Using transport calculations as event generators to design experiments

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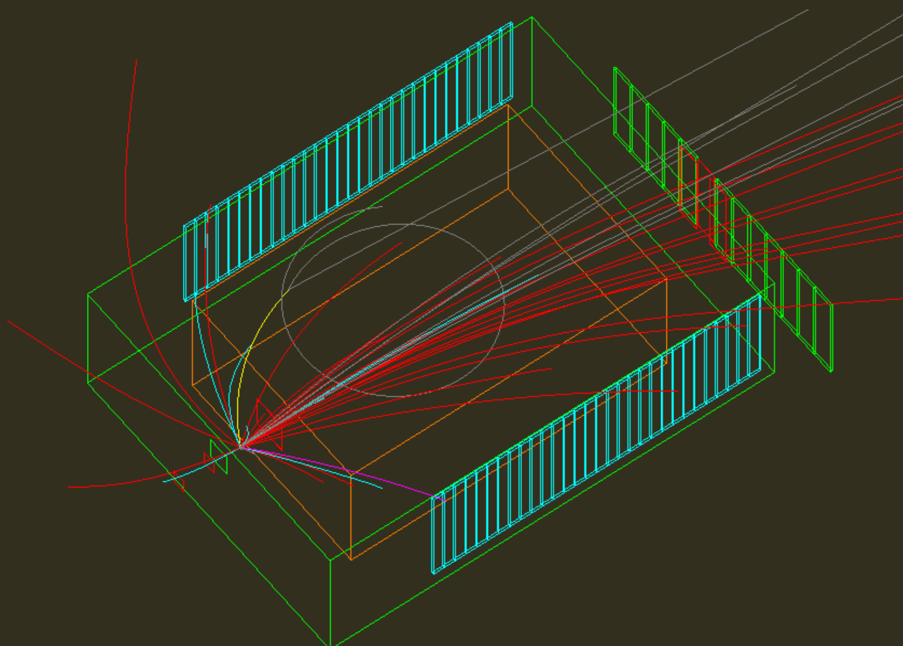

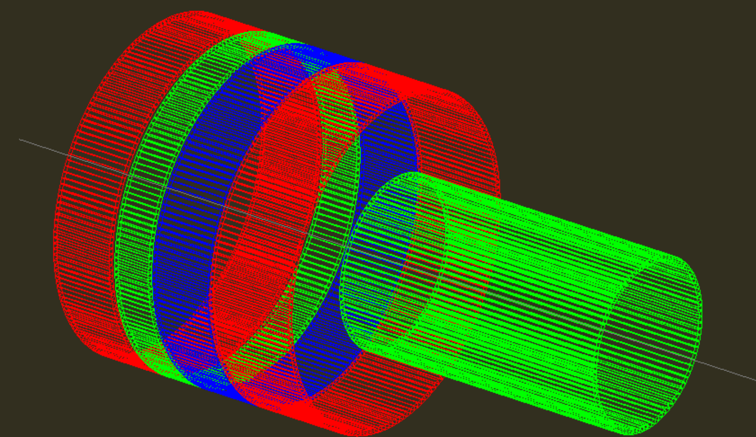

Transport 2017: International Workshop on Transport Simulations for Heavy Ion Collisions under Controlled Conditions

FRIB-MSU, March 27 - 30, 2017

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Outline

- UrQMD + GEANT4
- SPiRIT @ RIKEN (2016)
- ASY-EOS II @ FAIR (2019?)

Work flow

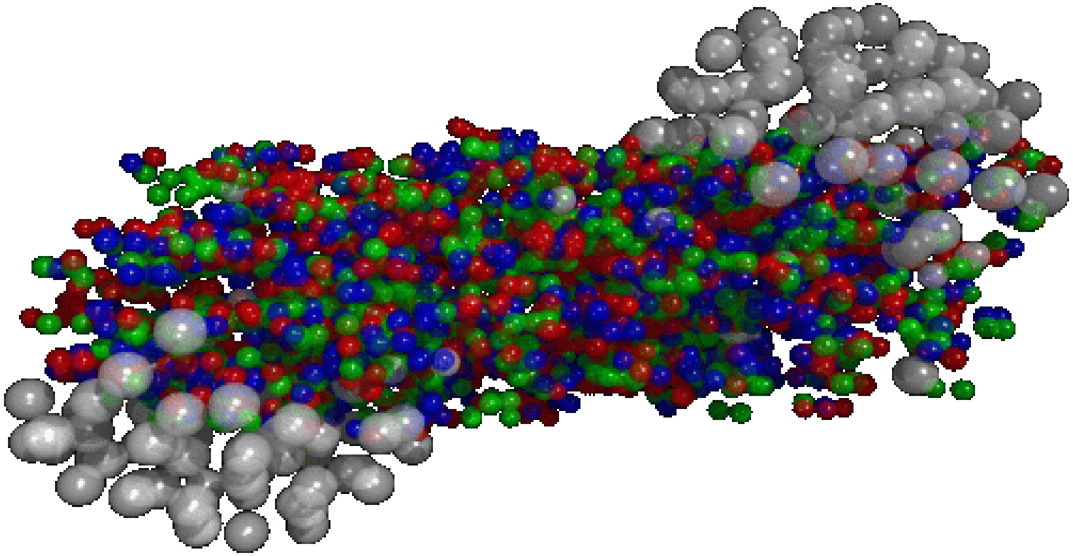
- generate events → perform some *MD simulations (*UU*, SMM ???)
- define clusters (event-by-event)
- estimate excitation energies
- account for secondary decays (in flight?)
- randomize the reaction plane
- transform to LAB
- propagate to detectors, account for interactions with matter (energy loss, multiple Coulomb scattering, ionization, e^-/h^+ production, scintillation, light propagation, secondary reactions, δ electrons, Cherenkov, bremsstrahlung), magnetic/electric fields, etc
- account for unstable particle decays

GEANT4 / some MC PHITS

↓

- design experiments
- infer/optimize the detector properties and performance (material, geometry, granularity, readout system, etc.)
- estimate efficiencies (geometric, detection, triggering, trapping)
- estimate energy losses, doses, timing properties, etc.
- support data analysis

UrQMD
main advantages as an event generator

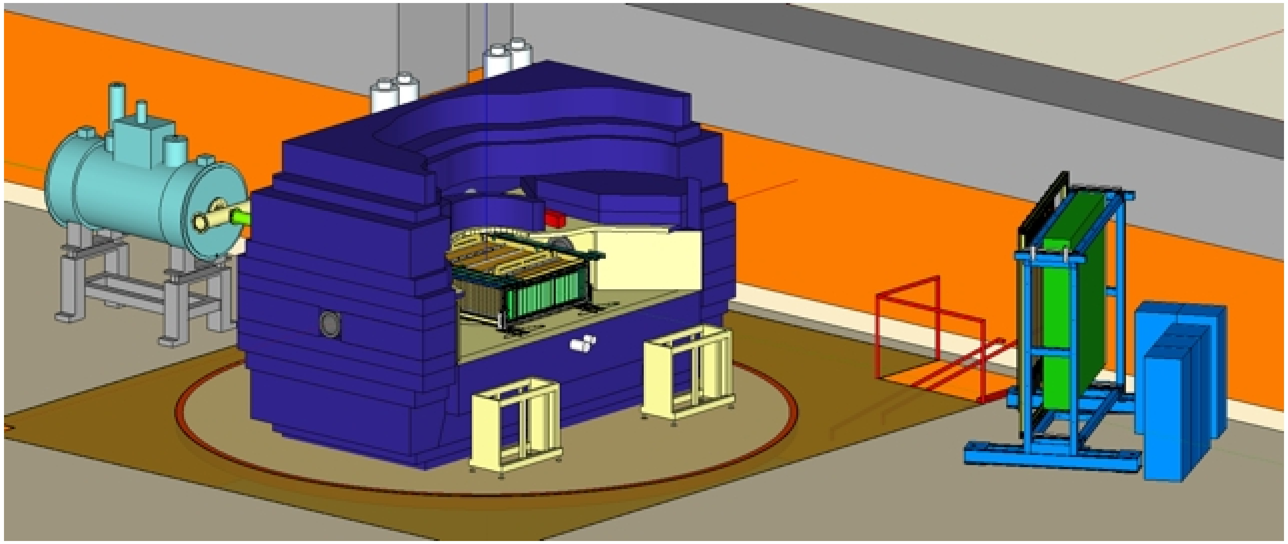


- relativistic dynamics
- first order effects accounted for (mean field (HARD EOS), collisions, Pauli blocking)
- particle production
- open source (https://urqmd.org/)
- documented, maintained, easy to run

SPiRIT @ RIKEN (2016)

Determination of the density and momentum dependence of the EOS at supra-saturation densities

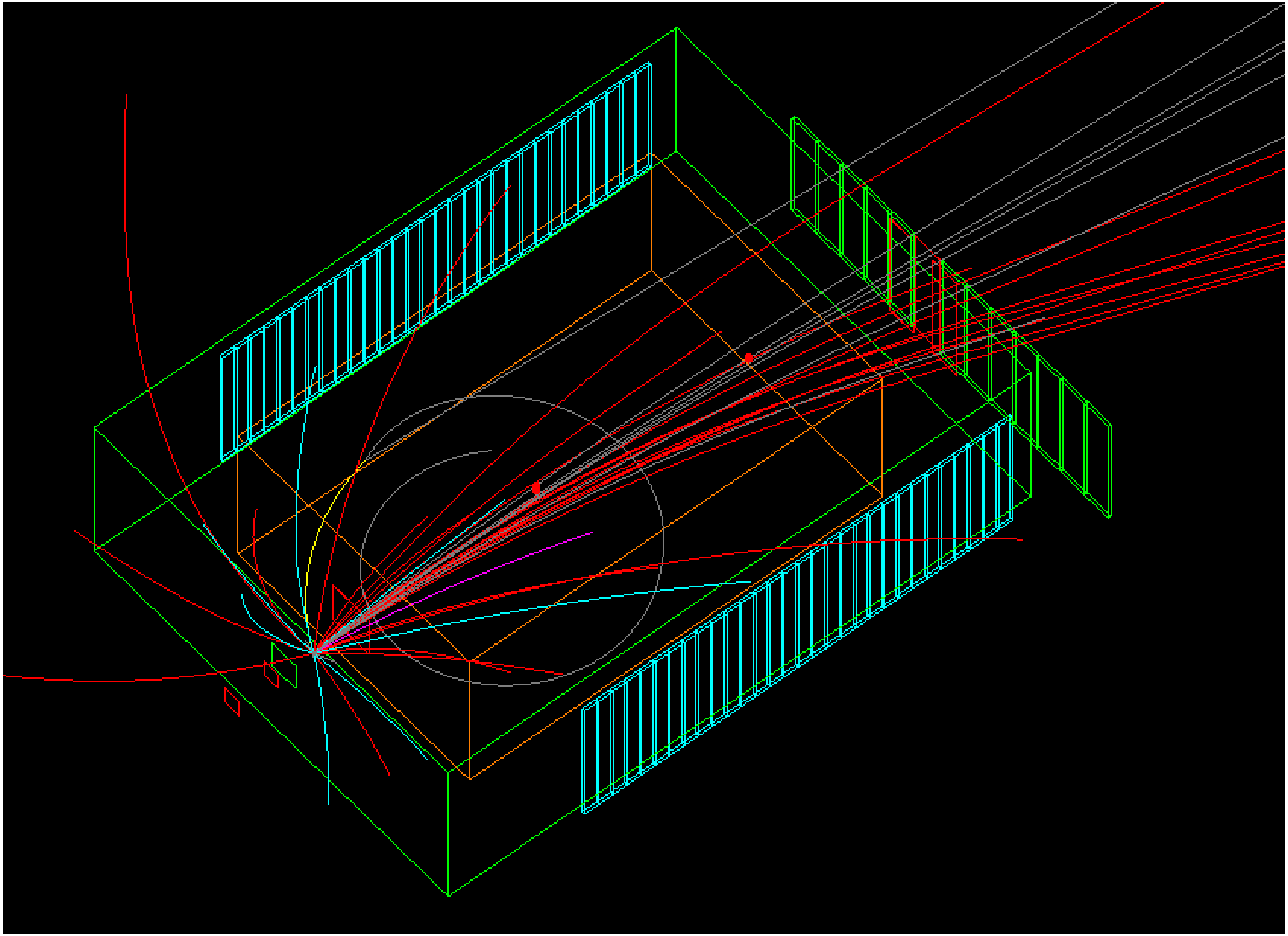
Stable and radioactive systems at 300 AMeV
$^{132}Sn+^{124}Sn$; $^{124}Sn+^{112}Sn$
$^{108}Sn+^{112}Sn$; $^{112}Sn+^{124}Sn$



Observables:
ratios: π^{-}/π^{+}, n/p, t/^{3}He,
flow: n, p, t, ^{3}He

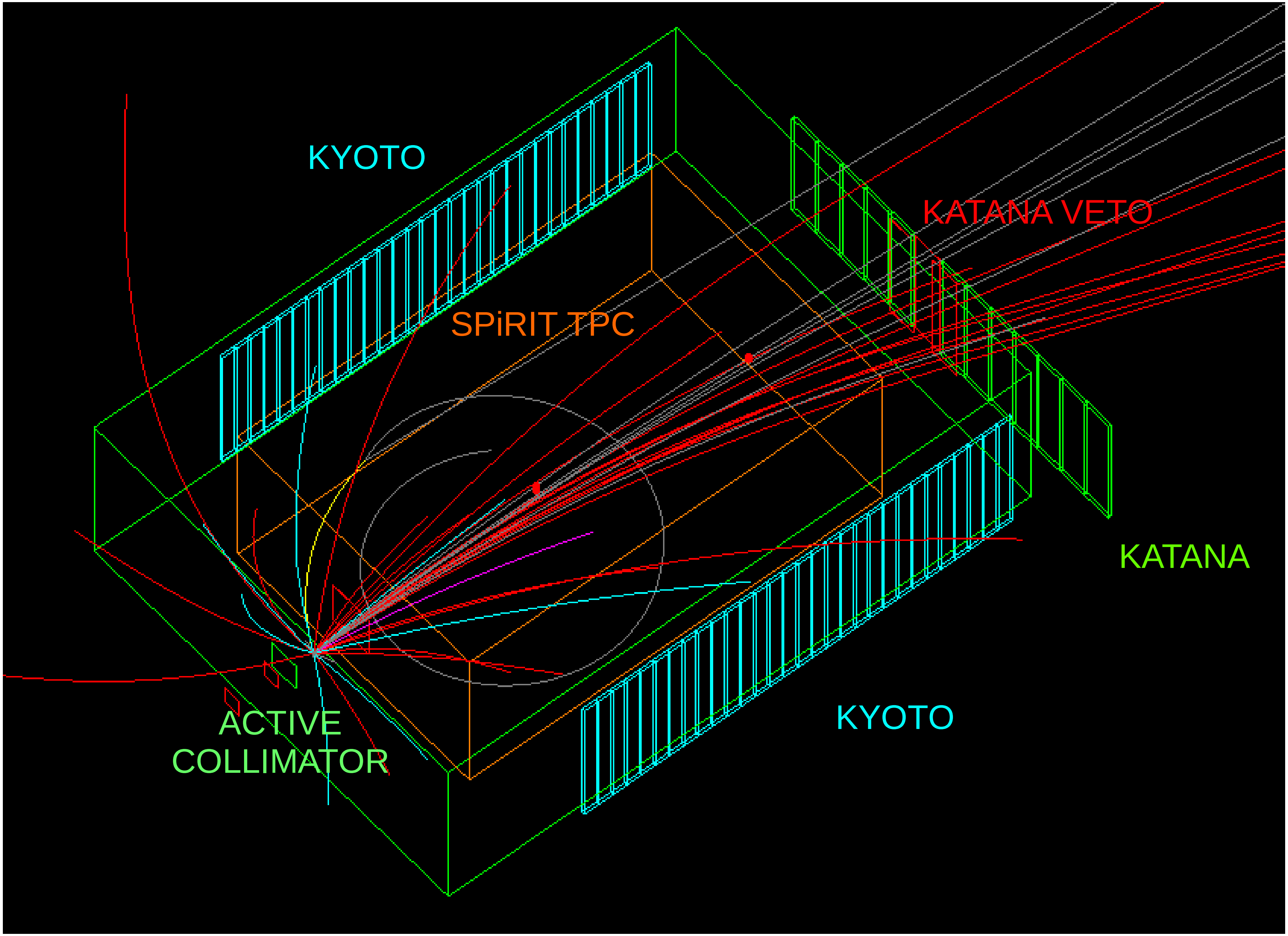
Main detectors:
SPiRIT TPC inside SAMURAI
KYOTO + KATANA
NeuLAND

SPiRIT @ RIKEN (2016)

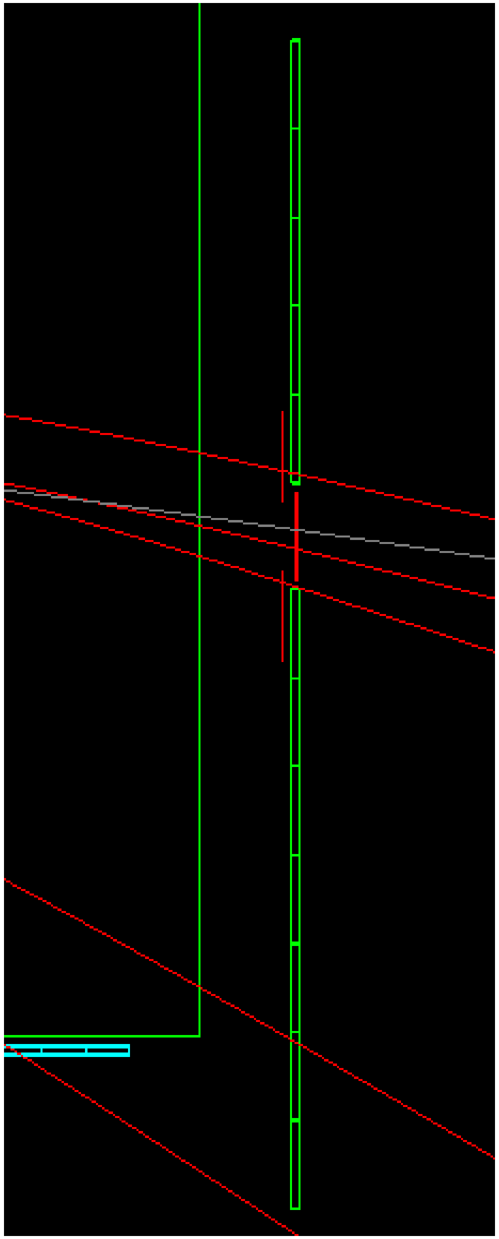


UrQMD+GEANT4 simulation

SPiRIT @ RIKEN (2016)



UrQMD+GEANT4 simulation

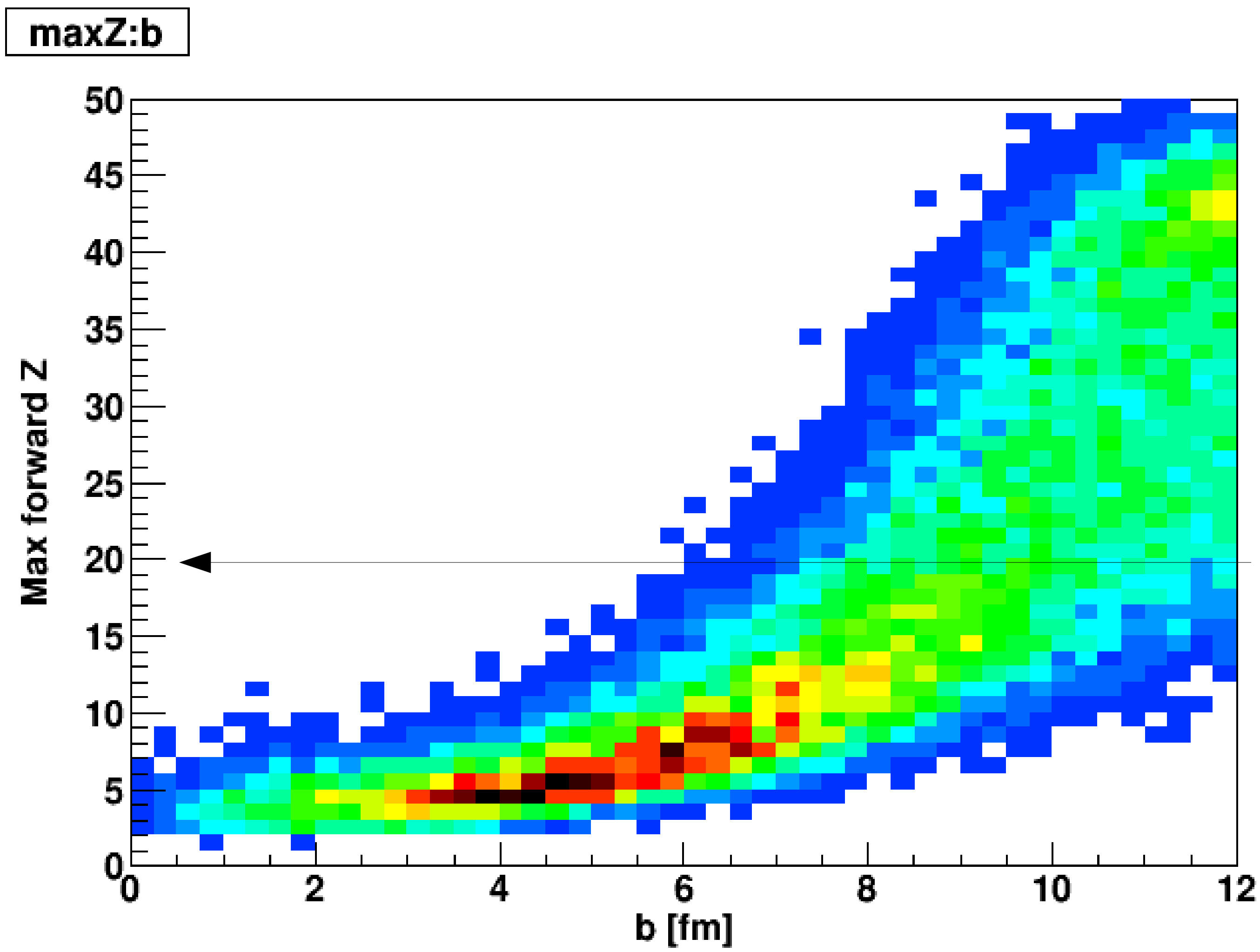


High TPC gain to detect pions and light charged particles
&
beam particles and heavy fragments pass through the TPC
↓
keep gating grid closed for Z>20

KATANA:
3 Veto bars centered around the beam position
12 Multiplicity bars (7 on right + 5 on left)

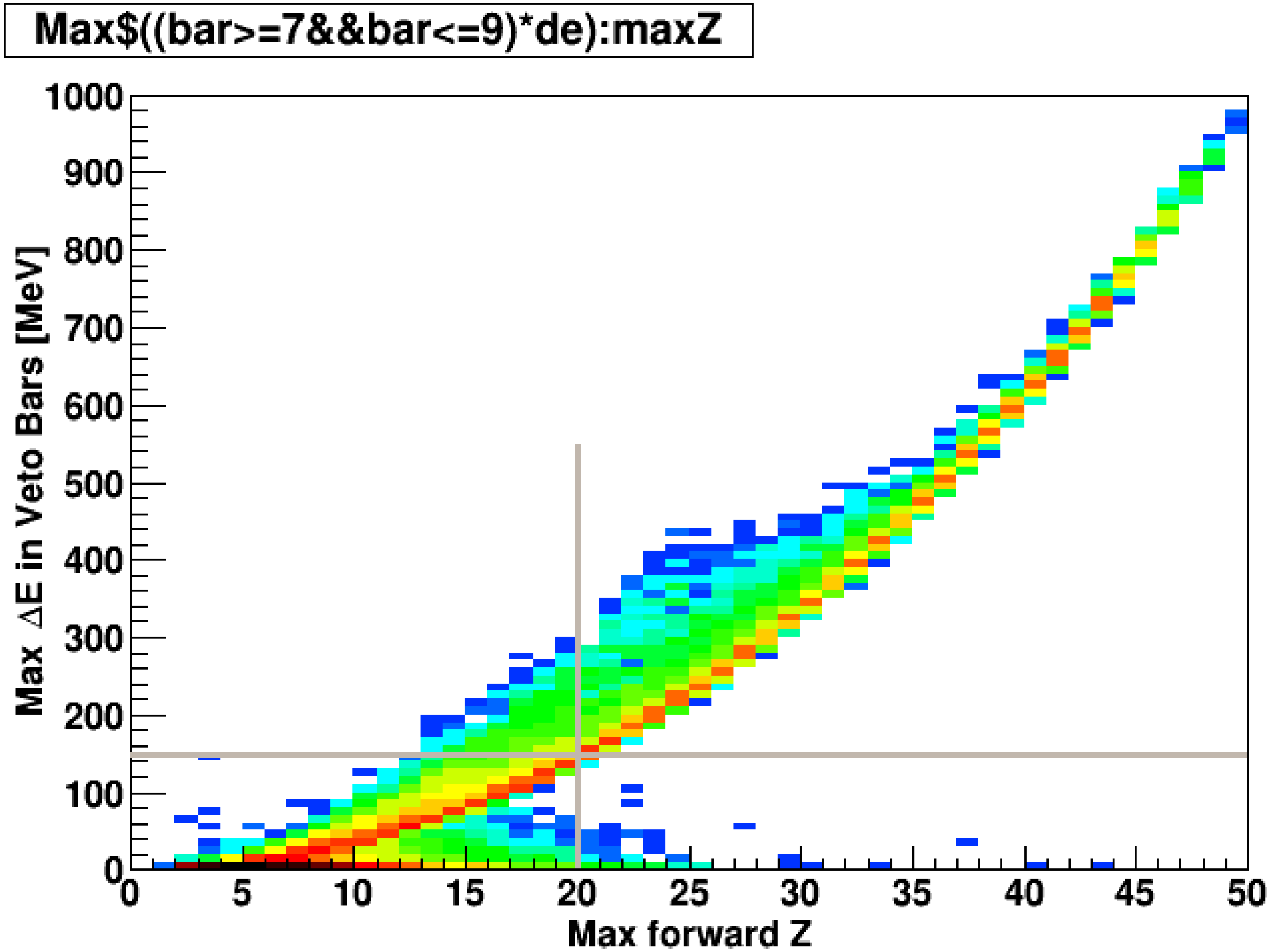
UrQMD+GEANT4 simulation

UrQMD + clustering: $^{132}Sn+^{124}Sn$ @ 300 AMeV



UrQMD+GEANT4 simulation

Max energy loss in Veto bars

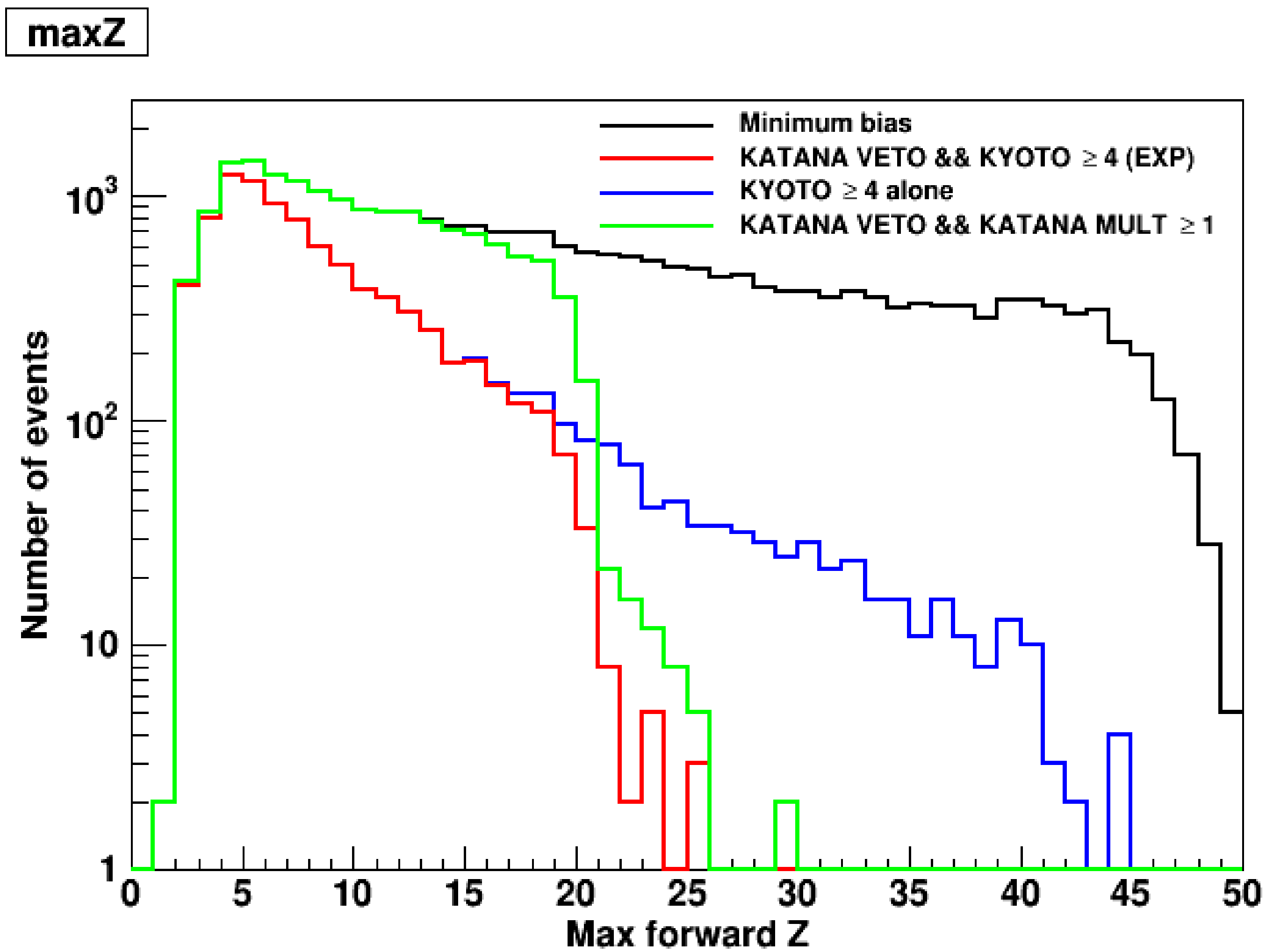


Bethe-Bloch:

$\Delta E \sim AZ^2/E$

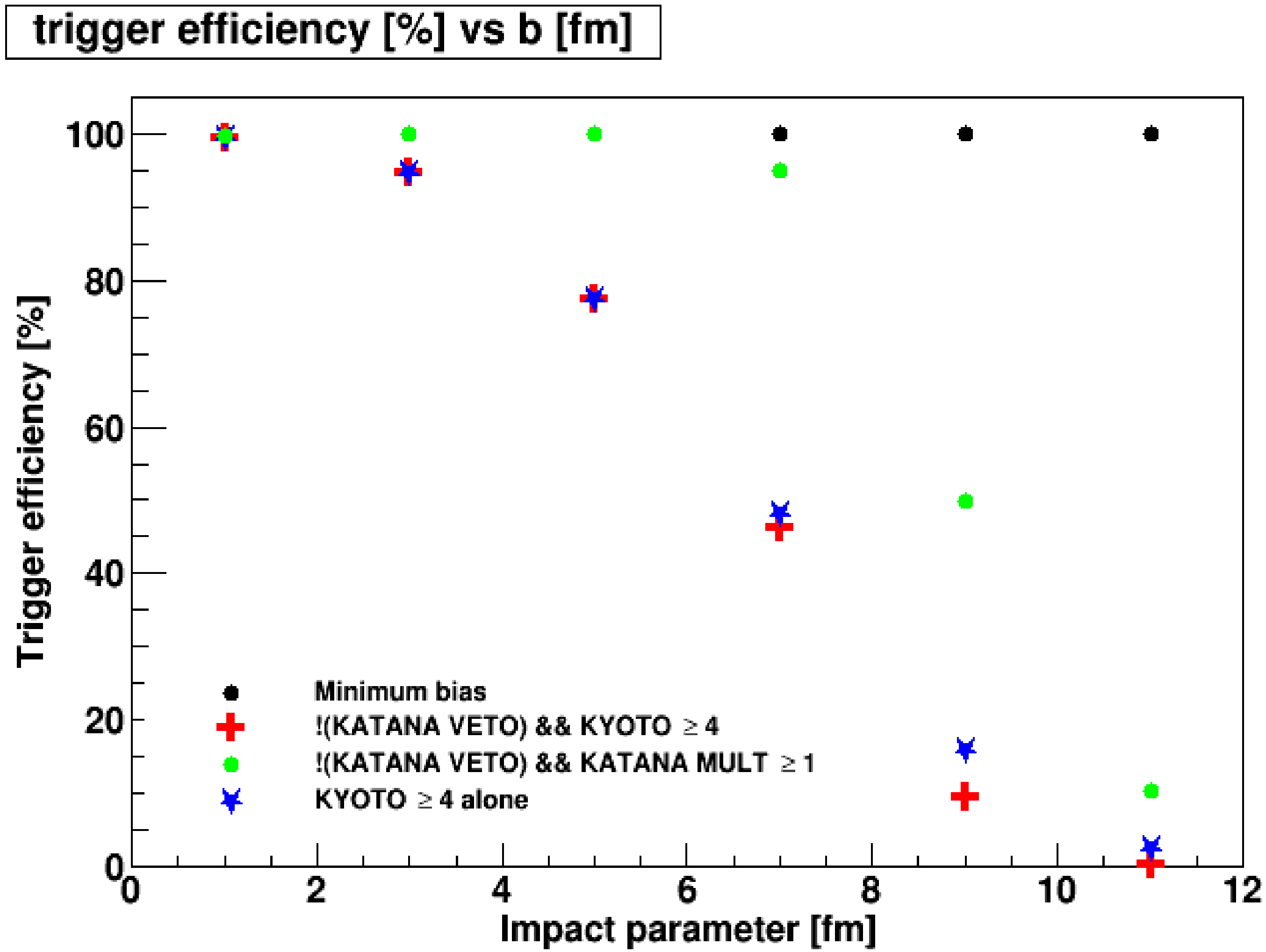
UrQMD+GEANT4 simulation

Veto efficiency for heavy charges



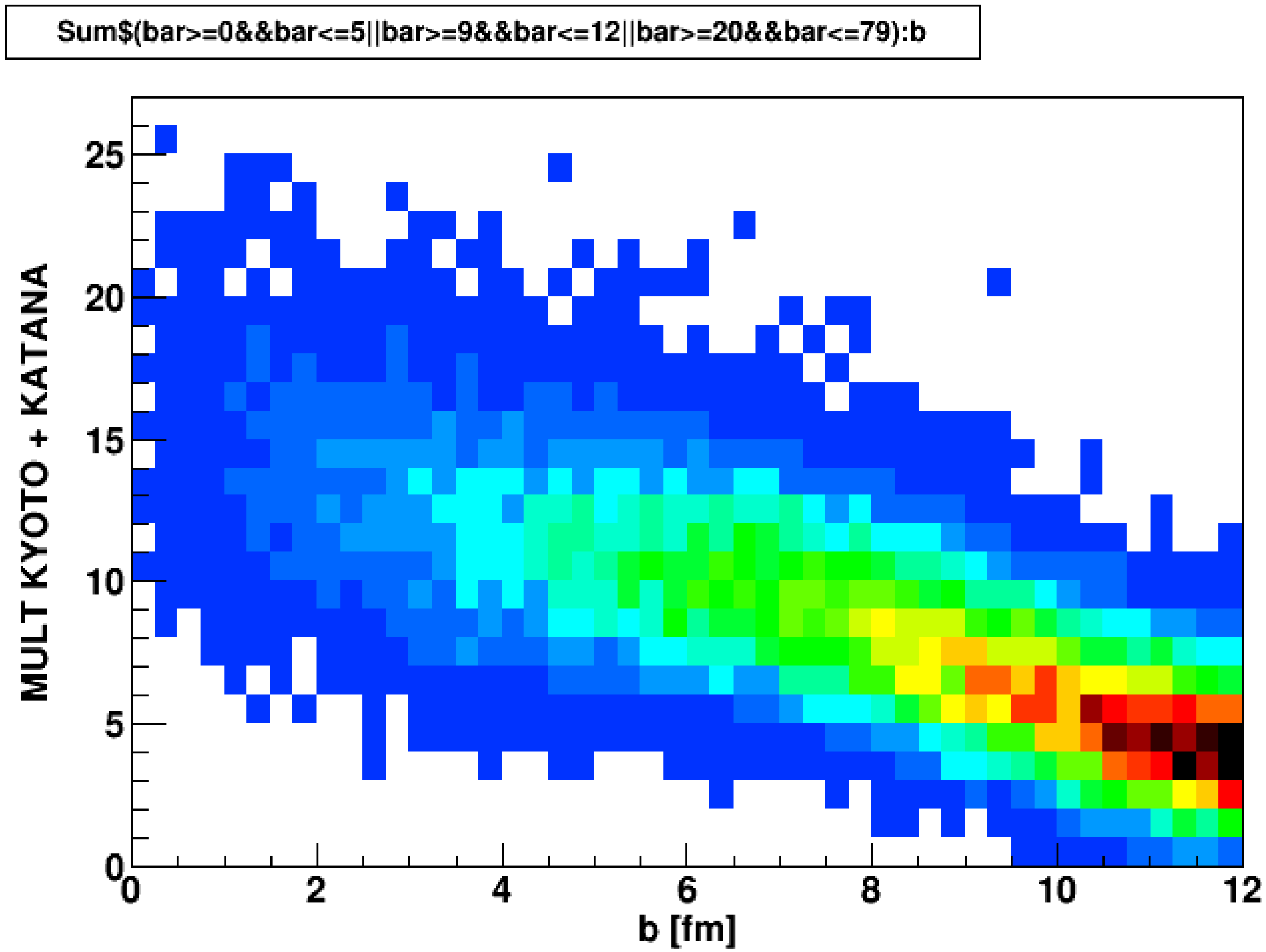
UrQMD+GEANT4 simulation

Trigger efficiency vs b



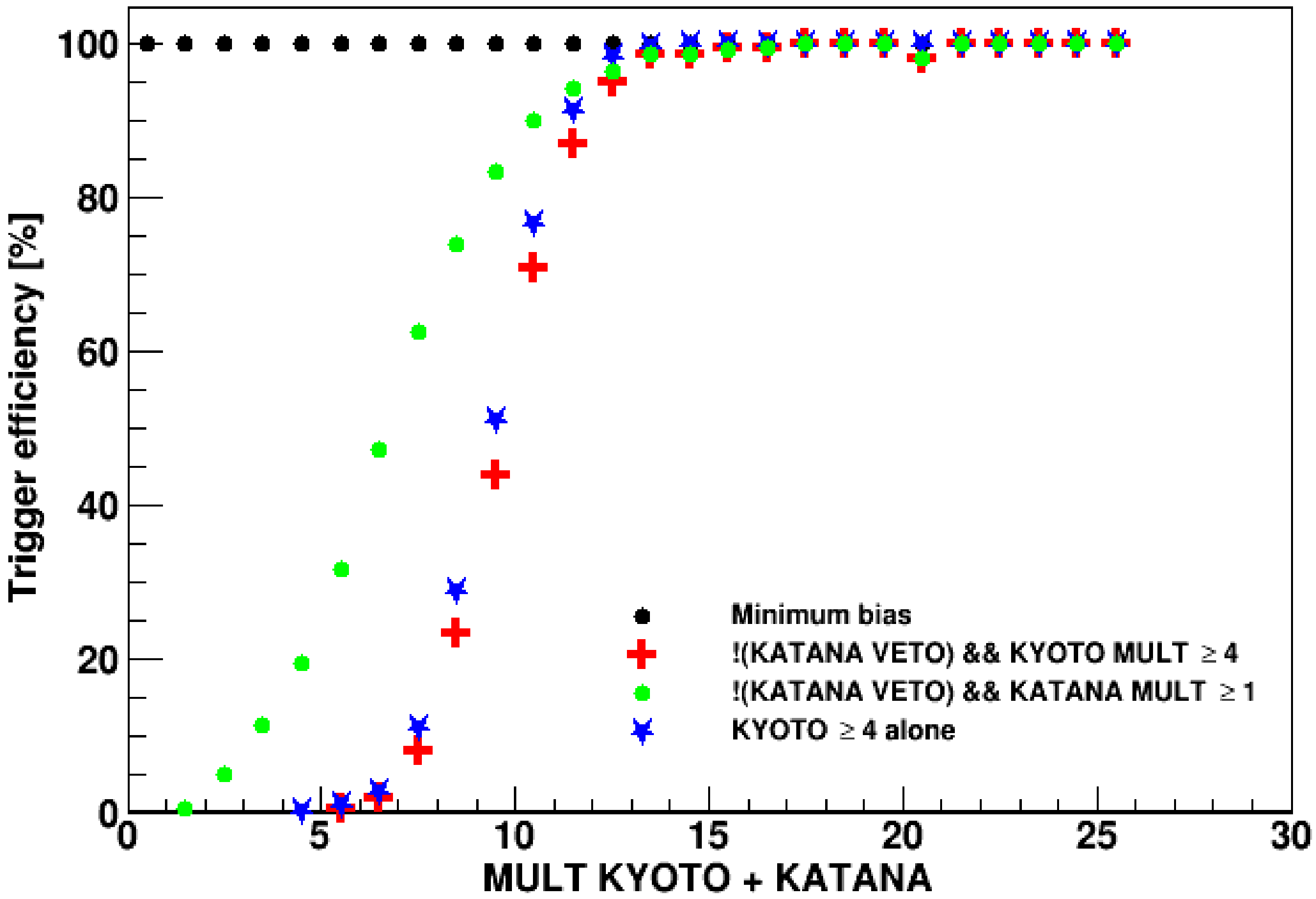
UrQMD+GEANT4 simulation

MULT vs impact parameter



UrQMD+GEANT4 simulation

Trigger efficiency vs MULT

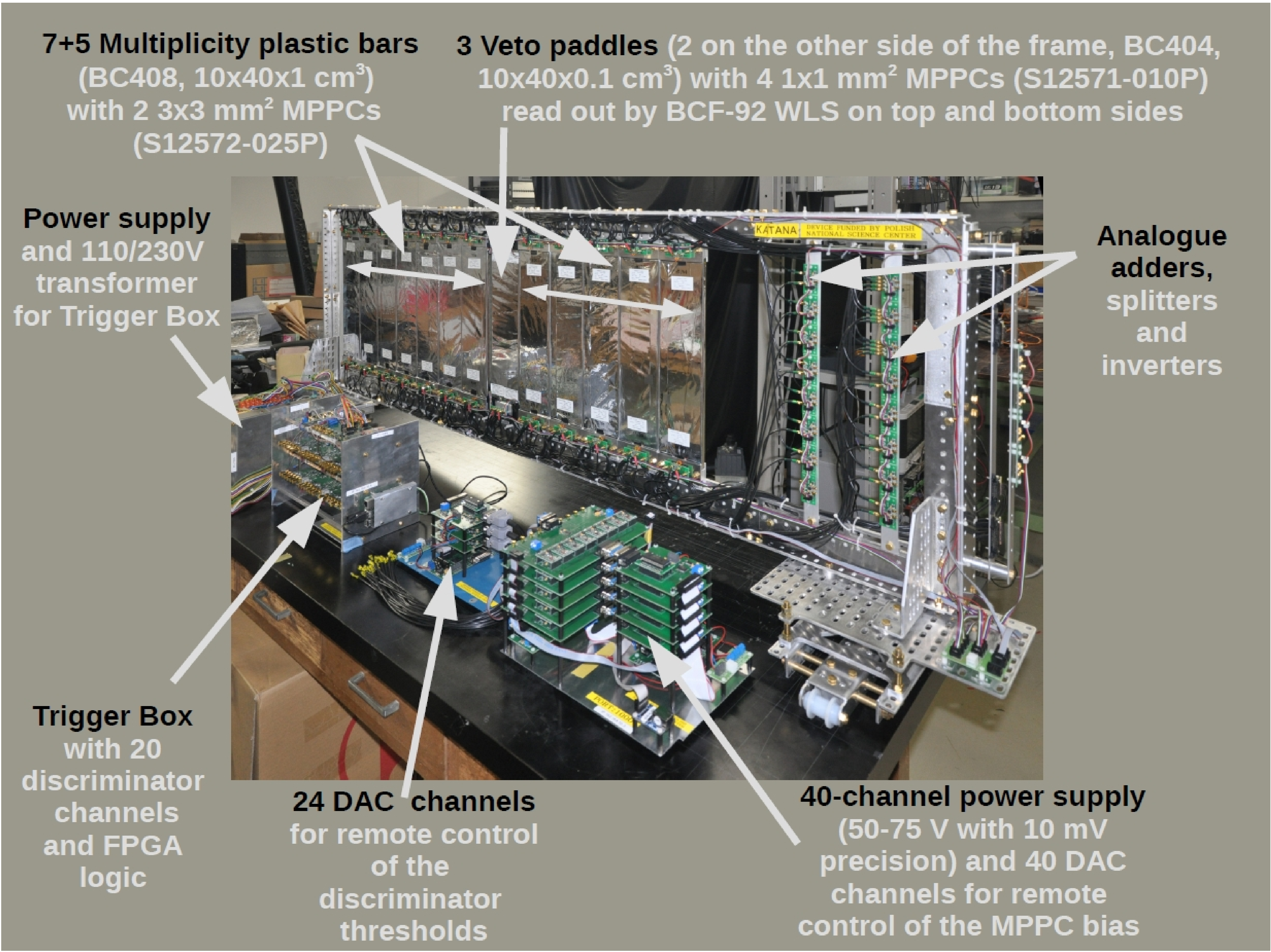


UrQMD+GEANT4 simulation

KATANA main requirements

(more than just a trigger...)

- High trigger efficiency for central and semi-central collisions → GEANT4 + UrQMD simulations to test various options and setups
- Fast VETO signal for fragments with Z>20 to close the Gating Grid → Fast plastics (BC404)
Fast preamps
Trigger Box with FPGA logic
- Insensitivity to magnetic field → MPPCs (HAMAMATSU)
- Possibly low position dependence of the signal amplitudes → Wave Length Shifters (BCF-92) for VETO paddles
- Stability and beam time respect → Remote control of discriminator thresholds, bias voltages and temperatures
- Provide data, handle Active Collimator signals → Include trigger detector in DAQ

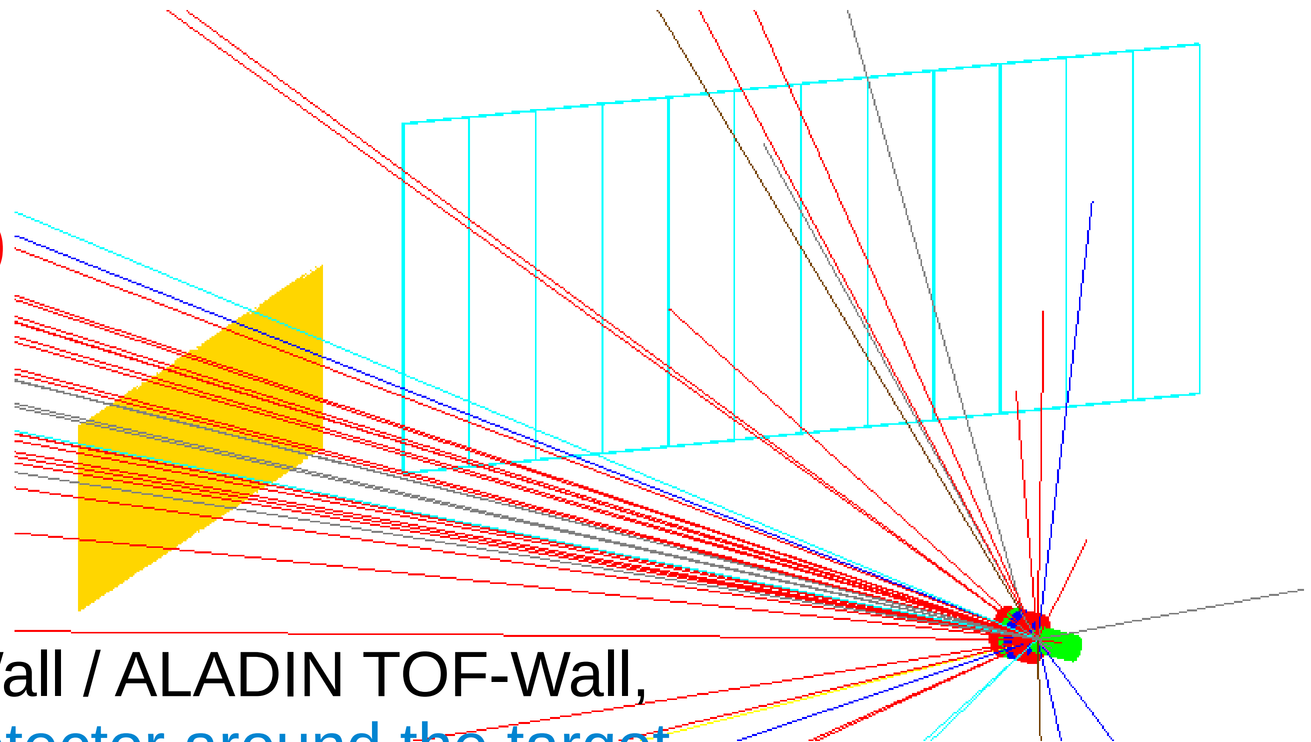

7+5 Multiplicity plastic bars (BC408, 10x40x1 cm³) with 2 3x3 mm² MPPCs (S12572-025P)
3 Veto paddles (2 on the other side of the frame, BC404, 10x40x0.1 cm³) with 4 1x1 mm² MPPCs (S12571-010P) read out by BCF-92 WLS on top and bottom sides
Power supply and 110/230V transformer for Trigger Box
Analogue adders, splitters and inverters
KATANA
Trigger Box with 20 discriminator channels and FPGA logic
24 DAC channels for remote control of the discriminator thresholds
40-channel power supply (50-75 V with 10 mV precision) and 40 DAC channels for remote control of the MPPC bias

ASY-EOS II @ FAIR (2019?)

Determination of the density dependence of the EOS at supra-saturation densities

Symmetric and asymmetric systems
^{108}Sn, ^{132}Sn, ^{197}Au @ 0.4, 1, 1.2 AGeV

Observables:
ratios: n/p, t/^{3}He, π^{-}/π^{+}(?)
flow: n, p, t, ^{3}He



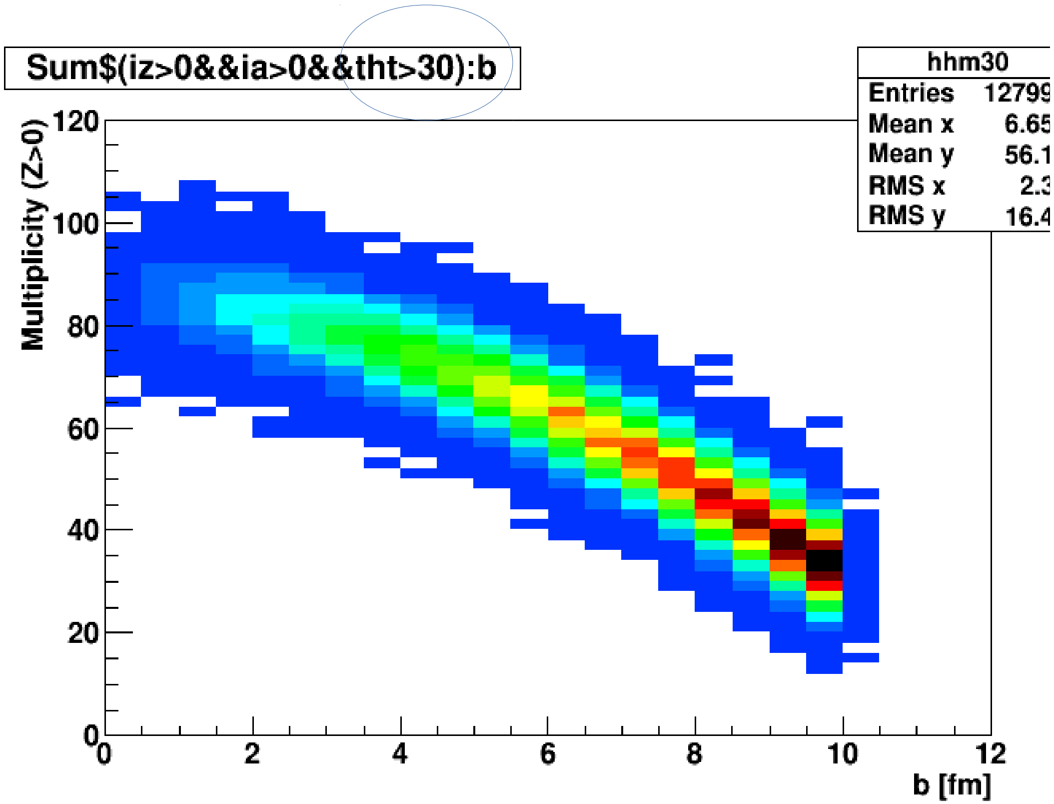
Main detectors:
NeuLAND, FOPI PlasticWall / ALADIN TOF-Wall,
Trigger/Reaction Plane detector around the target

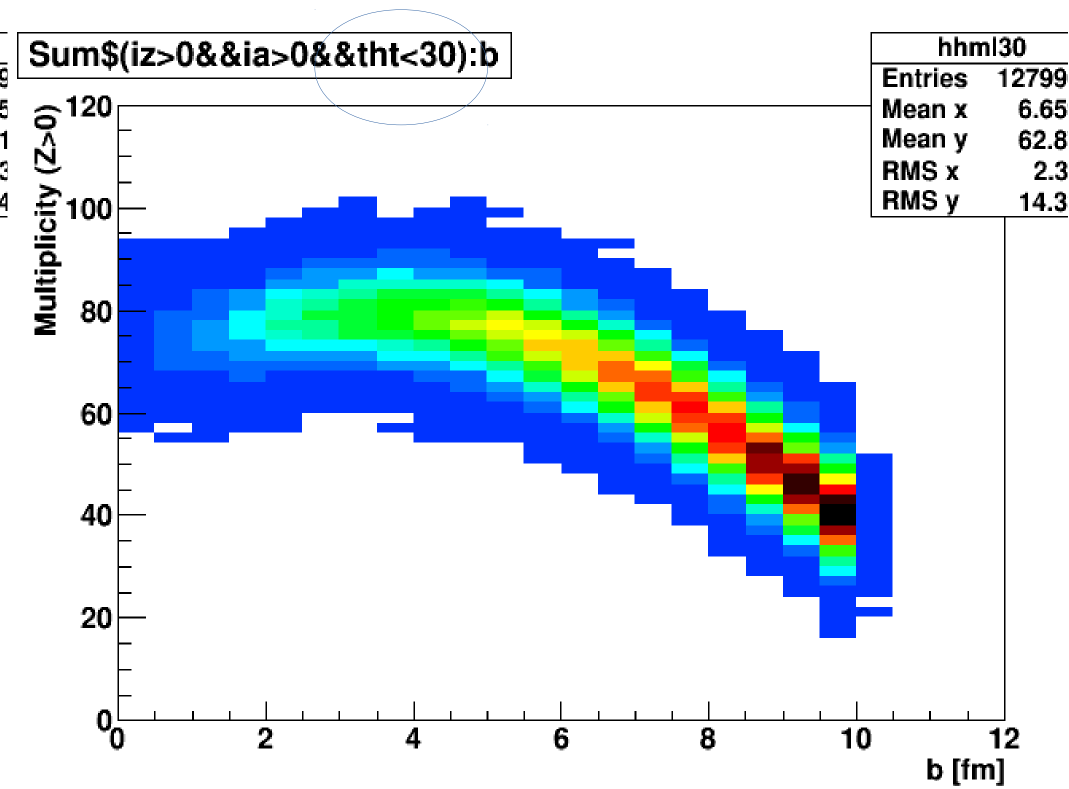
Trigger/Reaction Plane detector around the target

requirements:

- should cover angles > 30^o,
- high segmentation in azimuthal angle,
- high geometrical efficiency,
- low multihit probability,
- fast timing

UrQMD + clustering: Au+Au 1000 AMeV, 0-10 fm, 200 fm/c



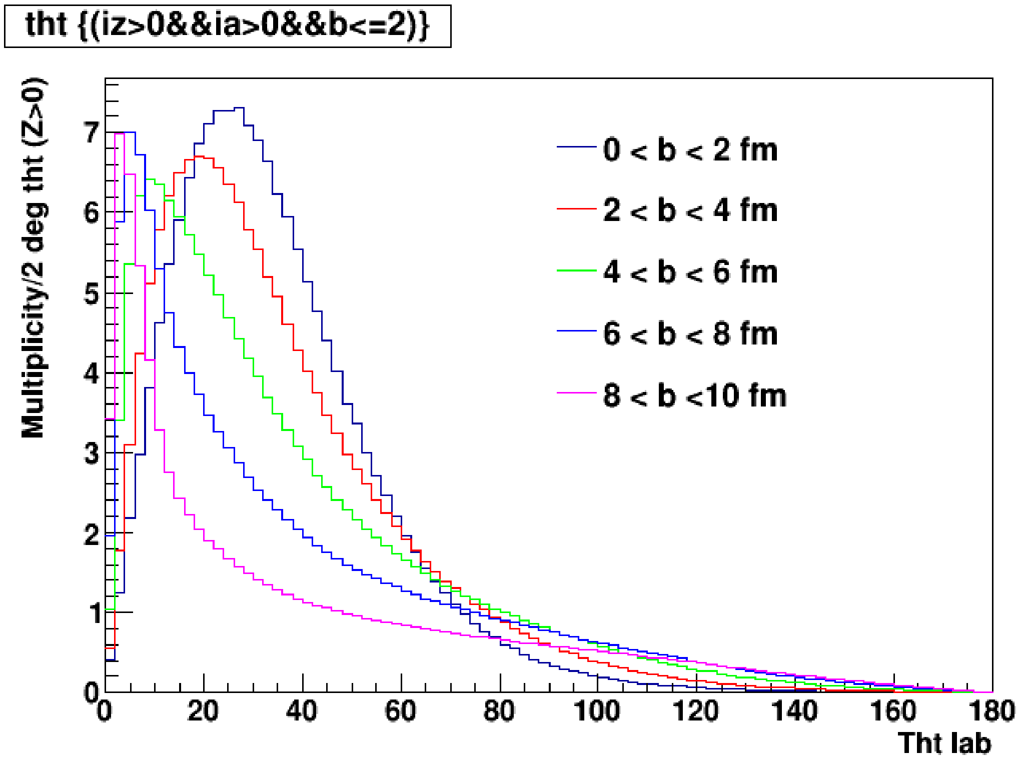


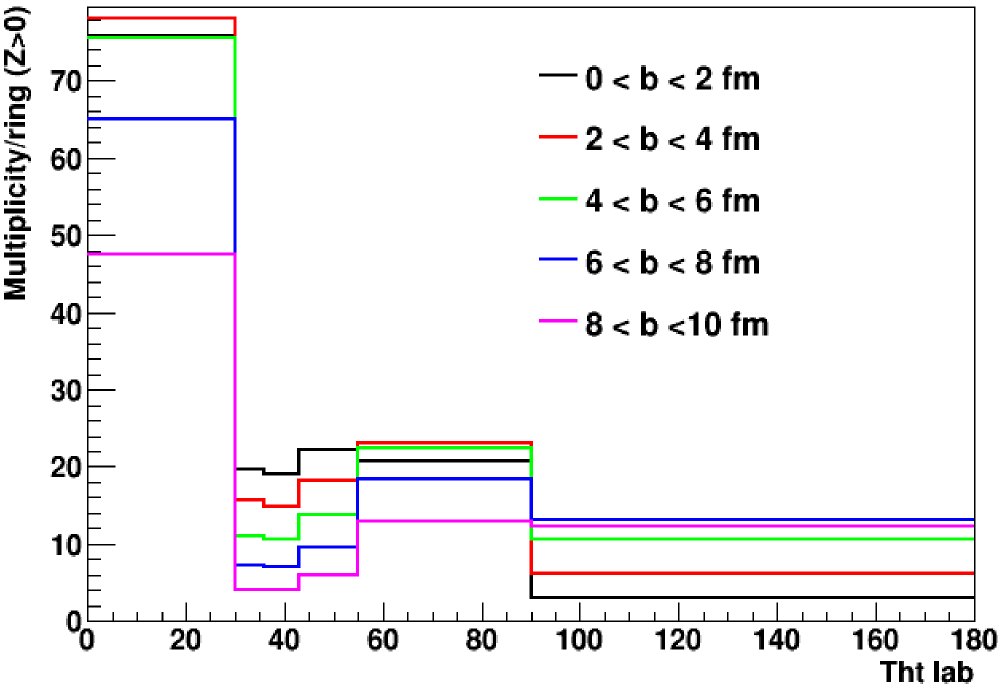
better correlation

UrQMD + clustering: Au+Au 1000 AMeV, 0-10 fm, 200 fm/c

Z>0, NO PIONS

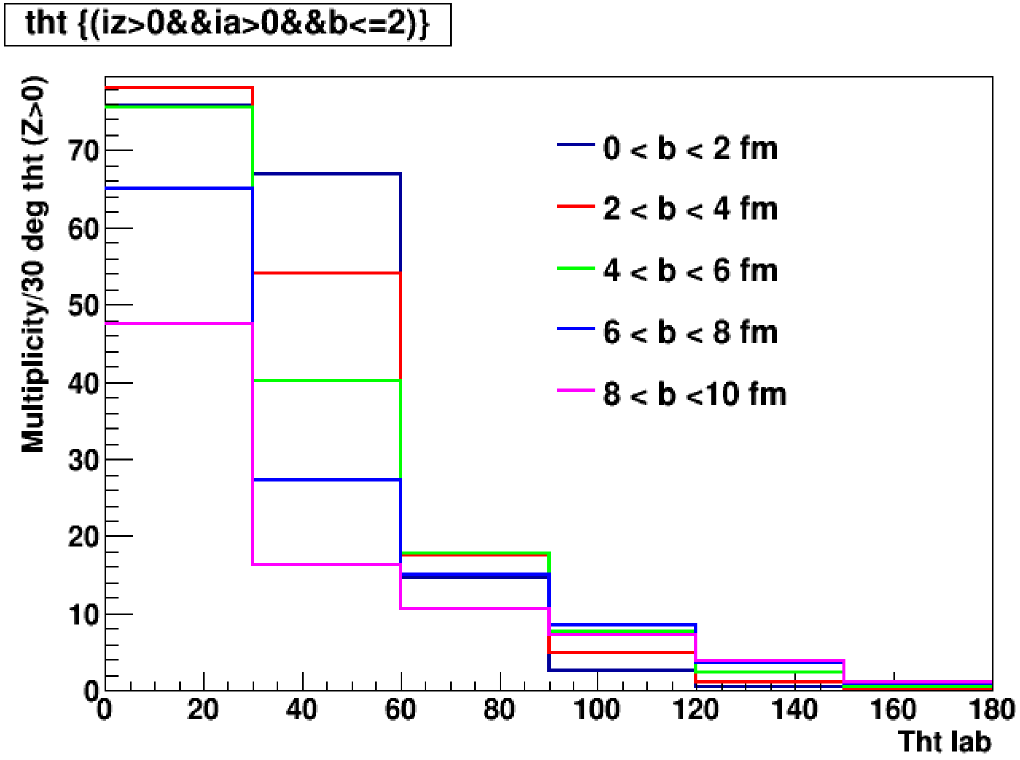
5 segments



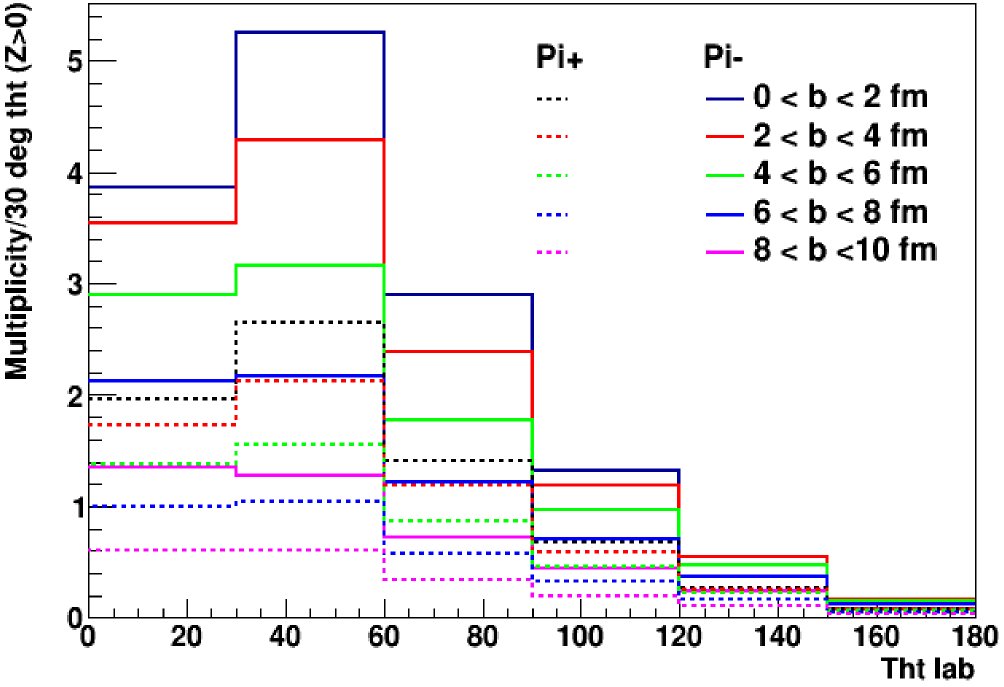


UrQMD + clustering: Au+Au 1000 AMeV, 0-10 fm, 200 fm/c

LCP+IMF

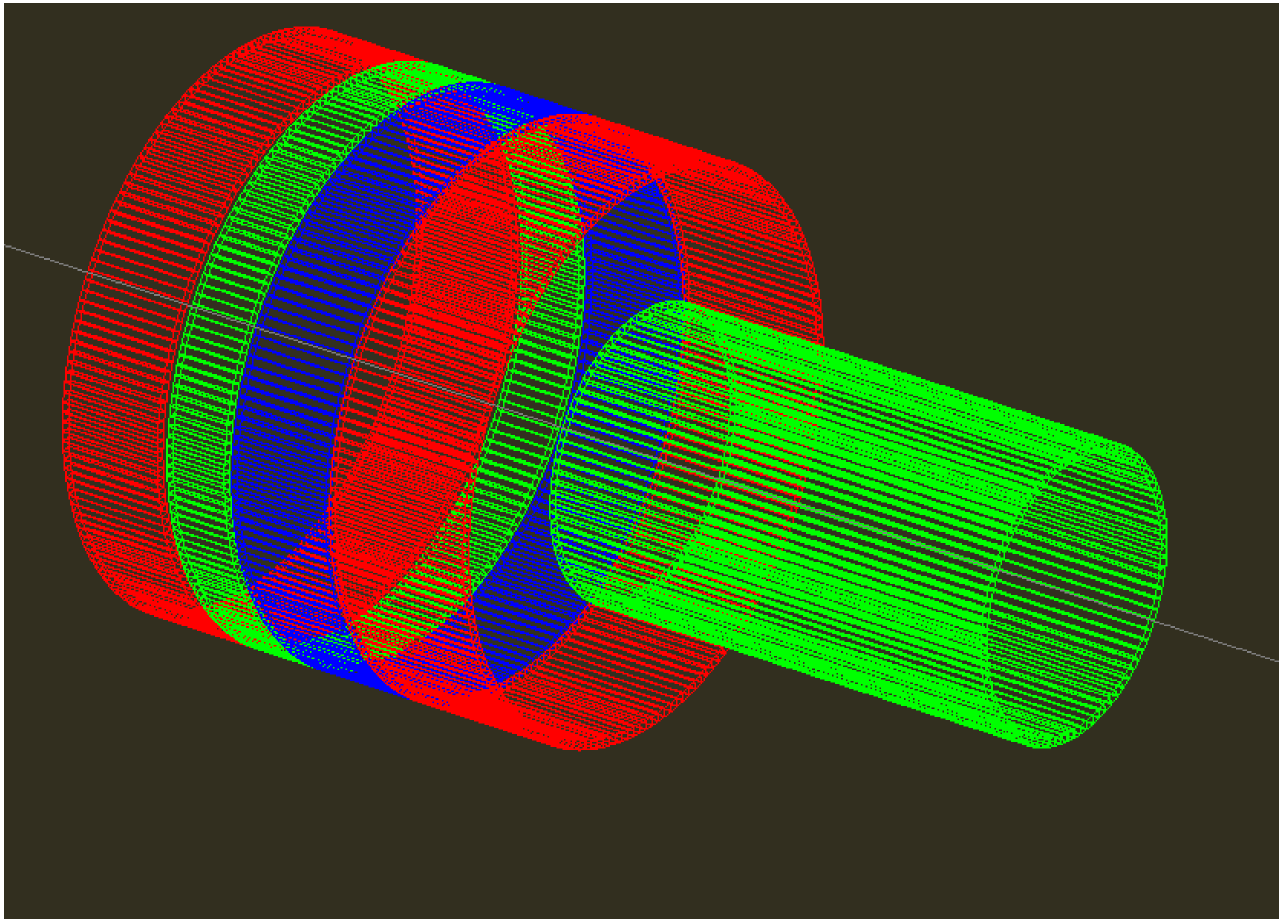


PIONS

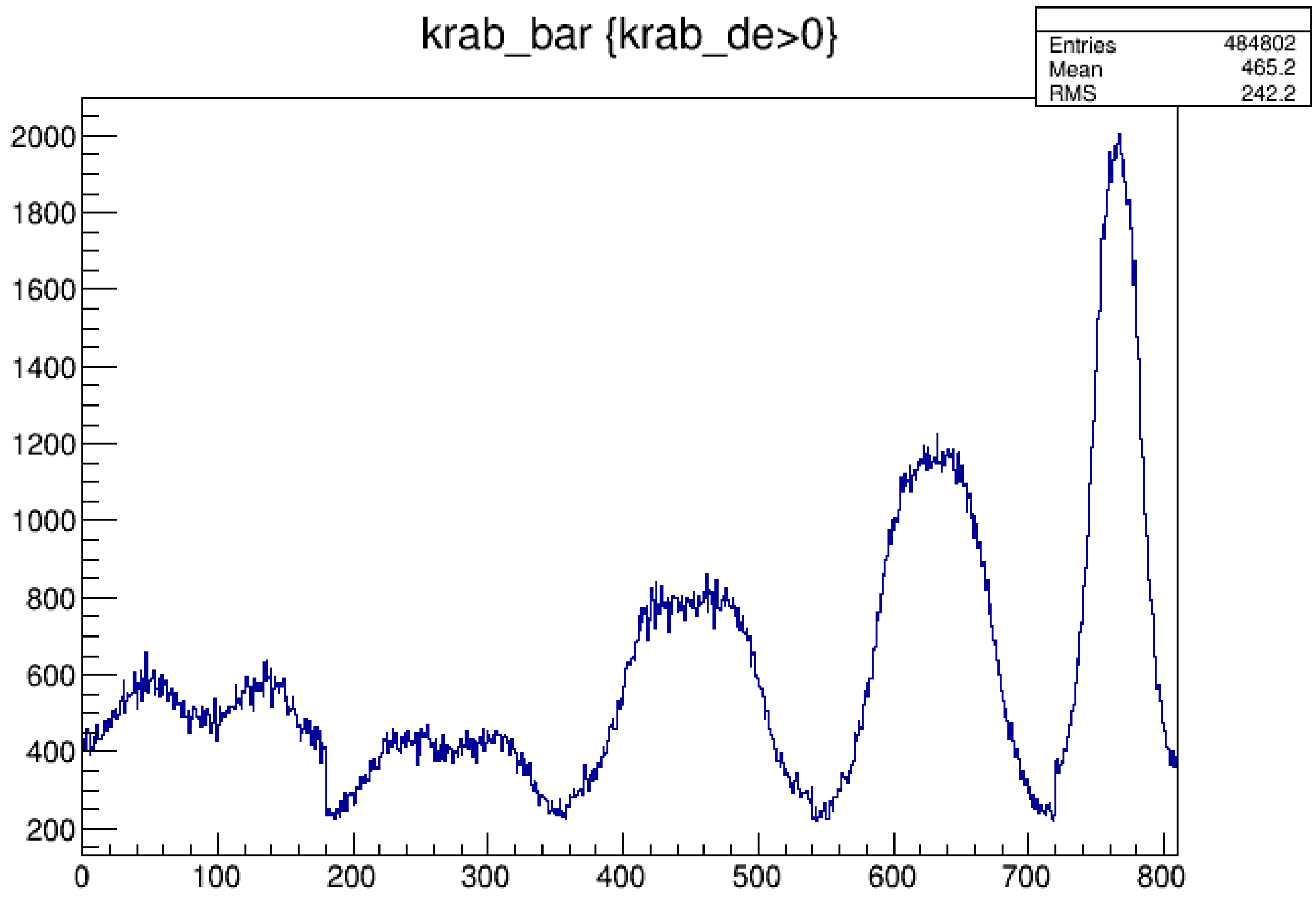


Trigger/Reaction Plane detector around the target:

- 5 rings of 4x4 mm^2 fast scintillating fibers (e.g. BCF-20) read out by SiPMs
- covers angles from 30° to 165°,
- segmentation assures more or less uniform count rates for Au+Au at 1 AGeV,
- geometrical efficiency ~95%
- ~10% of charged particles involved in multihits,
- ~5% multihit probability
- sufficiently large for radioactive beams
- sufficiently small and lightweight not to disturb neutrons
- min radius - 6 cm,
- max radius - 12 cm
- length 43 cm
- 180 segments in forward rings
- 90 segments in backward ring
- 810 channels

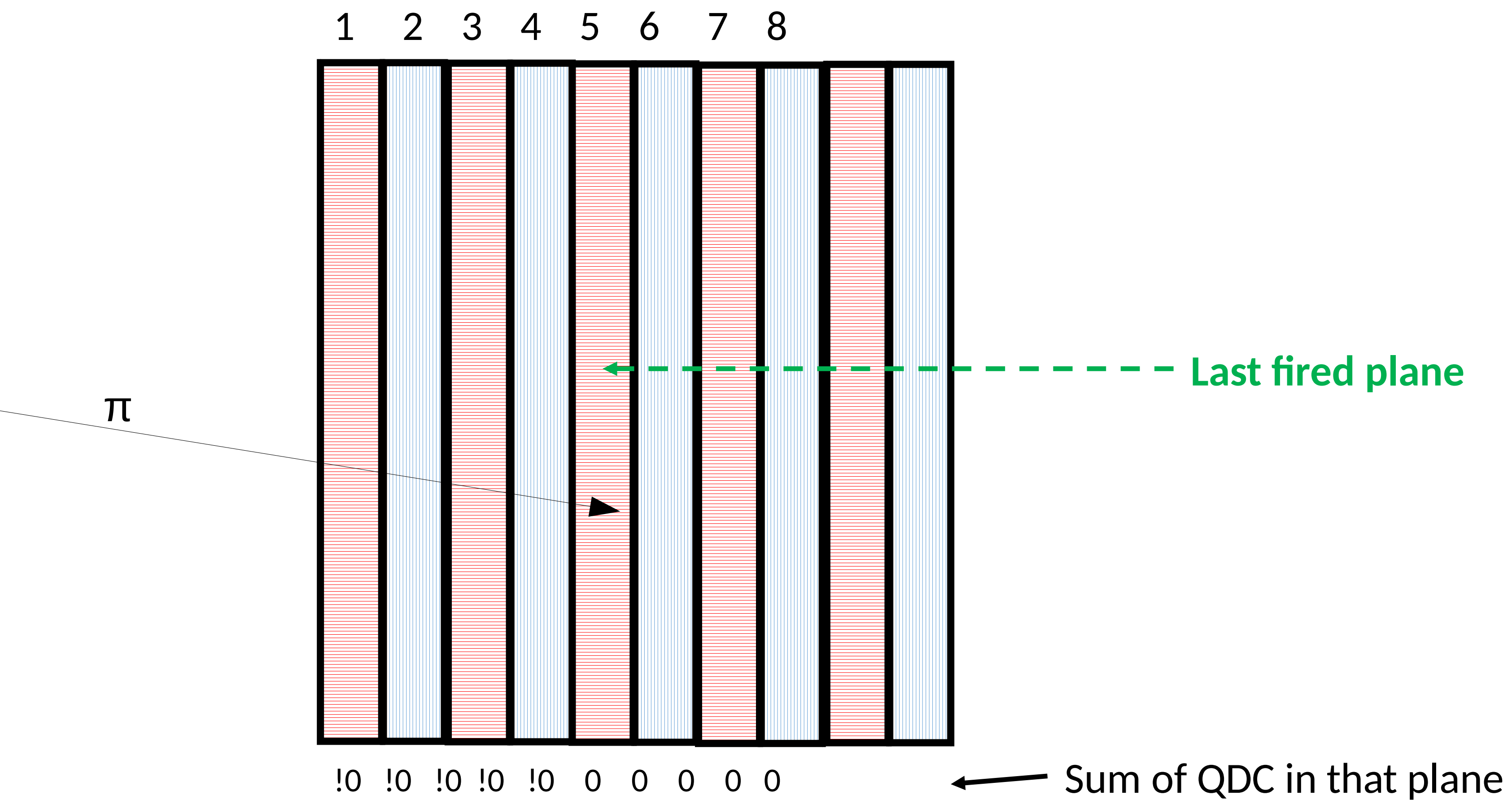


hits/segment



SciFi segment number

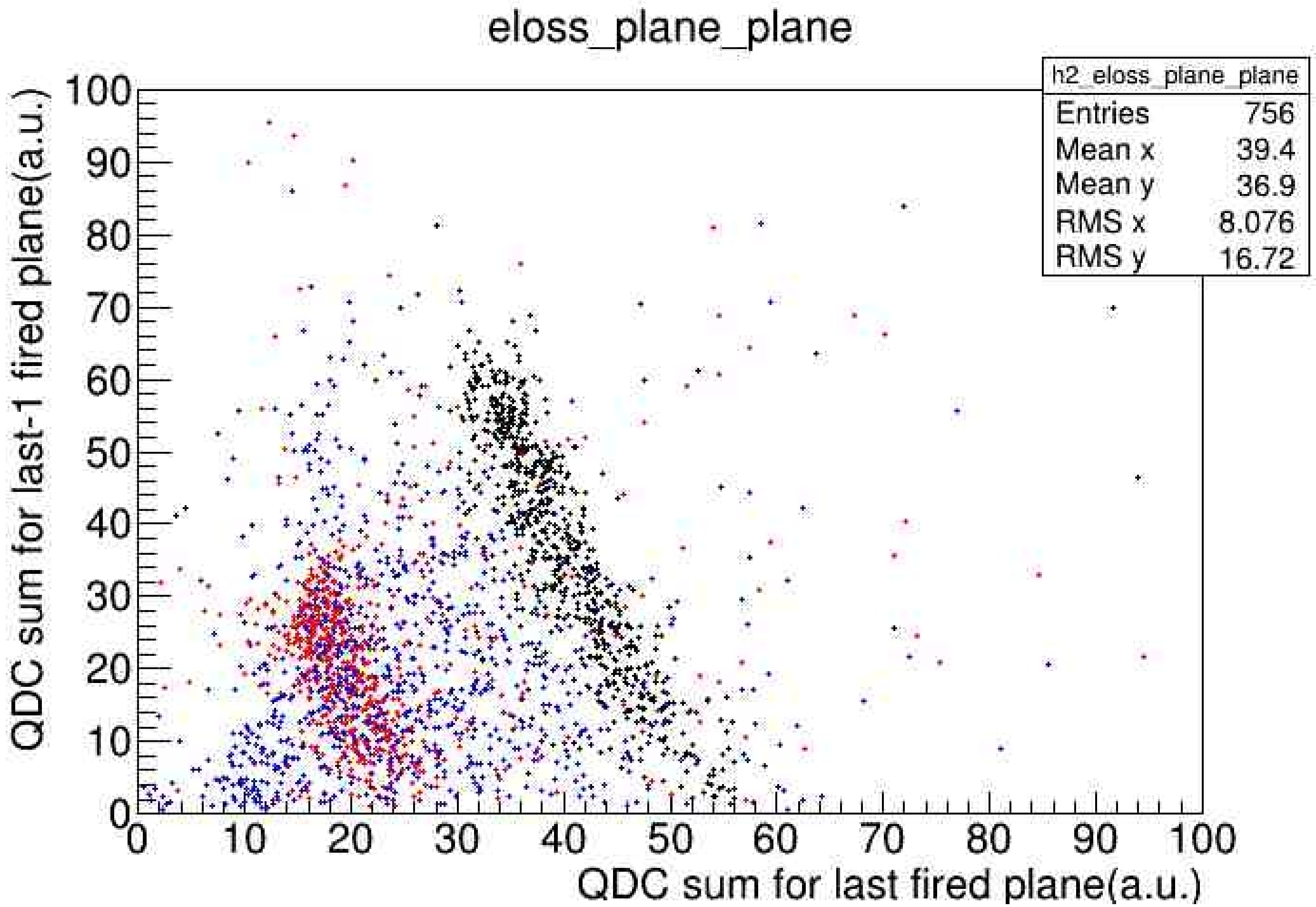
PIONS ???


1 2 3 4 5 6 7 8
Last fired plane
π
!0 !0 !0 !0 !0 0 0 0 0 0
Sum of QDC in that plane

Protons

pi+

pi-



NeuLAND can resolve pions from protons
but
can we distinguish pi+ from pi- ?

Beam energy dependence of charged pion ratio in ^{28}Si + In reactions

M. Sako[a,b,1,*], T. Murakami[a,b], Y. Nakai[b], Y. Ichikawa[a], K. Ieki[c], S. Imajo[a], T. Isobe[b], M. Matsushita[c], J. Murata[c], S. Nishimura[b], H. Sakurai[b], R.D. Sameshima[a], and E. Takada[d]

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[c]*Department of Physics, Rikkyo University, Tokyo 171-8501, Japan*
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https://arxiv.org/abs/1409.3322v1

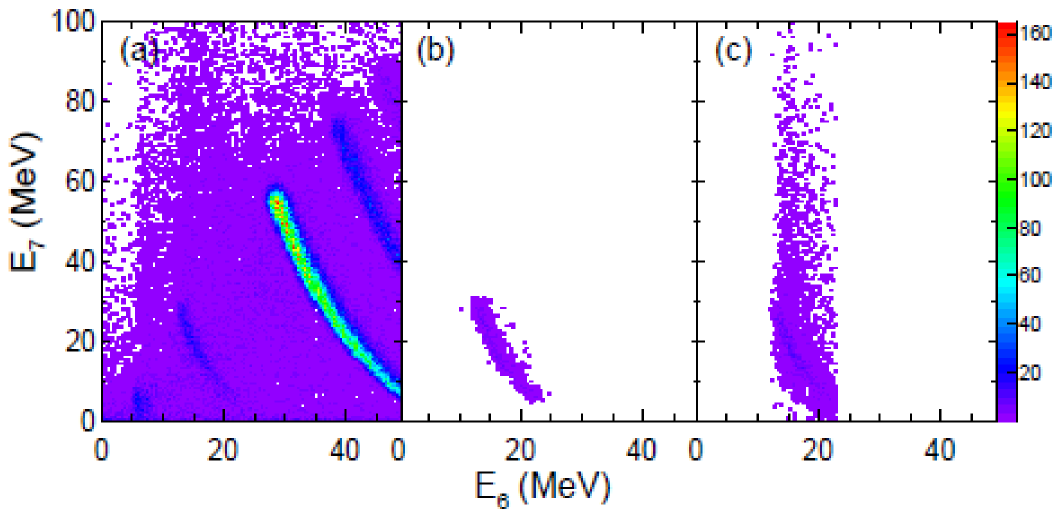

Figure 1: (Color online) Correlation of E_7 vs. E_6 with a beam energy of 600 MeV/nucleon at 60°. (a) All events with the condition of S_7. (b)π^+ event with the selection of a double pulse. (c) Charged pion events with the condition of S_7 and G_7.

The experiment was performed at the PH2 beam-line of the Heavy Ion Medical Accelerator in Chiba (HIMAC) in the National Institute of Radiological Science (NIRS). ^{28}Si beams were accelerated up to 400, 600, and 800 MeV/nucleon with a heavy-ion synchrotron. Typical beam intensities were about 1×10^7 particles per spill in a 3.3 sec cycle. A self-supporting natural indium plate (329 mg/cm^2 thick) was placed in a small vacuum chamber located at the end of the PH2-line.

Low-energy pion production with 800 MeV/N ^{20}Ne

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S. Nagamiya, H. Bowman, J. Ingersoll, and J. O. Rasmussen
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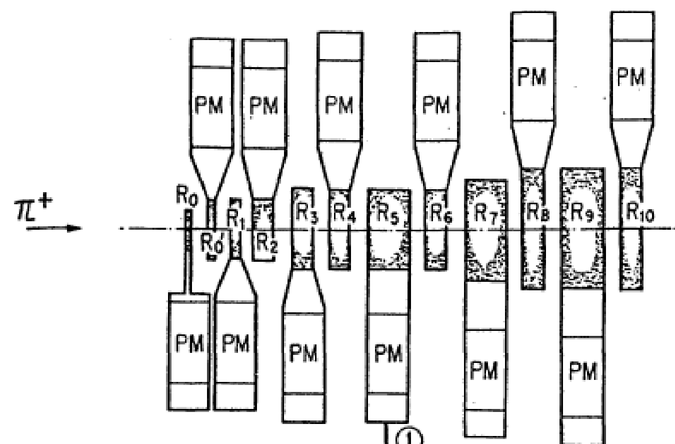
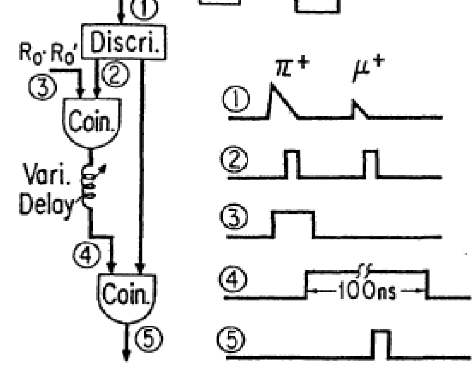
(Received 2 February 1979)



S I Z E (mm)	
R_0	3.2x 50.8x 50.8
R_0'	6.3x 76.2x 76.2
R_1	12.7x 76.2x 76.2
R_2	25.4x 76.2x 76.2
R_3	25.4x101.6x101.6
R_4	25.4x101.6x101.6
R_5	50.8x101.6x101.6
R_6	25.4x101.6x101.6
R_7	50.8x127.0x127.0
R_8	25.4x152.4x152.4
R_9	50.8x152.4x152.4
R_{10}	25.4x152.4x152.4



Summary

- *MD* codes extremely useful to design experiments and detectors
- Estimated trigger efficiency for the SPiRIT experiment
- Optimal design of the Trigger/Reaction Plane detector for the ASY-EOS II
- Detection of pions with NeuLAND feasible (?)

A wish:

- Please do not give up!
- Please provide us “model independent” predictions on pion sensitivity to the symmetry energy (or predictions with “theoretical” error bars).
- Could it be possible to have, as the main outcome of the code comparison project, one QMD-like and one BUU-like best compromise, open source, user tunable and user friendly code? (with clustering, if possible...) → a'la UrQMD but with reasonable EOS for symmetry energy studies