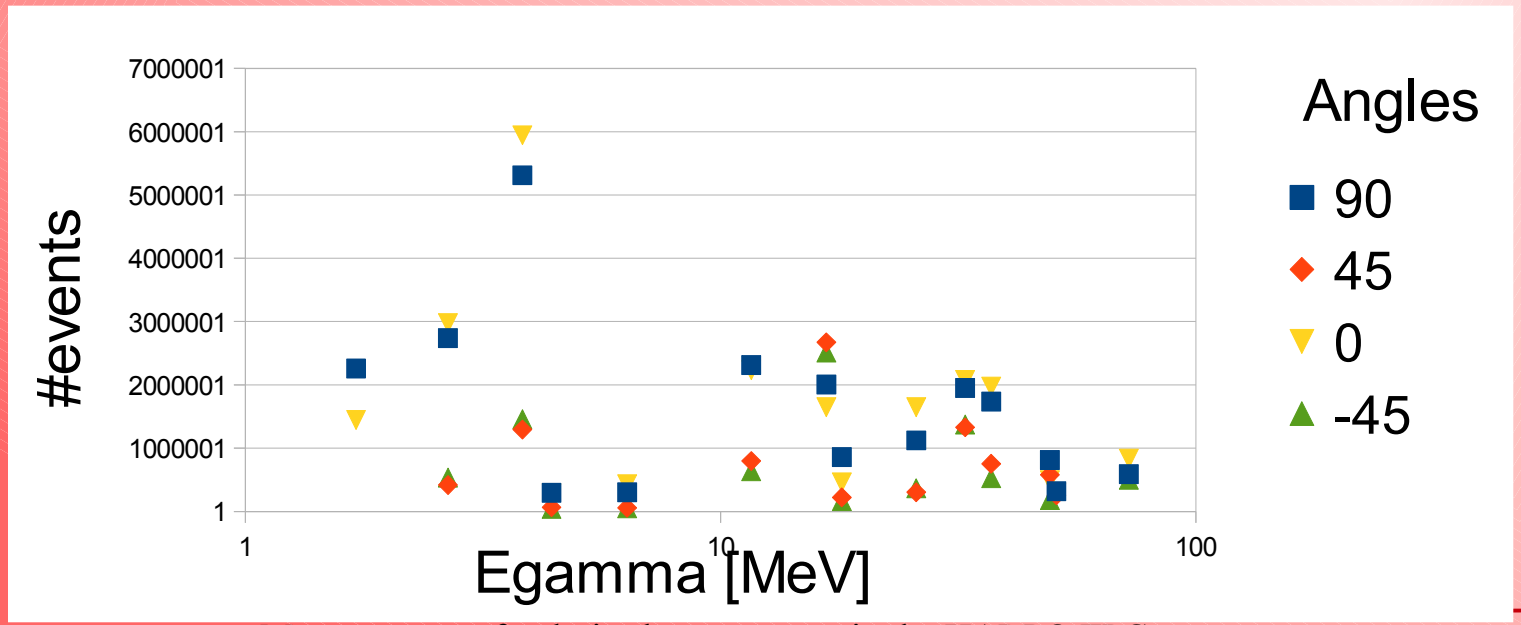
- TPC for measurement of polarised gamma rays
  - e^+e^- conversion (MeV~GeV)
  - Various astrophysics applications (in space)
  - Low multiple scattering => high angular resolution
  - Sensitive to linear polarisation
  - High pressure gas for higher conversion probability


e- beam
γ
Scattering
Collimator
Pulser
Laser
Laser
pulse

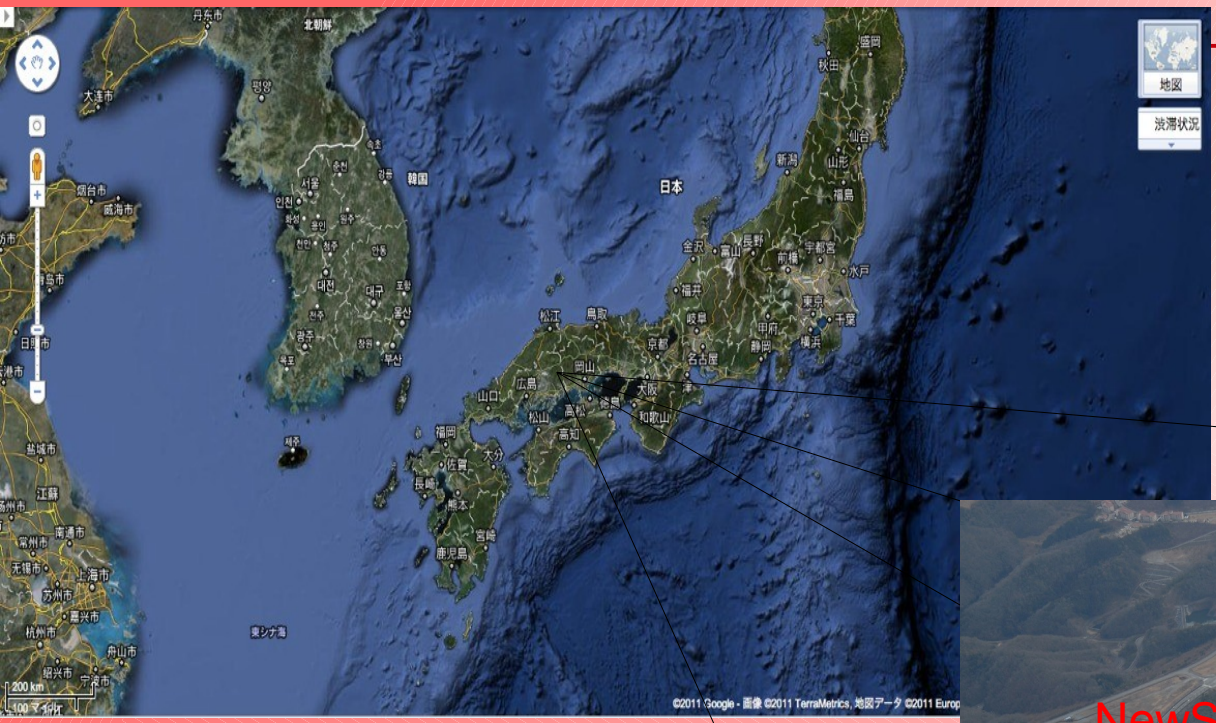

γ beam

Beam campaign

- ~20 days of data taking
- 13 gamma energies, polarised or not
- 4 TPC orientation for angle systematics
- >60Mevents, >1TB of data



NewSUBARU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NewSUBARU
XFEL
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Storage
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