Overview of the HypHI Phase 0 and 0.5 experiments at GSI

GSI – Darmstadt, Germany
Dept. of Physics, The University of Tokyo

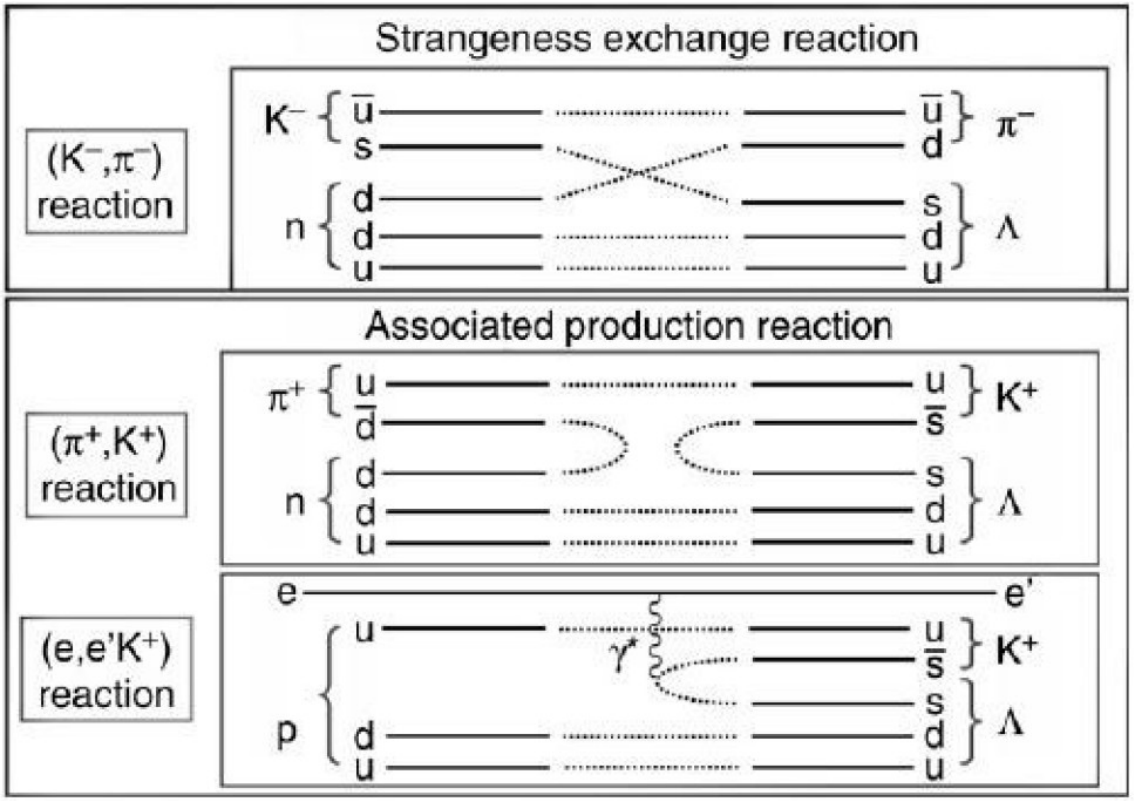
Daisuke Nakajima

Hypernuclear spectroscopy

Updated from: O. Hashimoto and H. Tamura, Prog. Part. Nucl. Phys. 57 (2006) 564.

Intensively studied by
meson, electron beam induced
reaction
(CERN, KEK, BNL, J-Lab)

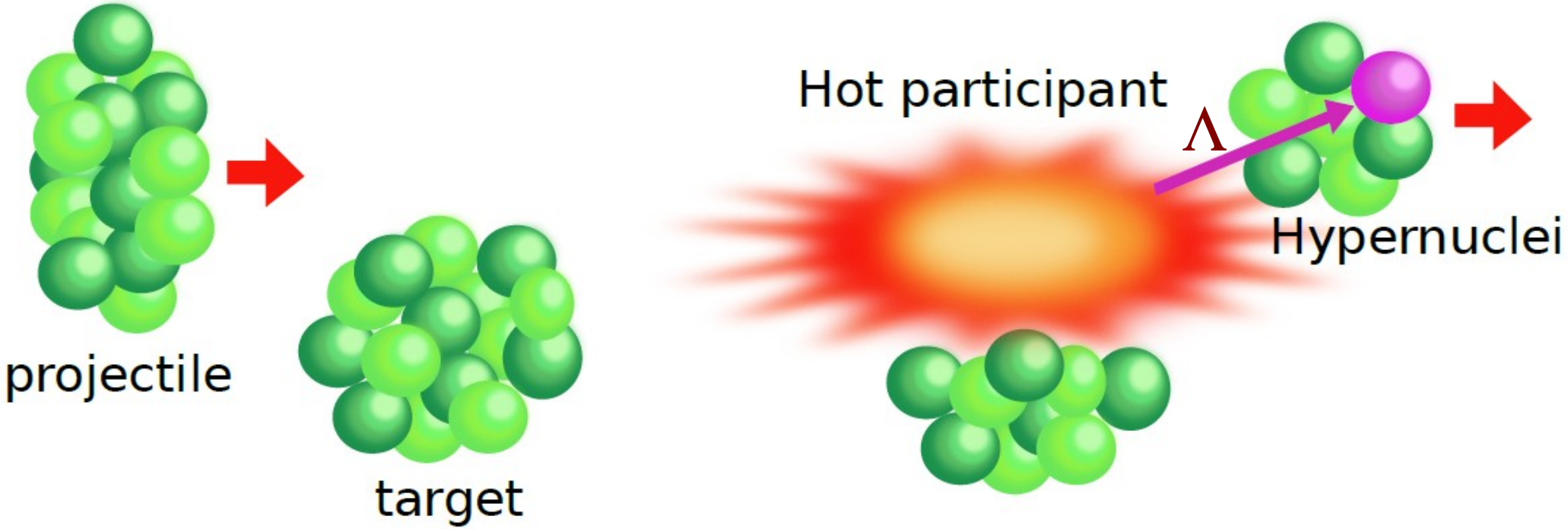
- **Precise spectroscopy**
- **Hypernuclear structure**



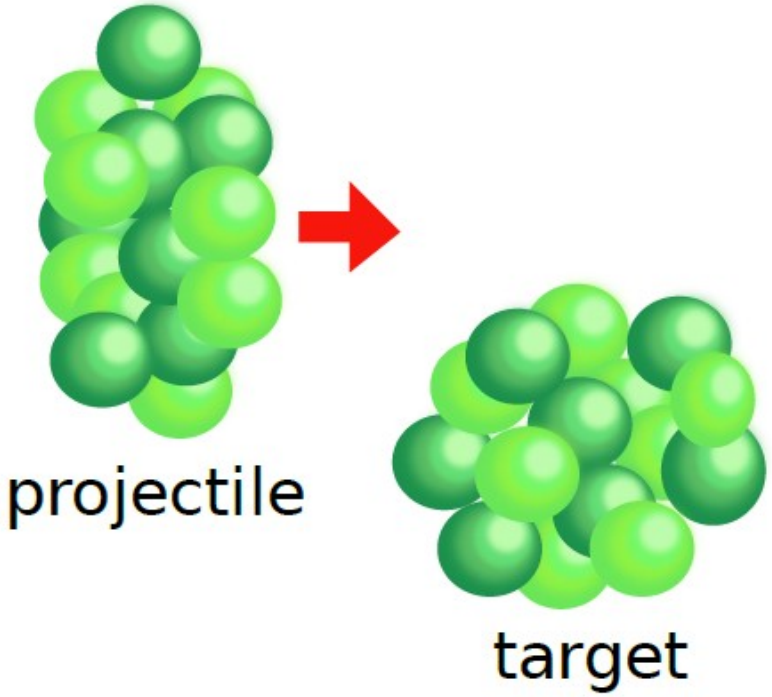
Another complemental approach with **heavy ion beam**

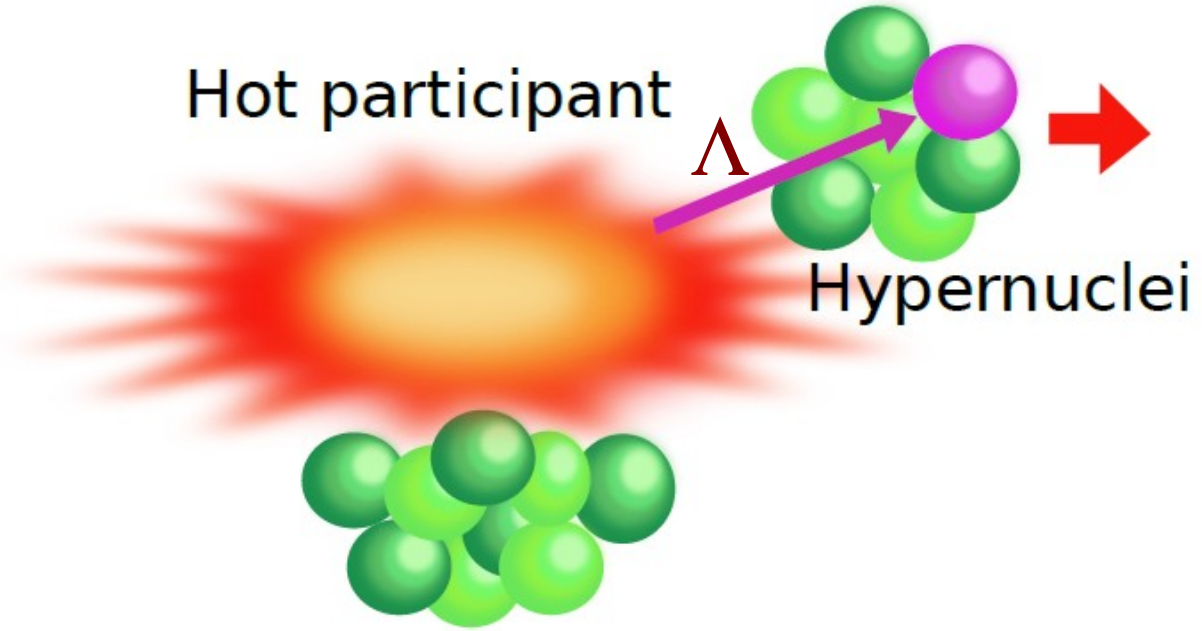
- **Proton/Neutron rich Hypernuclei**
- **Decay of Hypernucleai**
- **Magnetic moments**

Production of Hypernuclei with HypHI

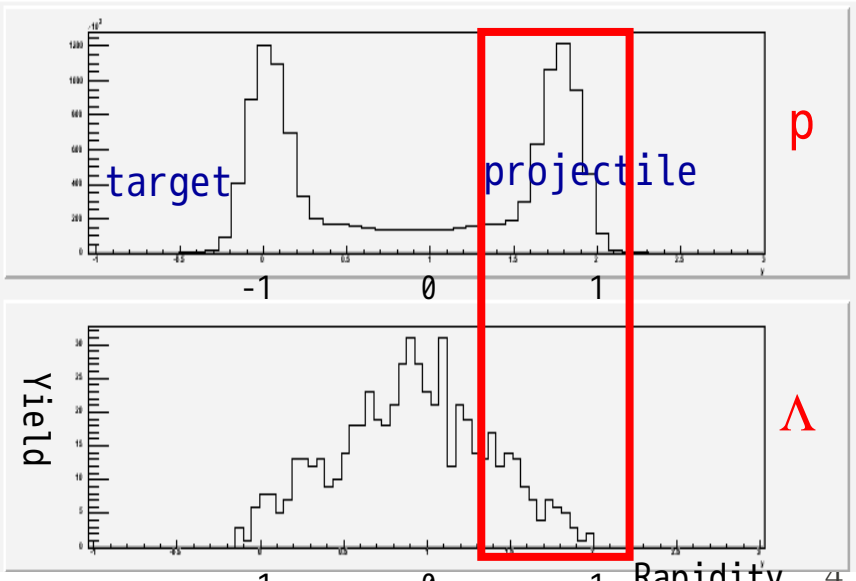


Production of Hypernuclei with HypHI

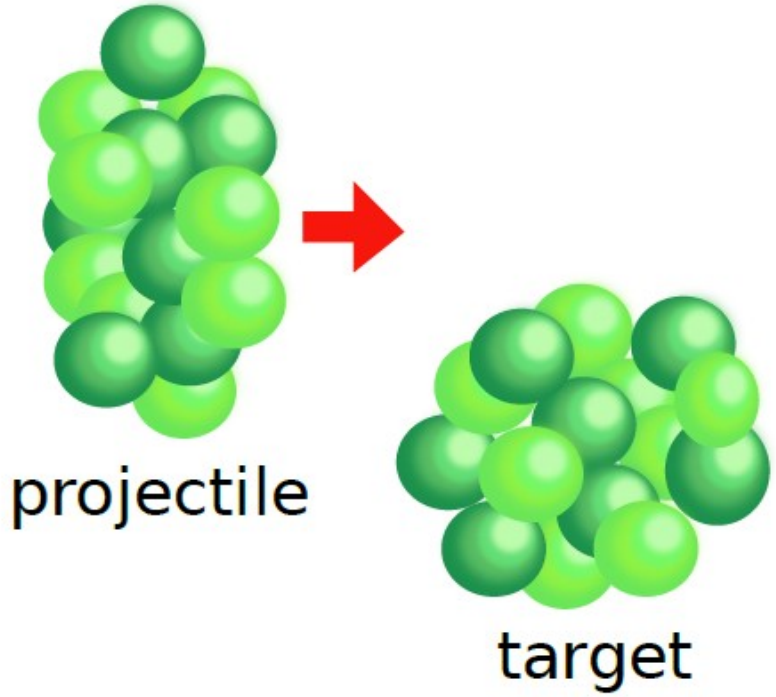


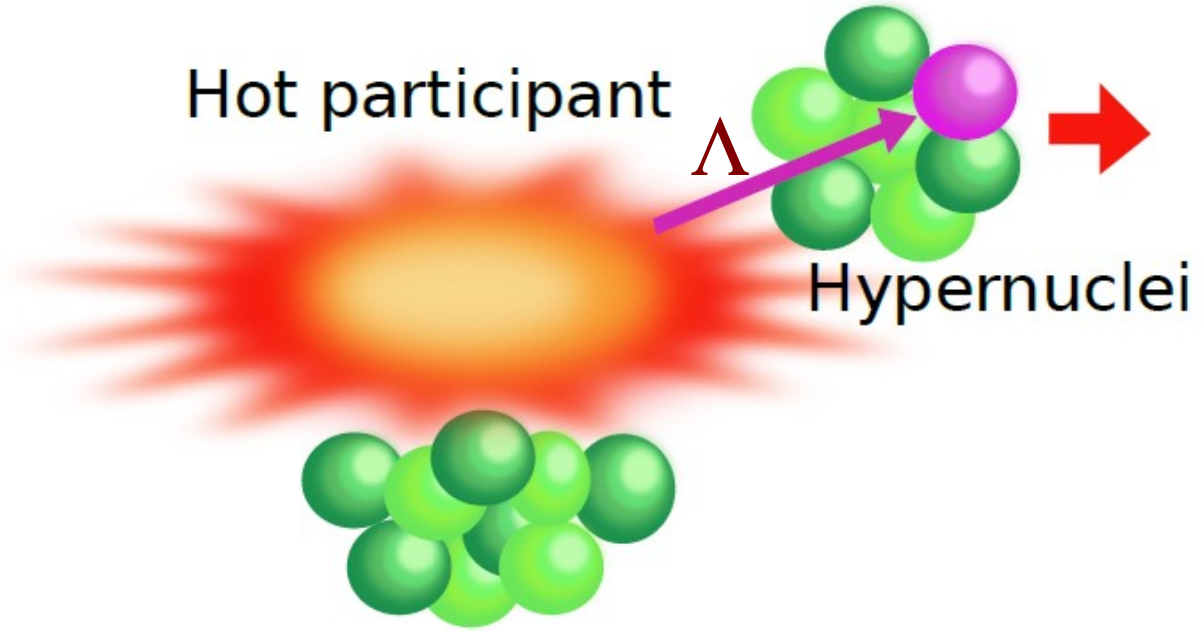


Coalescence of Λ in projectile fragments



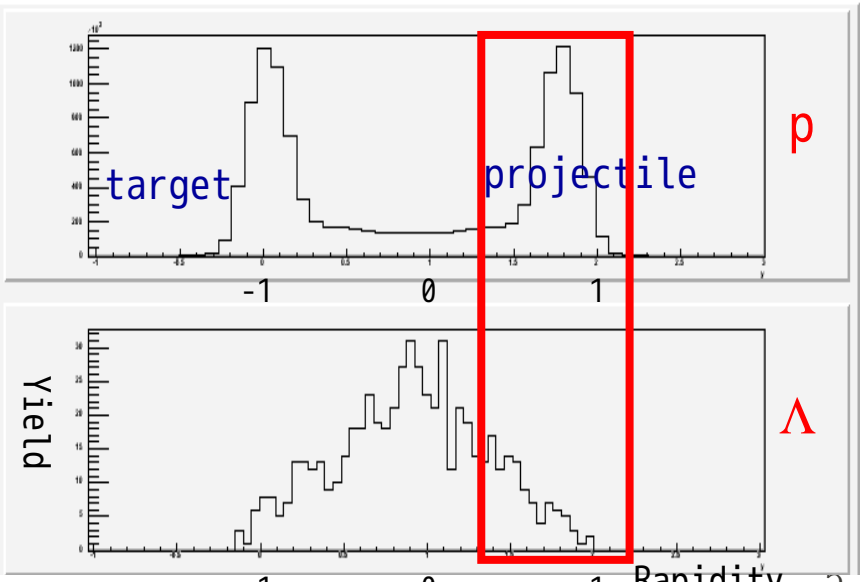
Production of Hypernuclei with HypHI



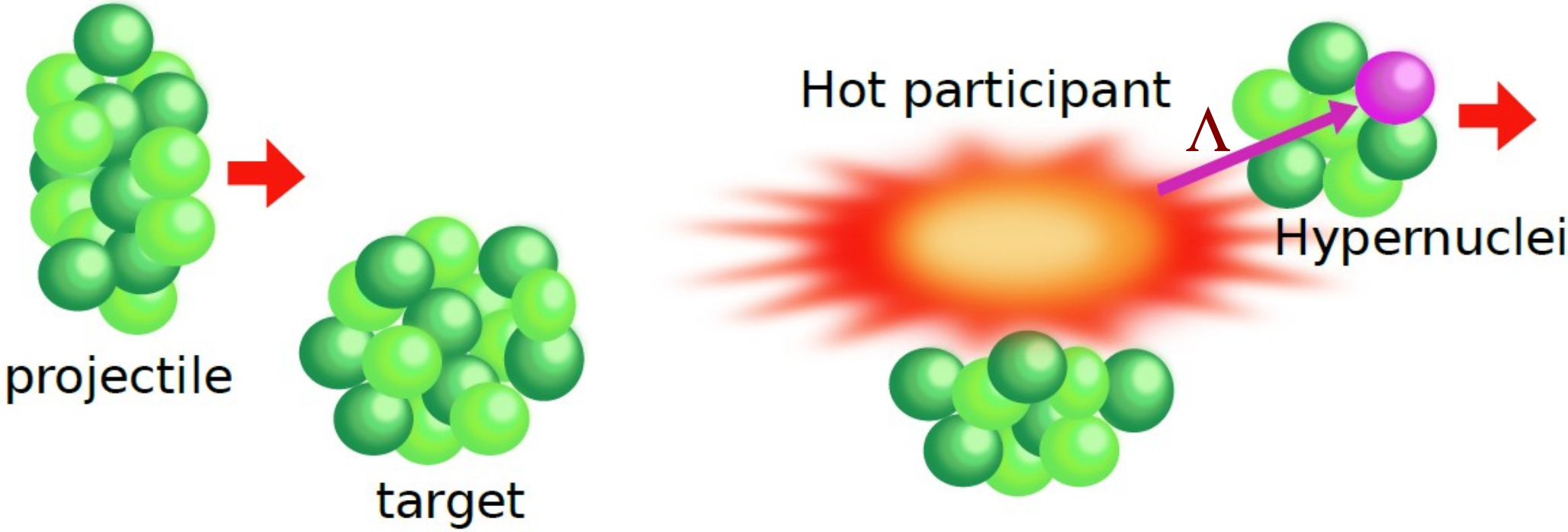


Coalescence of Λ in projectile fragments

NN->ΛKN energy threshold : ~ 1.6 GeV
- Available at GSI (~ 2 A GeV)
- Future facility FAIR (>20 A GeV)
- RI-beam from FRS, super-FRS



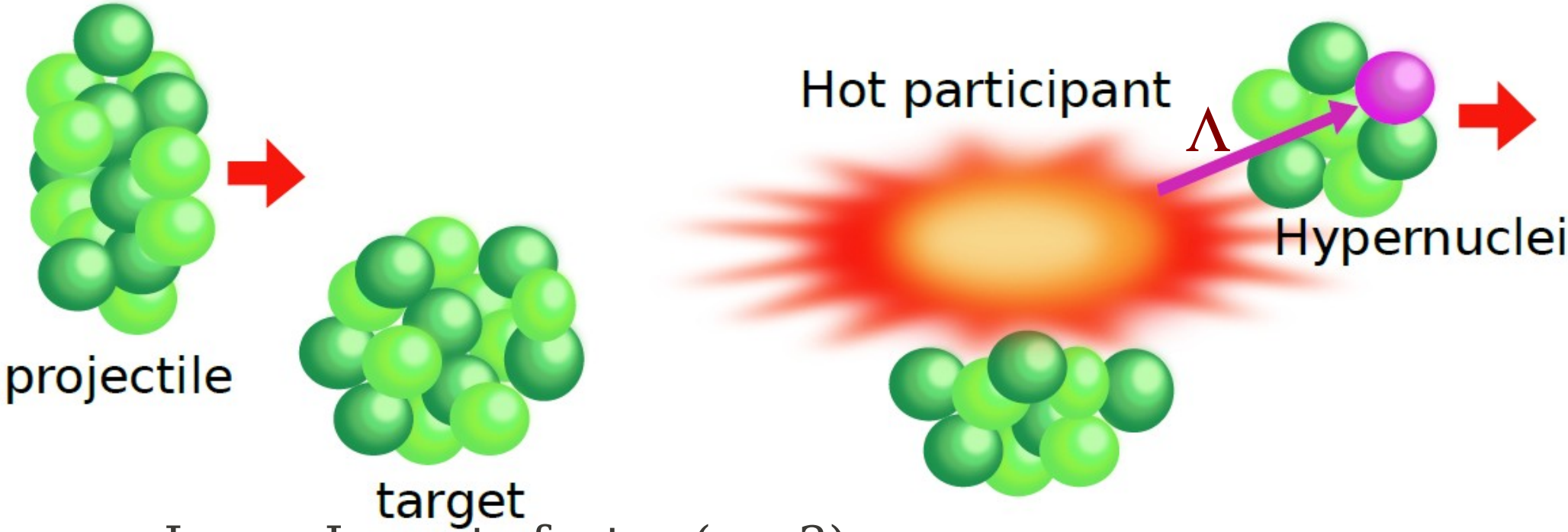
Proton/neutron rich Hypernuclei



- Hypernuclei smaller mass number than a projectile can be produced
- RI-beam available : Enhanced production of hypernuclei at drip-line

Hypernuclei far from the β-stability line

Relativistic Hypernuclei



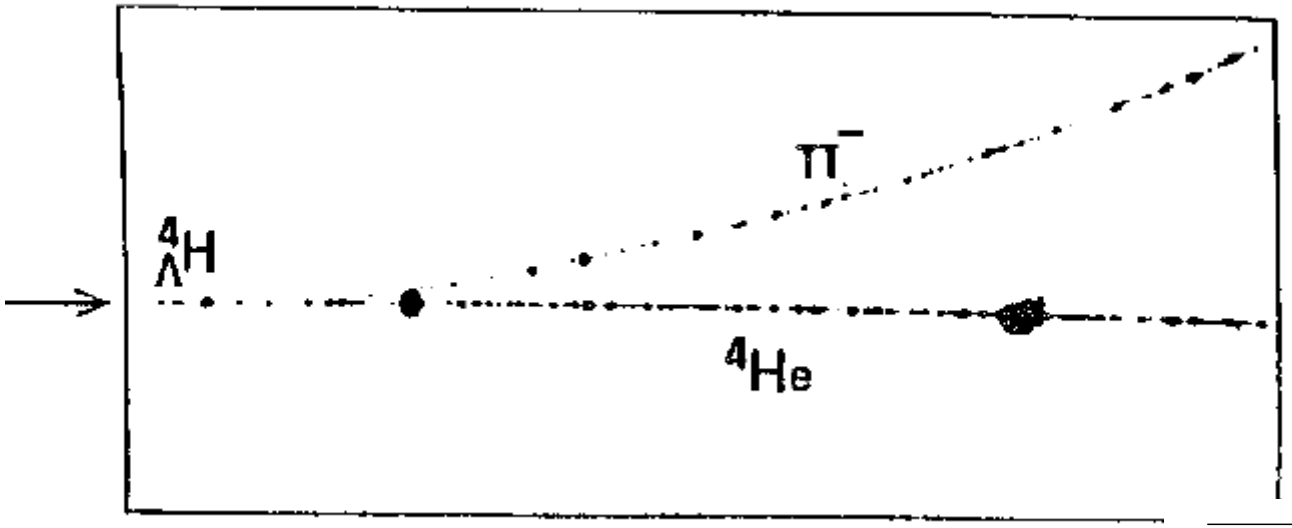
Large Lorentz factor (γ >3)
– longer effective life time

200 ps → 600 ps (γ ~ 3) at GSI : cτ ~ 20 cm
200 ps → 4 ns (γ ~20) at FAIR : cτ ~ 120 cm

Study hypernuclei in flight

- Life time measurement
- Direct measurement of hypernuclear magnetic moments

Heavy ion induced reaction at Dubna (1989)



^{4}He beams at 3.7 GeV on a polyethylene target
^{7}Li beams at 3.0 GeV on a polyethylene target

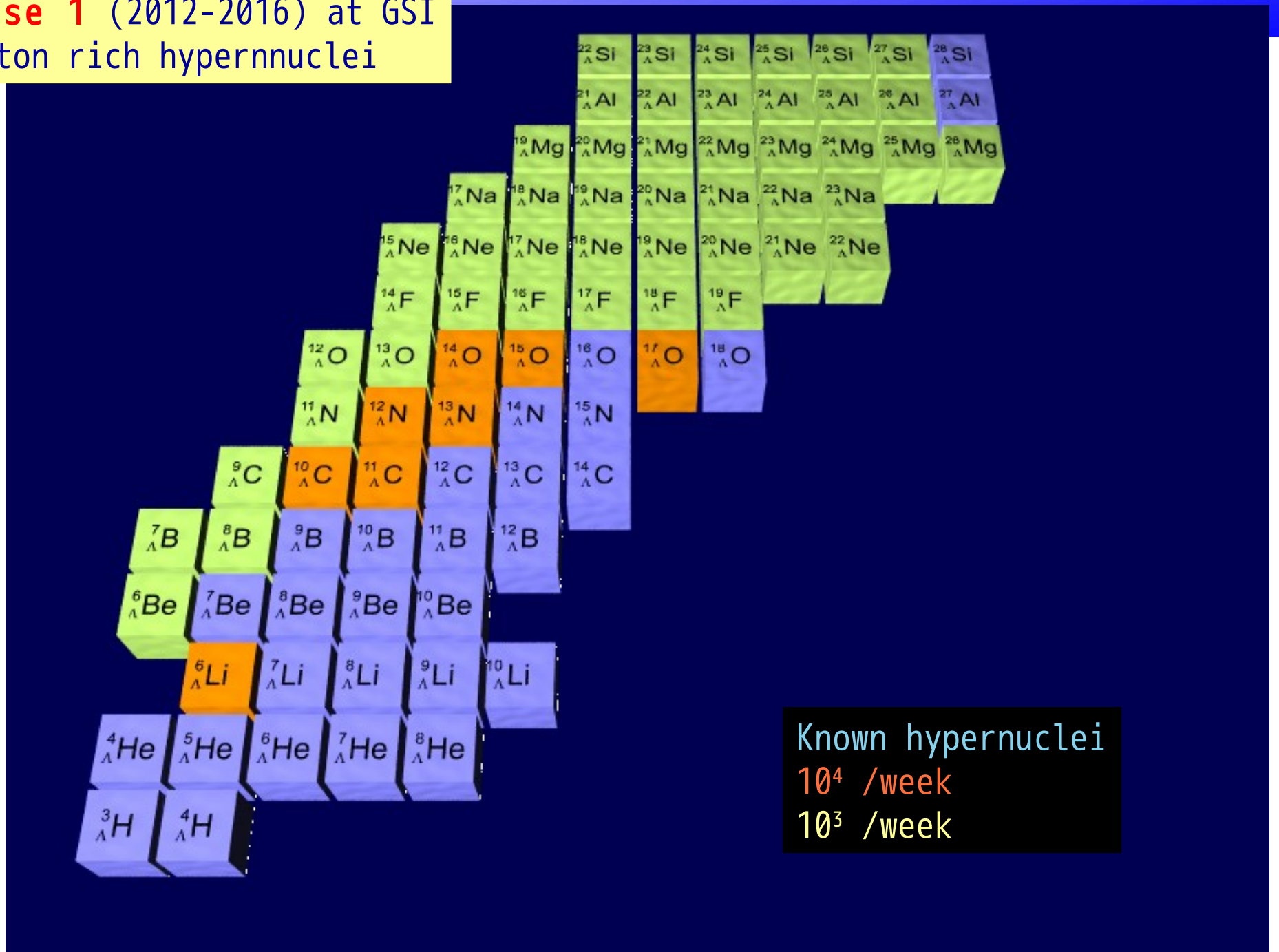
Cross section : ~ 0.1 μb

Reaction	Energy [A GeV]	Theoretical cross section [μb]	Experimental cross section [μb]
^{3}He+C$\rightarrow^3_\Lambda$H+X	5.14	0.03	$0.05^{+0.05}_{-0.02}$
^{4}He+C$\rightarrow^3_\Lambda$H+X	3.7	0.06	< 0.1
^{4}He+C$\rightarrow^4_\Lambda$H+X	2.2	0.08	< 0.08
	3.7	0.29	$0.4^{+0.4}_{-0.2}$
^{6}Li+C$\rightarrow^3_\Lambda$H+X	3.7	0.09	$0.2^{+0.3}_{-0.15}$
^{6}Li+C$\rightarrow^4_\Lambda$H+X	3.7	0.20	$0.3^{+0.3}_{-0.15}$
^{6}Li+C$\rightarrow^5_\Lambda$He+X	3.7	0.83	
^{6}Li+C$\rightarrow^7_\Lambda$Li+X	3.7	0.16	
^{7}Li+C$\rightarrow^3_\Lambda$H+X	3.0	0.22	
^{7}Li+C$\rightarrow^4_\Lambda$H+X	3.0	0.68	
^{7}Li+C$\rightarrow^5_\Lambda$He+X	3.0	0.84	
^{7}Li+C$\rightarrow^6_\Lambda$He+X	3.0	0.25	< 0.5
^{7}Li+C$\rightarrow^7_\Lambda$Li+X	3.0	0.11	< 1
^{12}C+C$\rightarrow^3_\Lambda$H+X	3.7	0.22	
^{12}C+C$\rightarrow^4_\Lambda$H($^4_\Lambda$He)+X	3.7	0.39	
^{12}C+C$\rightarrow^5_\Lambda$He+X	3.7	2.58	
^{12}C+C$\rightarrow^6_\Lambda$He+X	3.7	0.32	
^{12}C+C$\rightarrow^{12}_\Lambda$C+X	3.7	0.18	

Present hypernuclear landscape

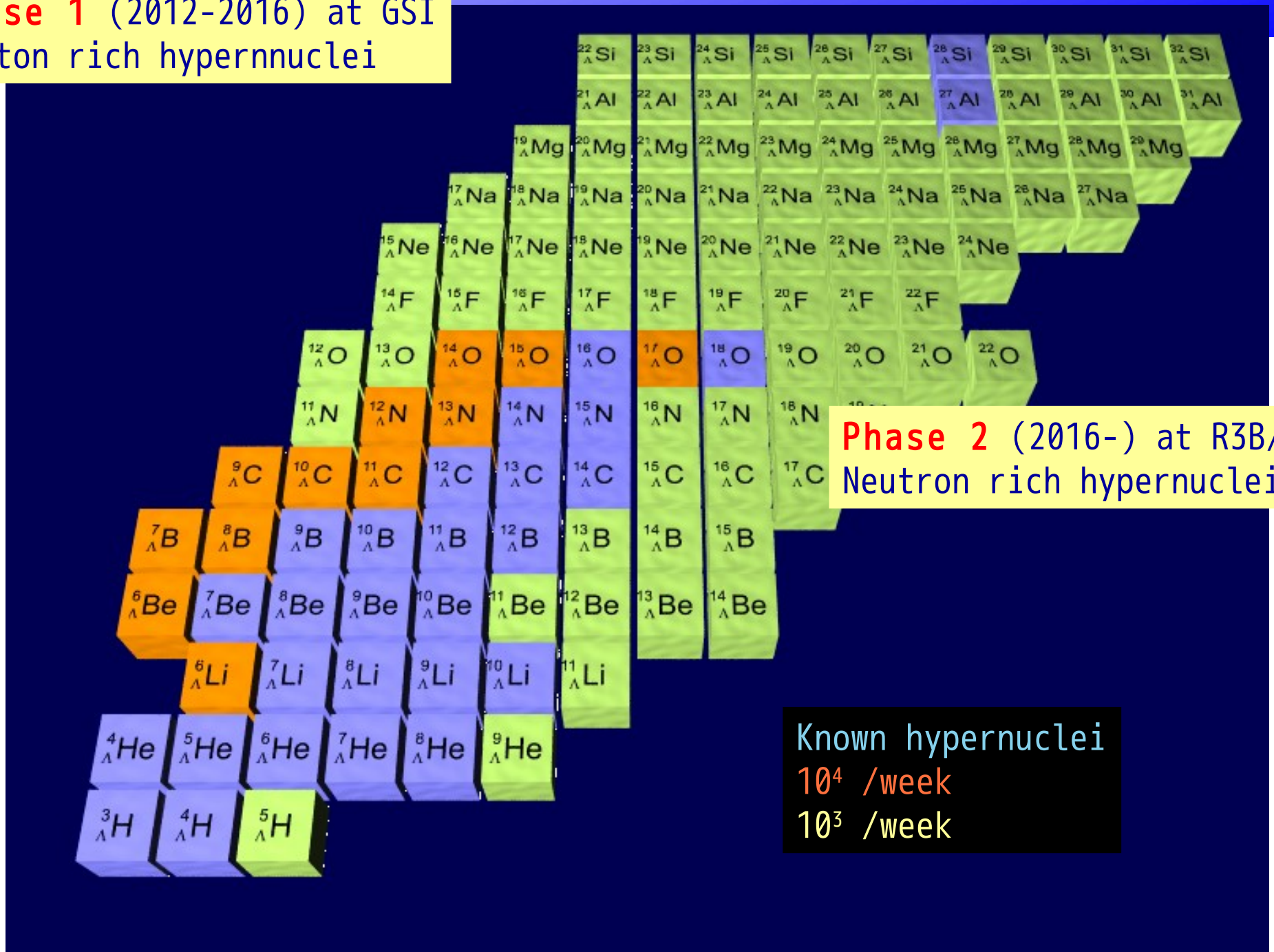
Hypernuclear landscape with HypHI

Phase 1 (2012-2016) at GSI
Proton rich hypernnuclei



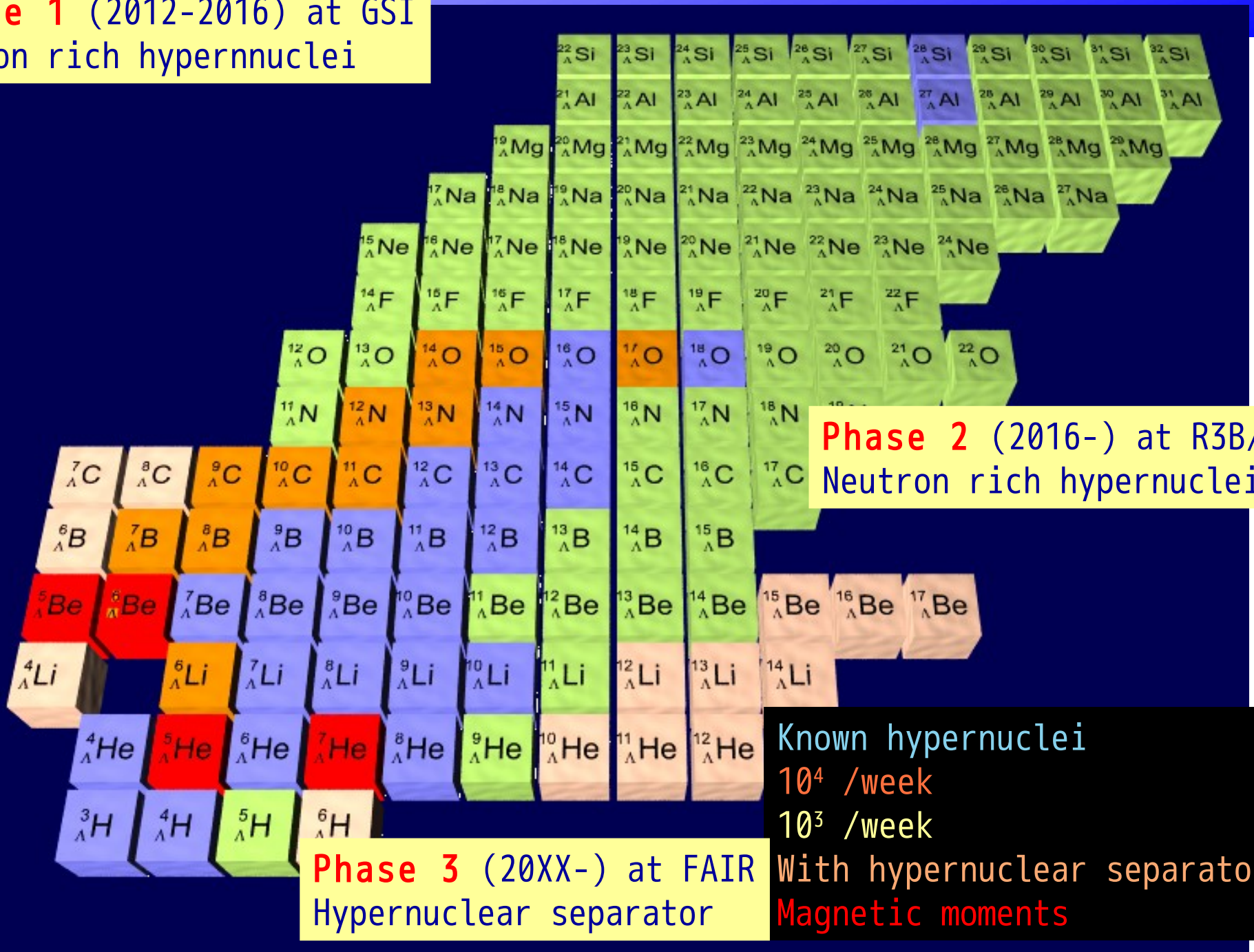
Hypernuclear landscape with HypHI

Phase 1 (2012-2016) at GSI
Proton rich hypernnuclei



Hypernuclear landscape with HypHI

Phase 1 (2012-2016) at GSI
Proton rich hypernnuclei



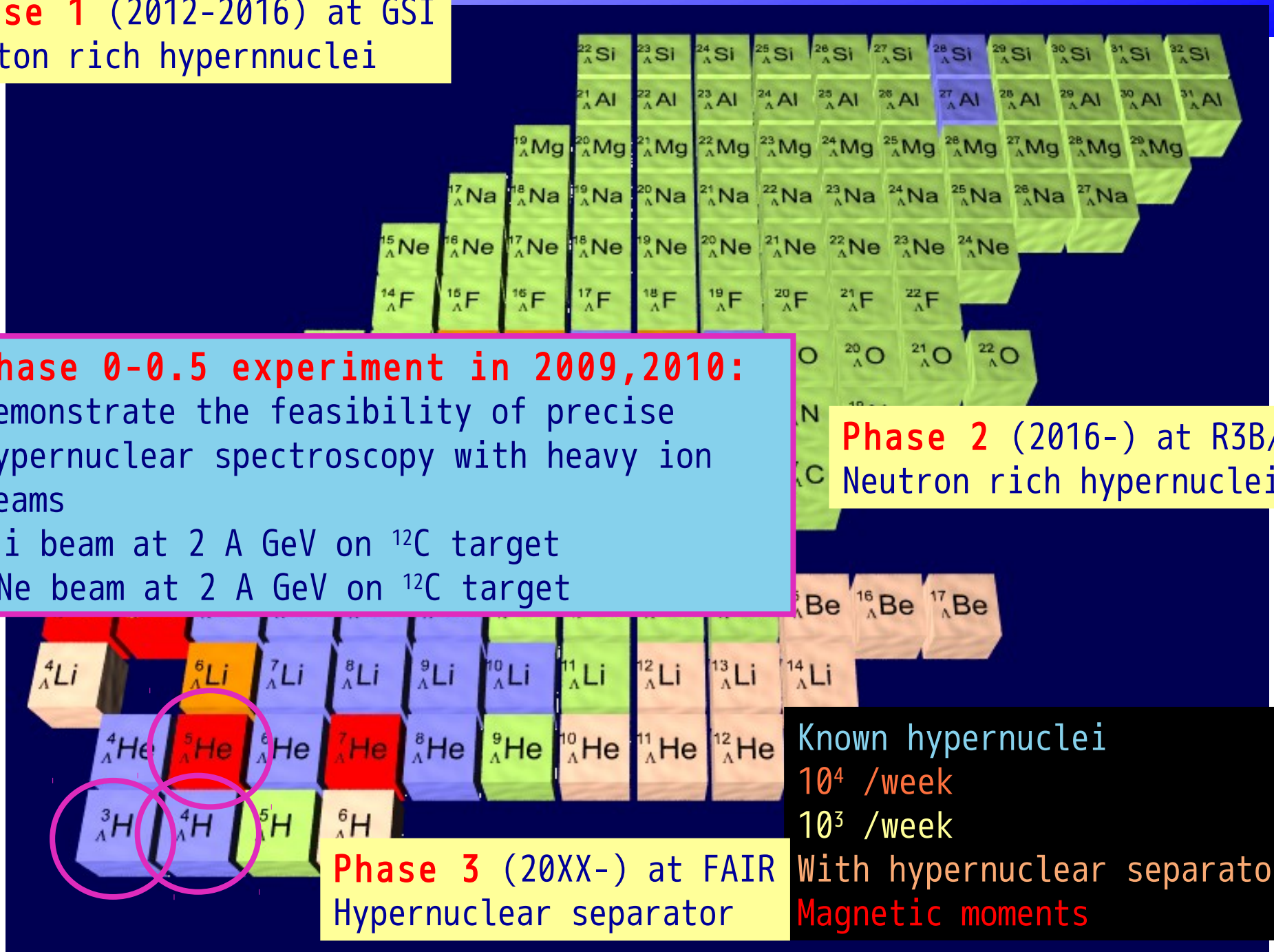
Phase 2 (2016-) at R3B/FAIR
Neutron rich hypernuclei

Phase 3 (20XX-) at FAIR
Hypernuclear separator

Known hypernuclei
10^4 /week
10^3 /week
With hypernuclear separator
Magnetic moments

Hypernuclear landscape with HypHI

Phase 1 (2012-2016) at GSI
Proton rich hypernnuclei



Phase 0-0.5 experiment in 2009,2010:
Demonstrate the feasibility of precise hypernuclear spectroscopy with heavy ion beams
^{6}Li beam at 2 A GeV on ^{12}C target
^{20}Ne beam at 2 A GeV on ^{12}C target

Phase 2 (2016-) at R3B/FAIR
Neutron rich hypernuclei

Phase 3 (20XX-) at FAIR
Hypernuclear separator

Known hypernuclei
10^4 /week
10^3 /week
With hypernuclear separator
Magnetic moments

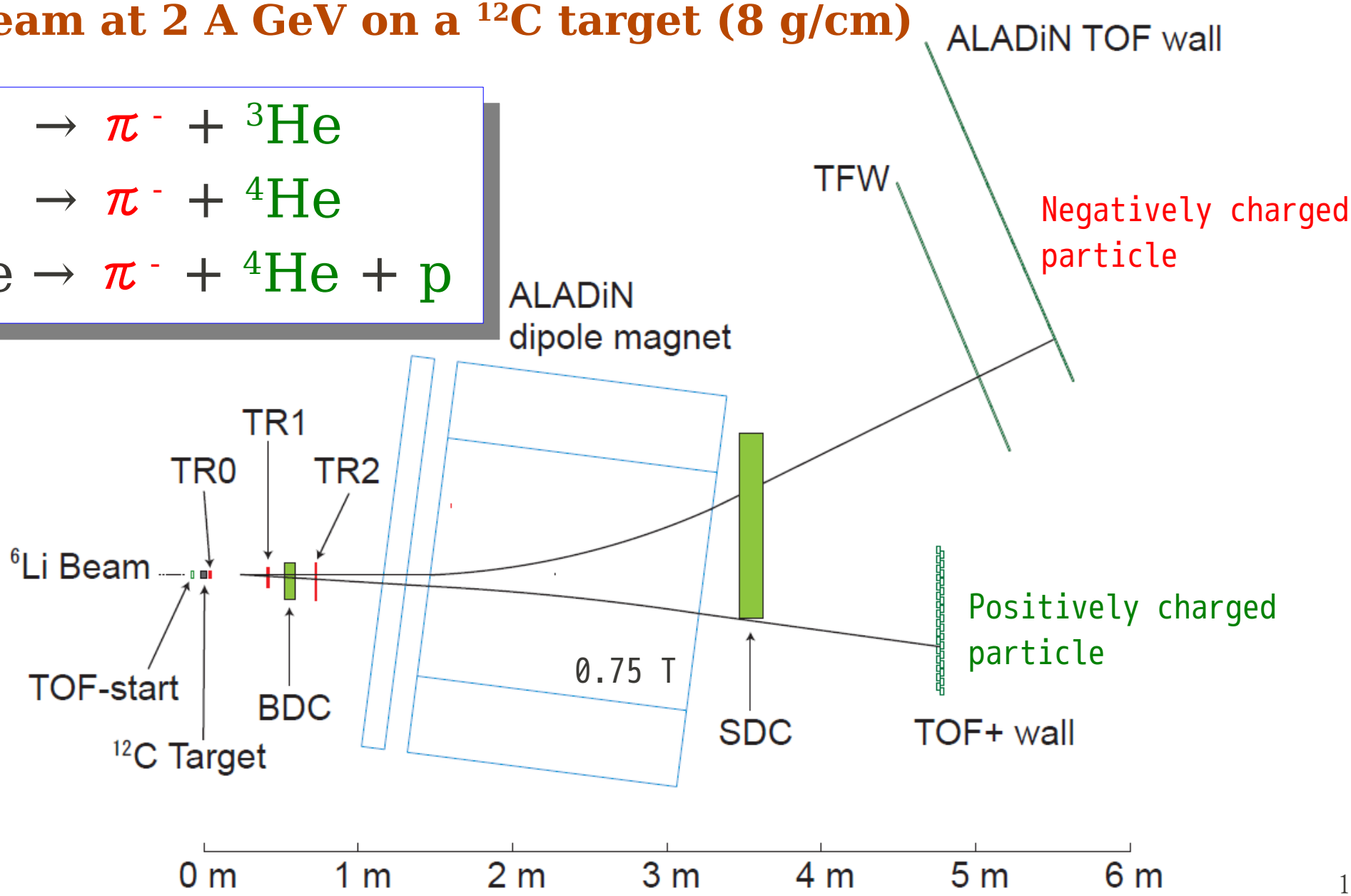
HypHI Phase 0 experiment
Oct. 2009

^{6}Li beam at 2 A GeV on a ^{12}C target (8 g/cm)

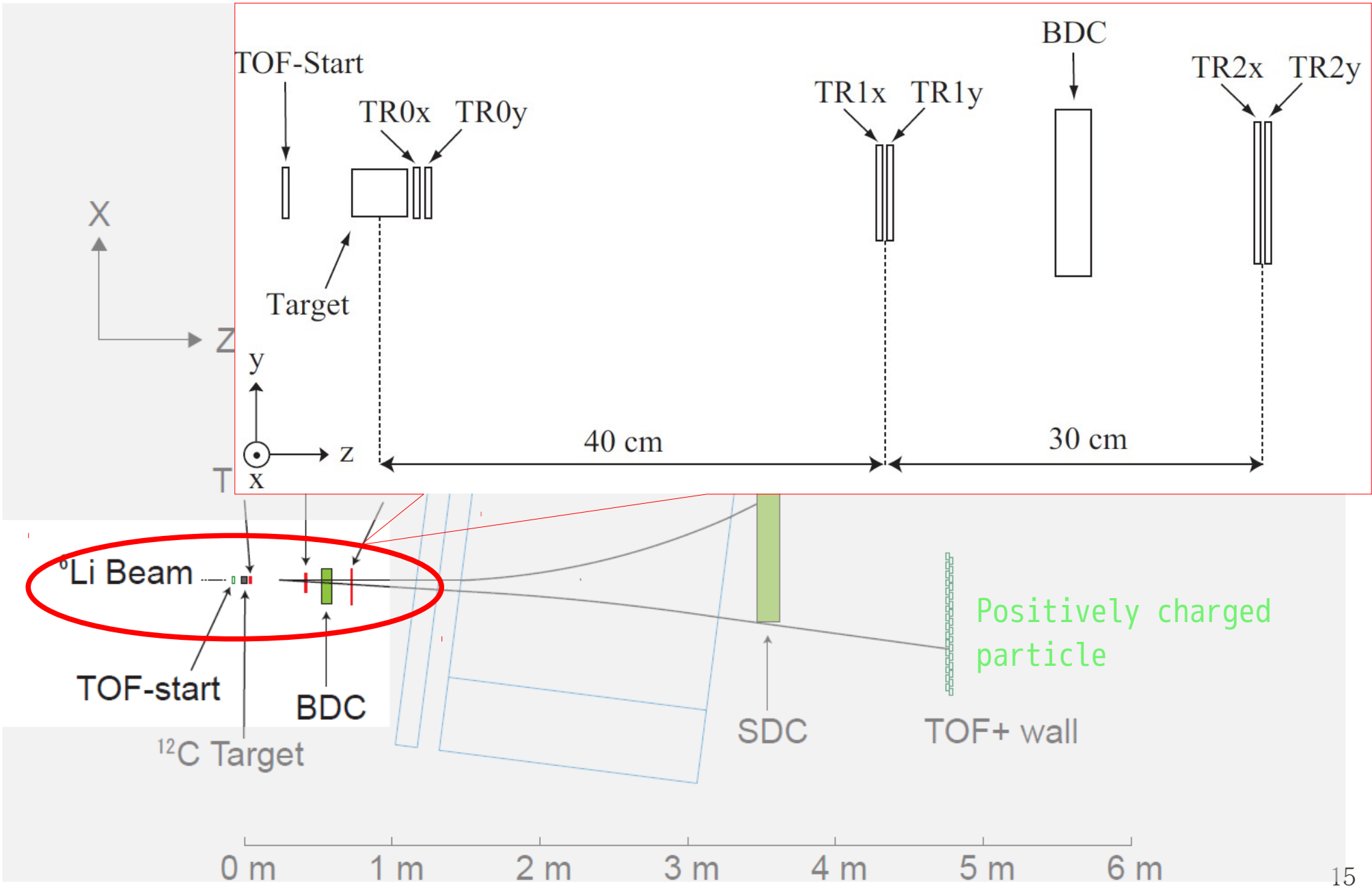
$^{3}_{\Lambda}H \rightarrow \pi^{-} + {}^{3}He$

$^{4}_{\Lambda}H \rightarrow \pi^{-} + {}^{4}He$

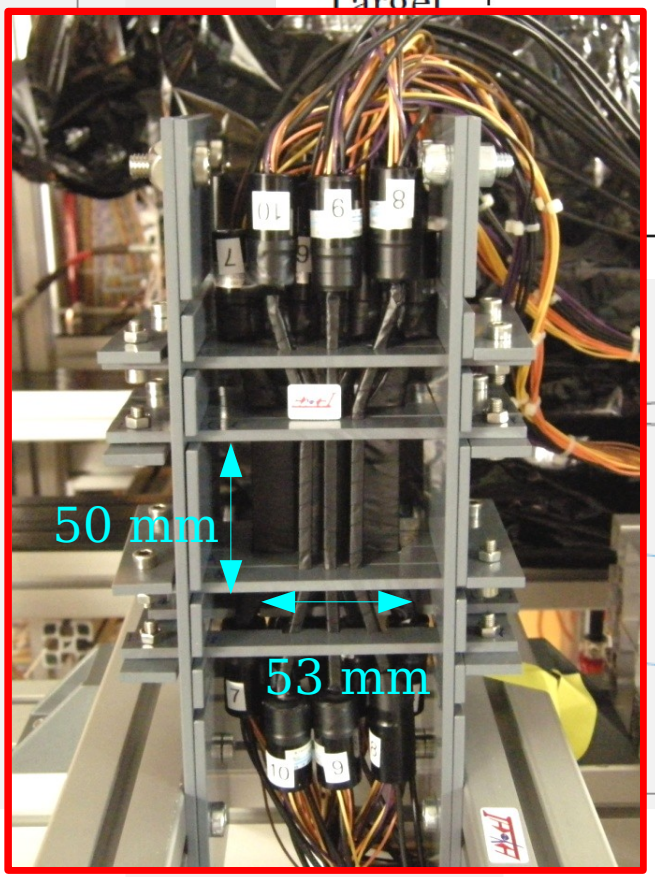
$^{5}_{\Lambda}He \rightarrow \pi^{-} + {}^{4}He + p$



Setup upstream

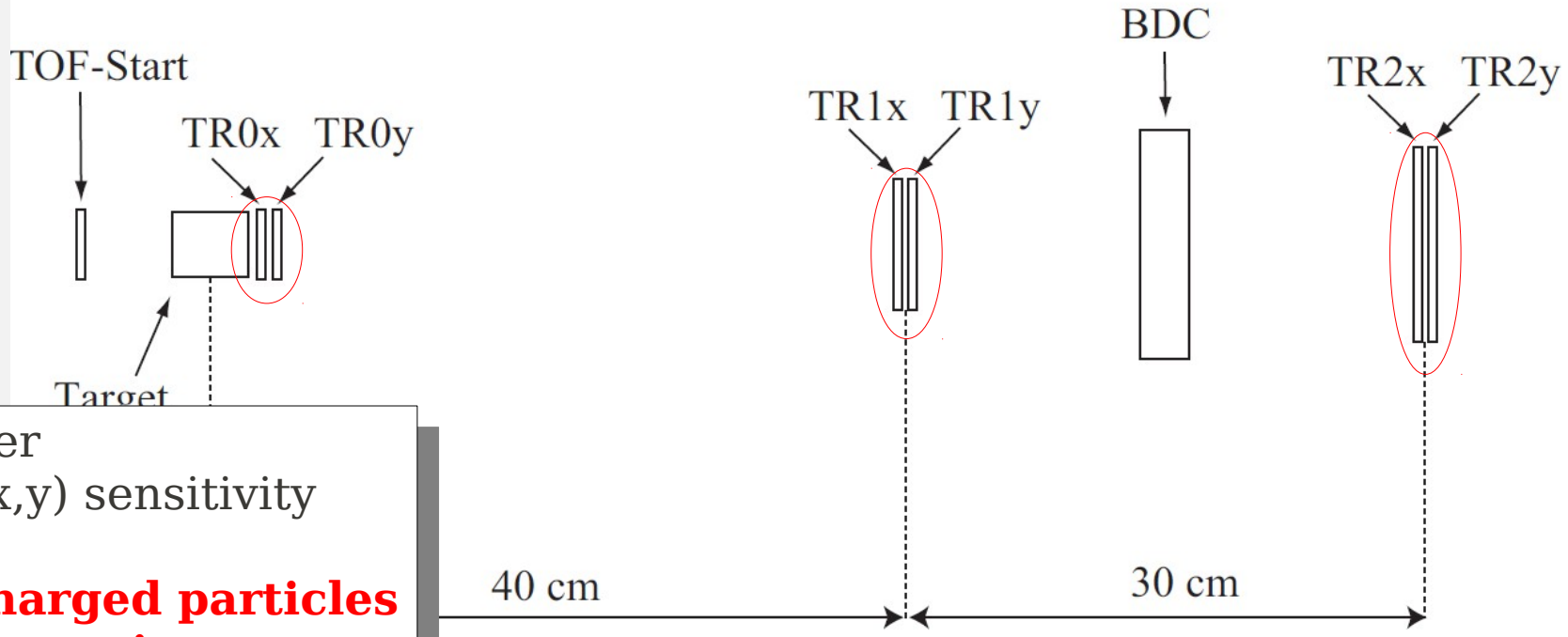


TOF – start


50 mm
53 mm

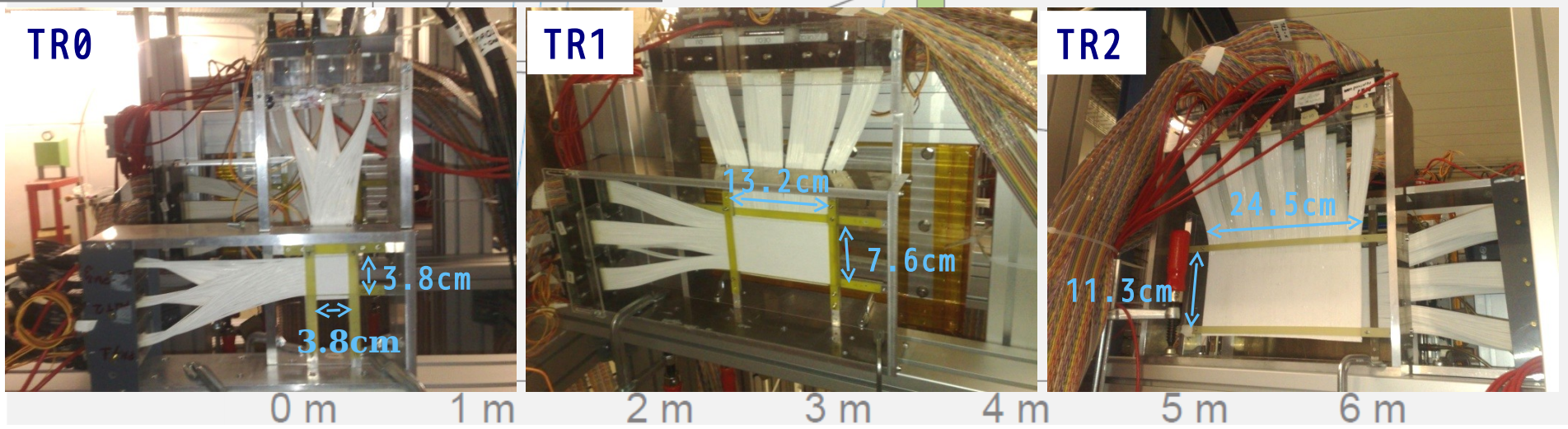
TOF-Start
TR0x TR0y
Target
X
BDC
TR1x TR1y
TR2x TR2y
10 segmented plastic scintillator bar
Start timing of Time-Of-Flight
σ~300 ps
Positively charged particle
SDC
TOF+ wall
2 m
3 m
4 m
5 m
6 m

Scintillating Fiber Detector

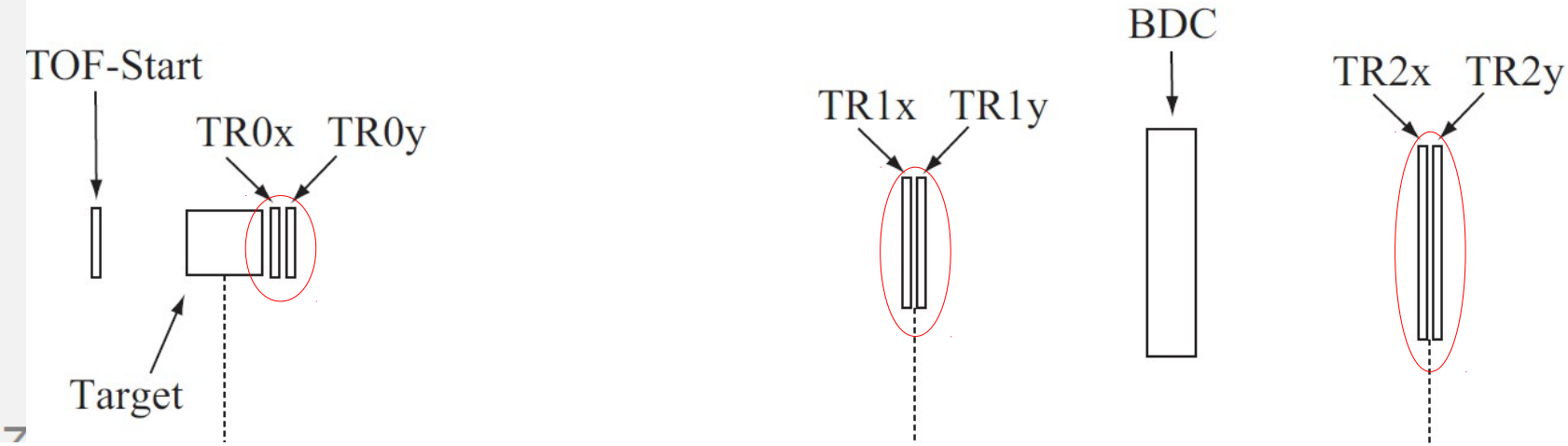


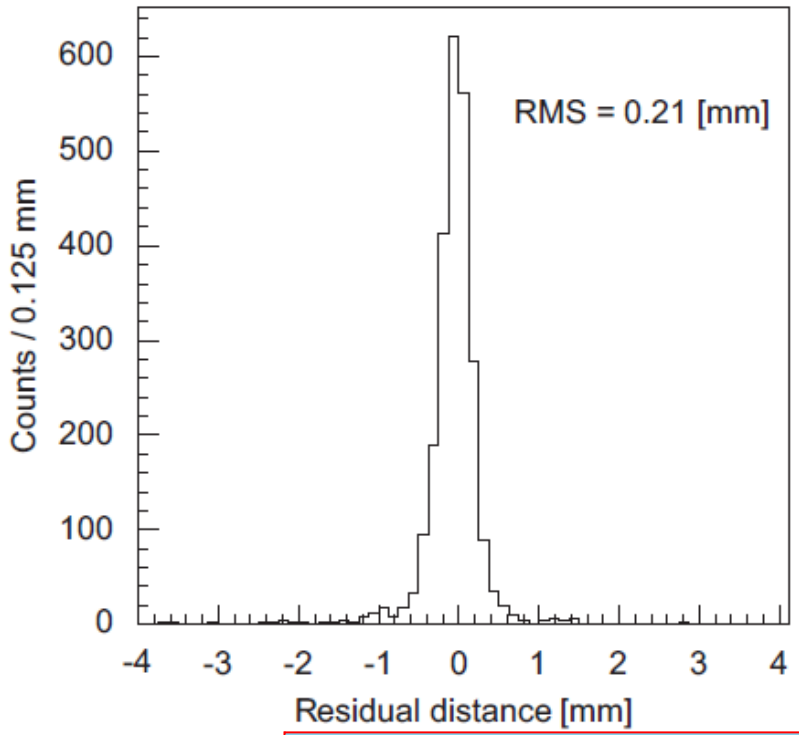
Scintillating fiber
2 dimentional (x,y) sensitivity

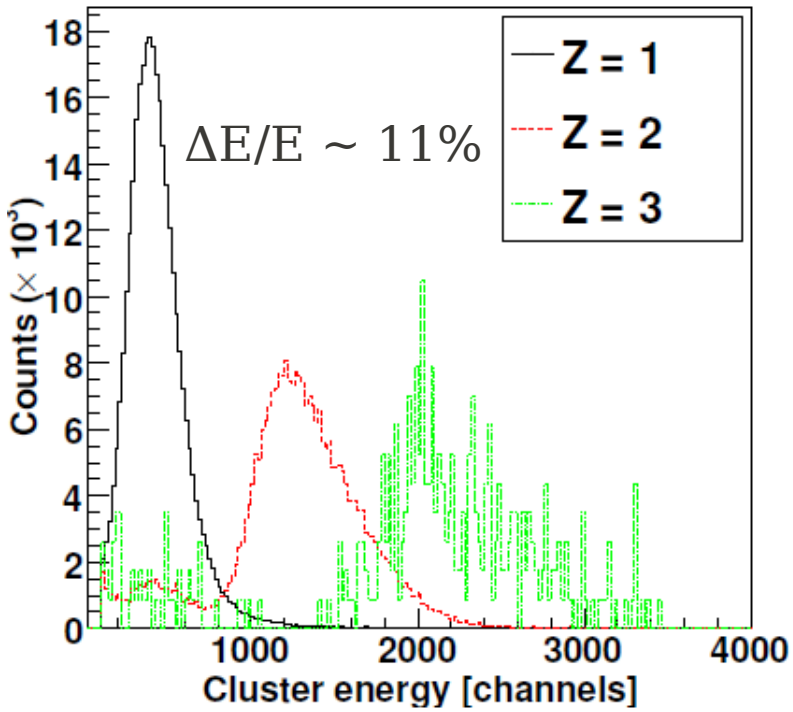
Tracking all charged particles
Secondary vertex trigger



Scintillating Fiber Detector



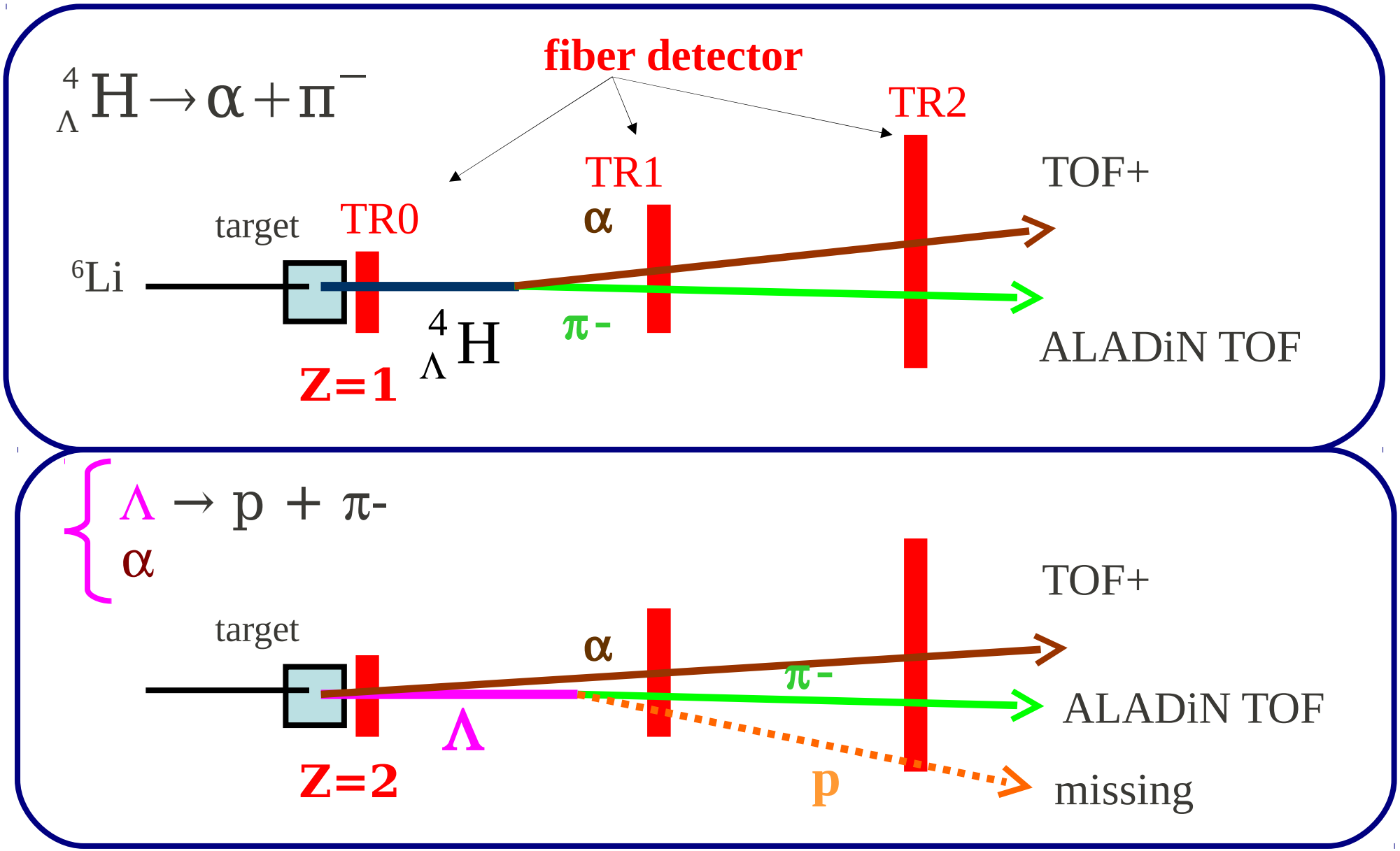




charged

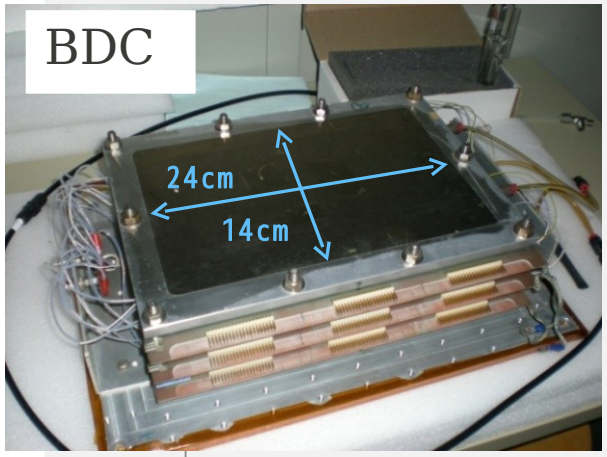
D. Nakajima, B. Oezel et al., NIM A 608 (2009) 287

The most crucial background



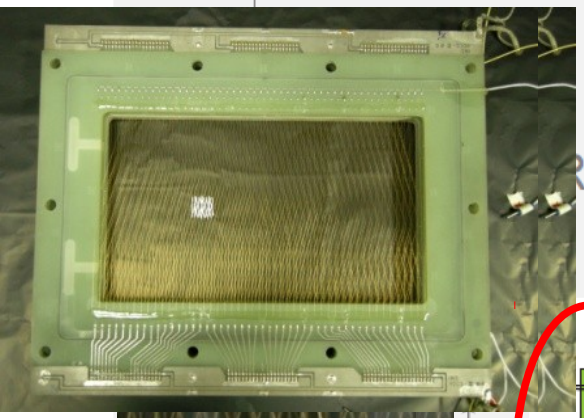
Drift Chamber : BDC, SDC
from KEK

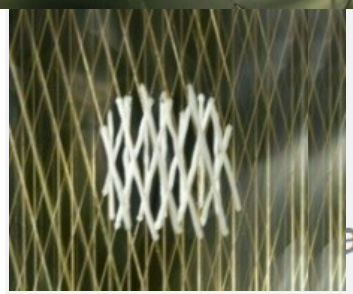
BDC



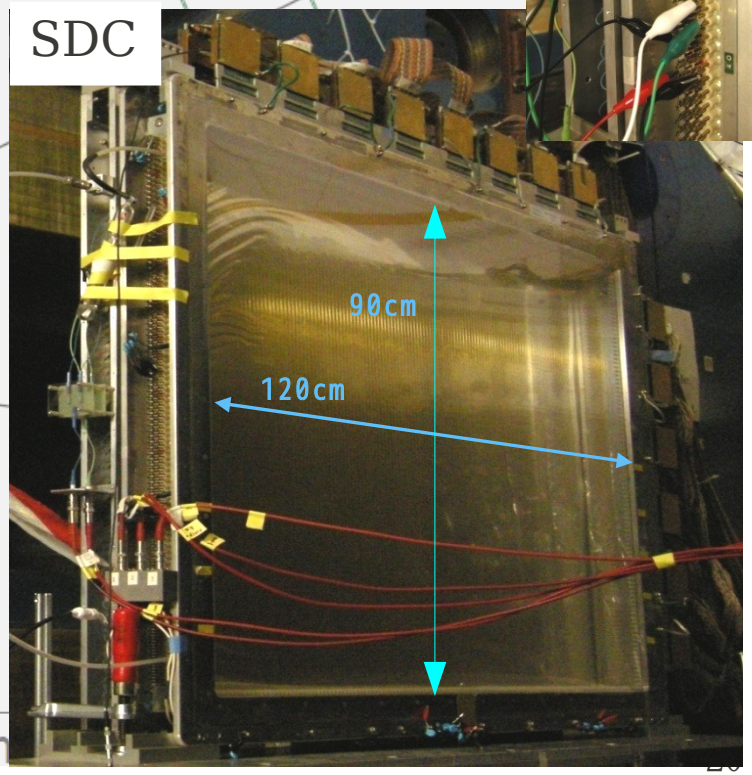
Wire layer with stereo angle

Solve stereo ambiguity in traking



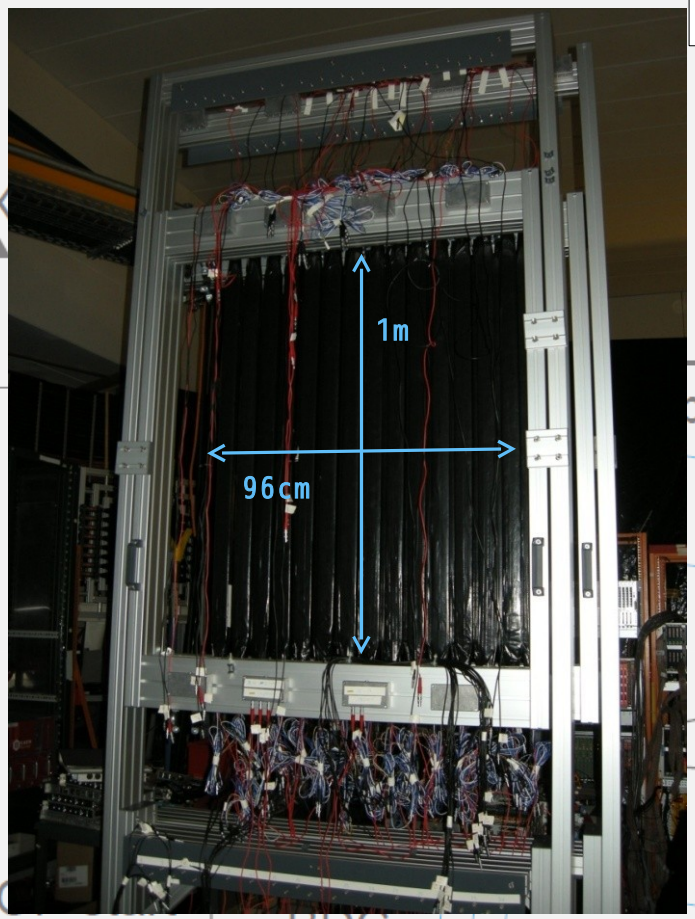


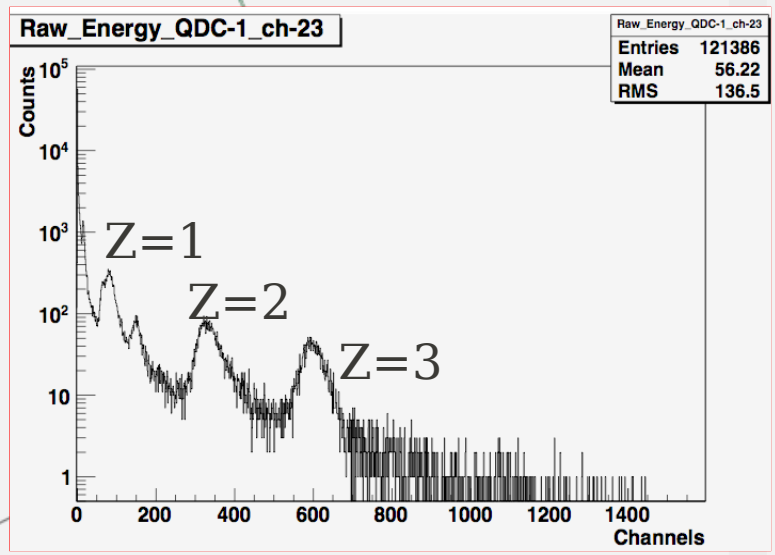
SDC



TOF+ wall

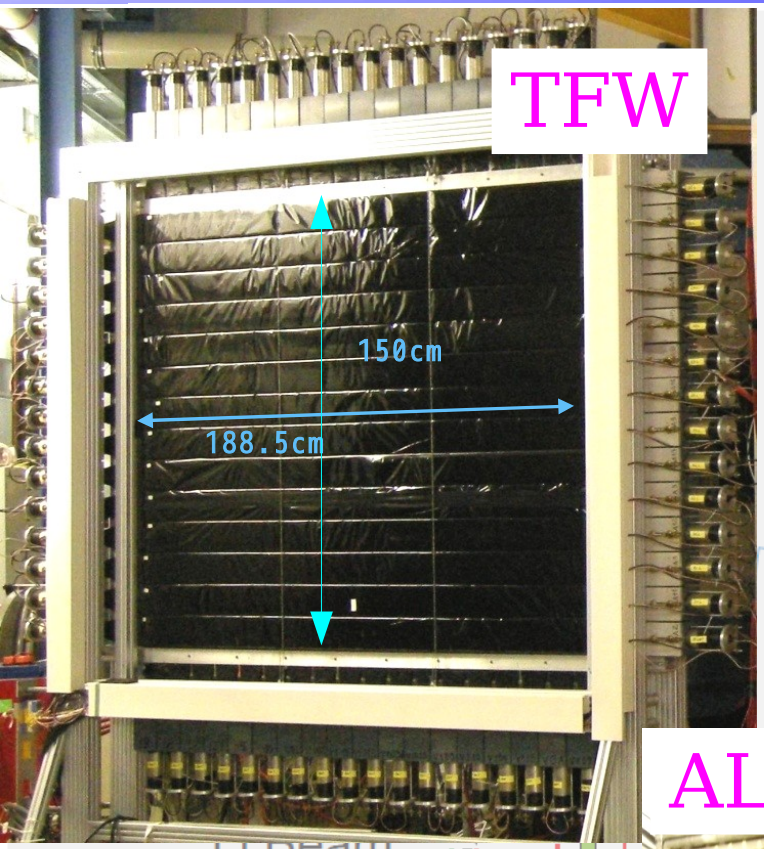
- Time Of Flight measurement (~200 ps)
- Charge sepatation of particles
- Tracking charged particles

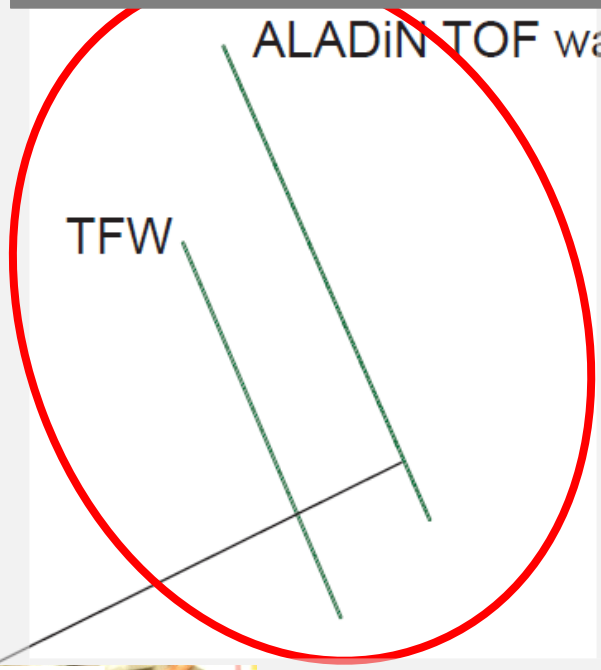


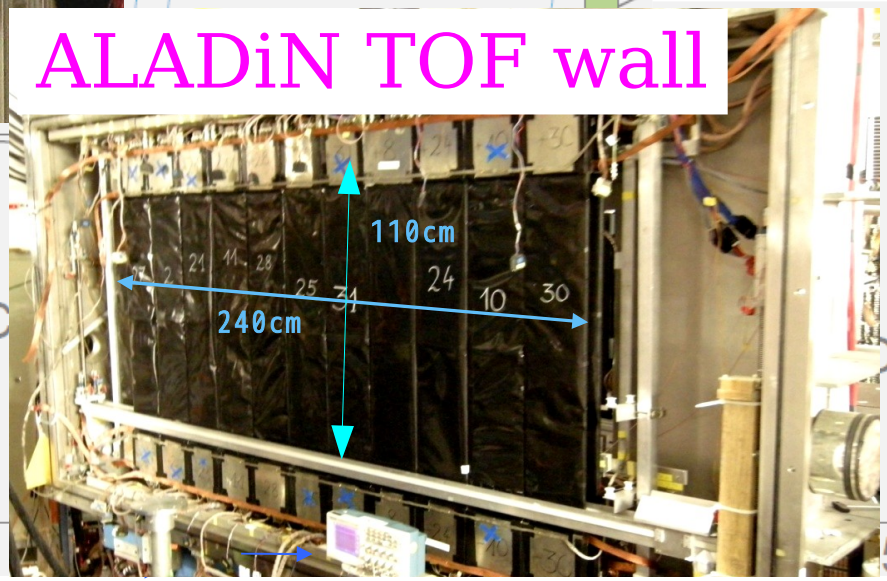


TFW and ALADiN TOF wall

- **Time Of Flight measurement**
- **Tracking charged particles**







ALADiN
dipole magnet

TOF-start

BDC

^{12}C Target

F+ wall

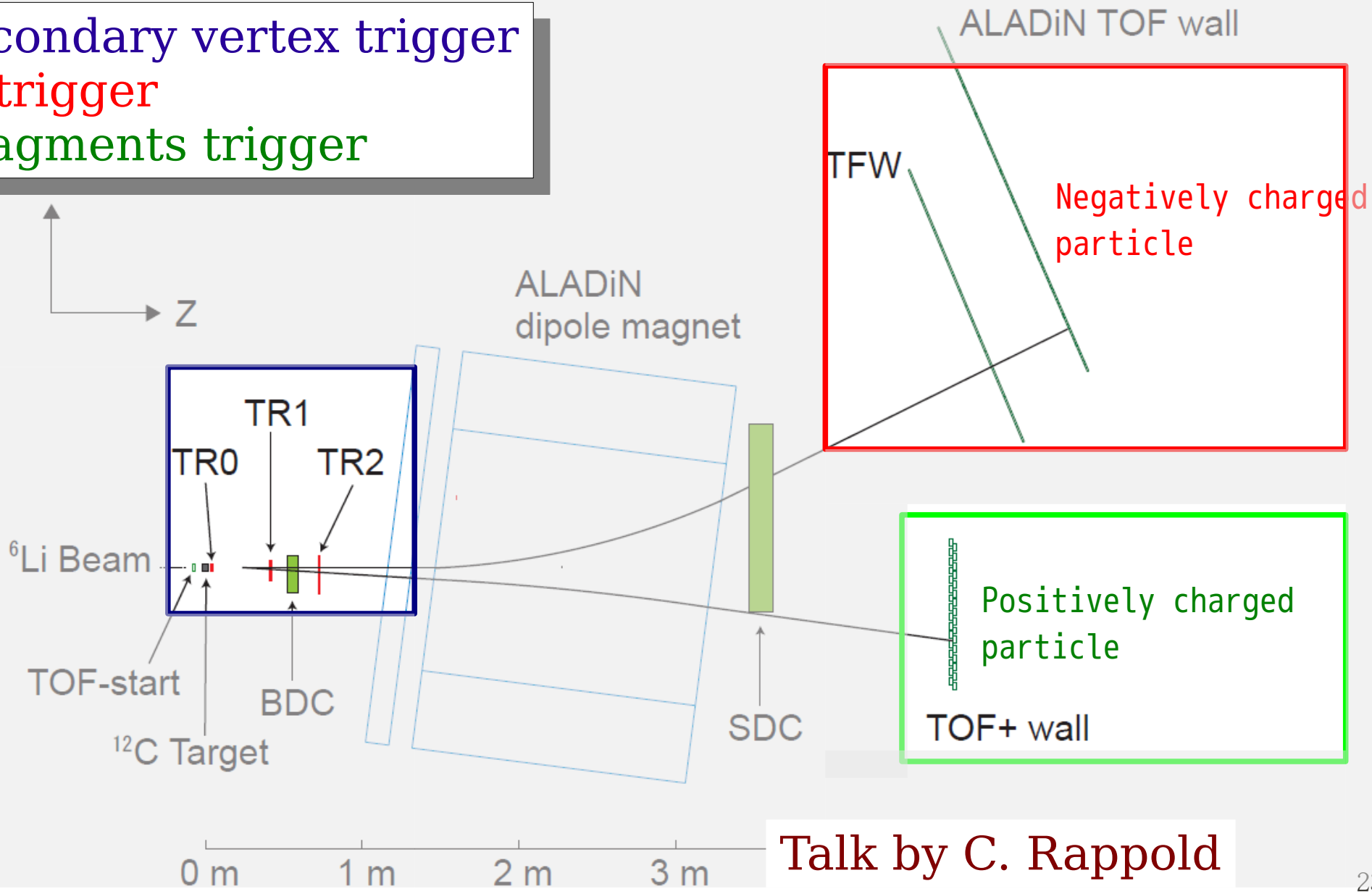
0 m

5 m

6 m

Trigger system

- Secondary vertex trigger
- π- trigger
- Fragments trigger

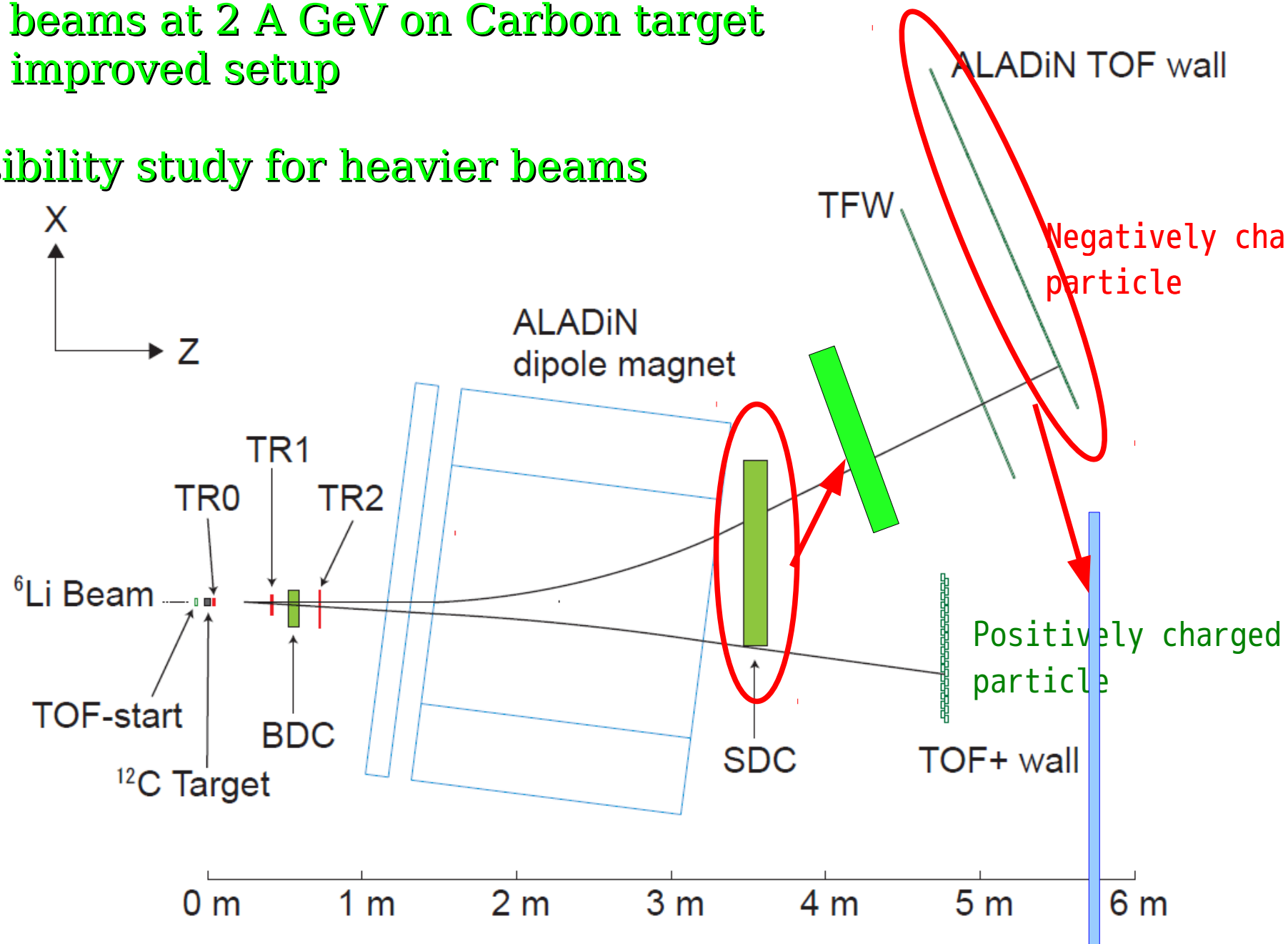


Talk by C. Rappold

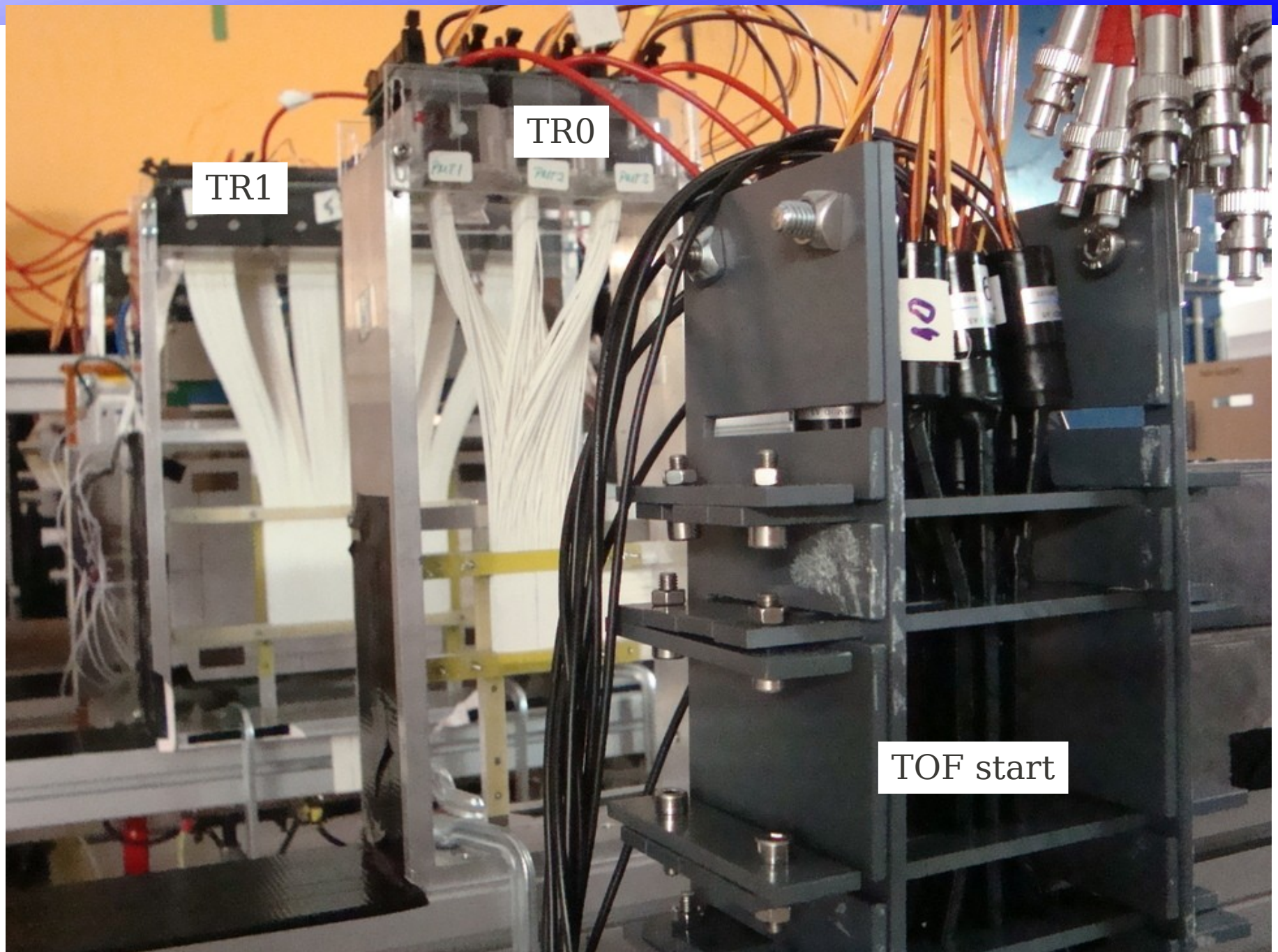
Setup (Phase 0.5)

^{20}Ne beams at 2 A GeV on Carbon target with improved setup

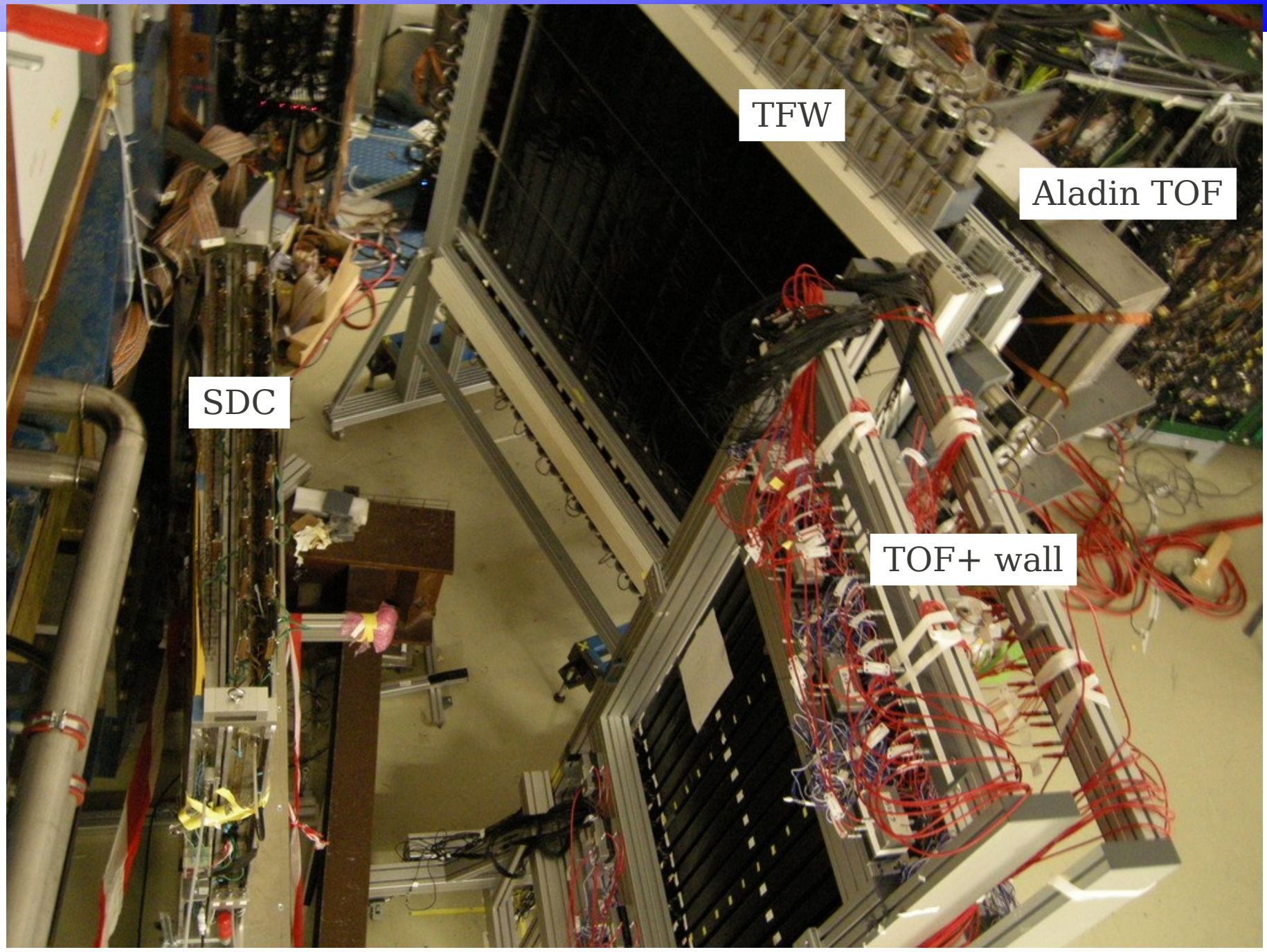
Feasibility study for heavier beams



Detectors upstream

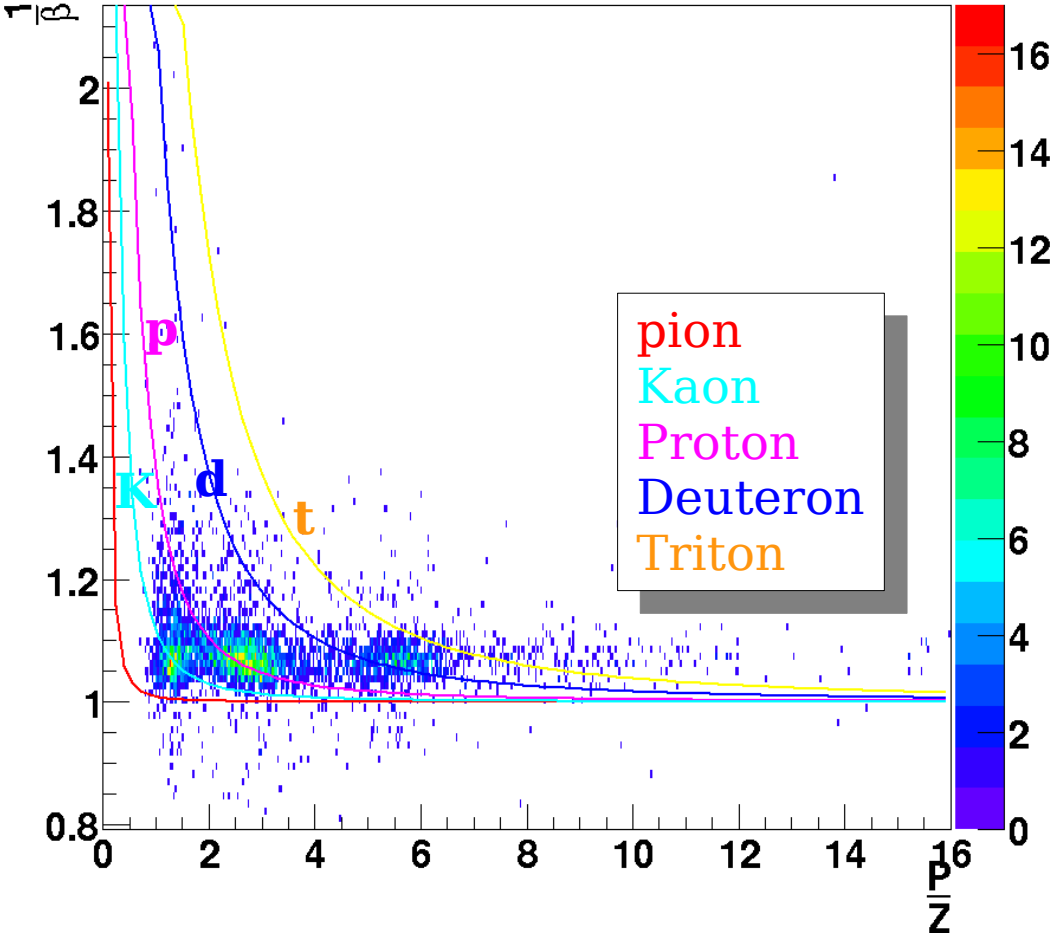


Detectors downstream

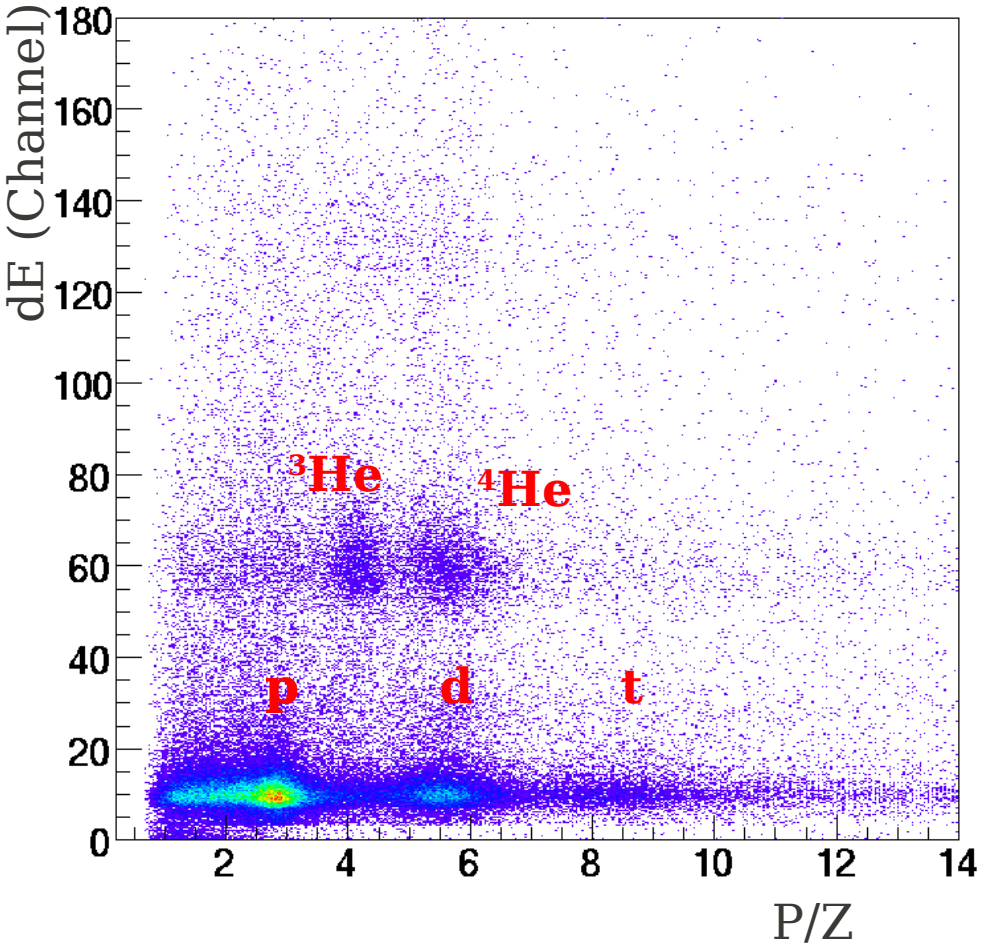


Particle identification

1/β vs P/Z



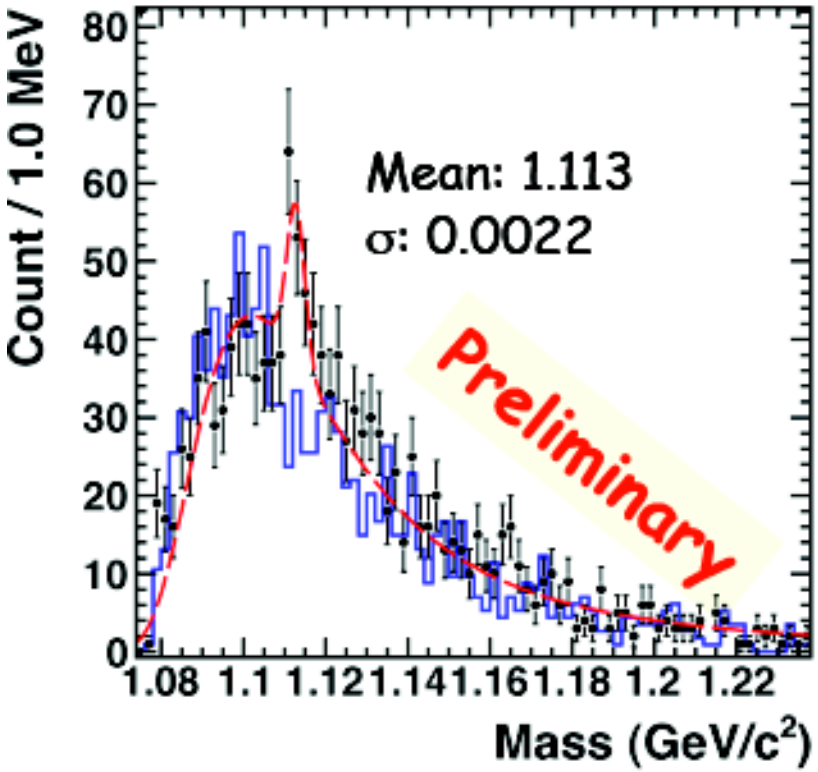
dE vs P/Z

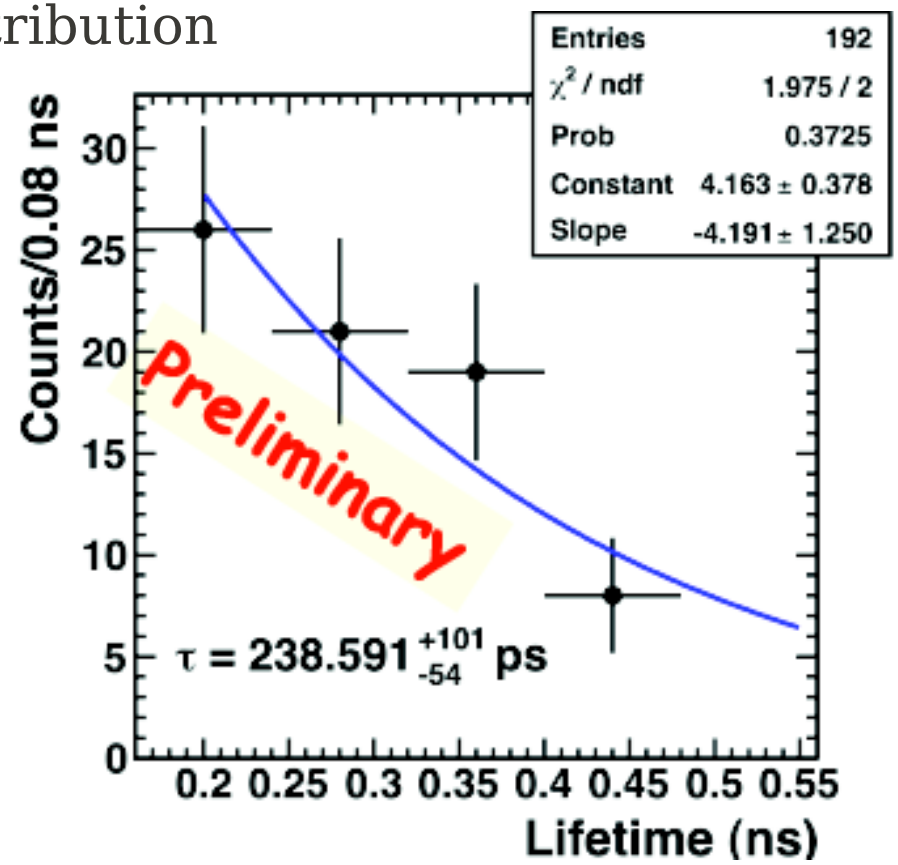


Lambda Hyperon

preliminary analysis with 5% statistics

Proton + π^- invariant mass distribution





Known Mass : 1.115 GeV

Known life time : 263 ps

Summary and near future plan

Summary

- The HypHI Phase 0, 0.5 experiments
  - Demonstrated feasibility of precise hypernuclear spectroscopy

- Full statistics analysis is in progress

Near Future Plan

- ~2012 : Phase 1 experiment preparation is started

People working for HypHI Phase 0-0.5

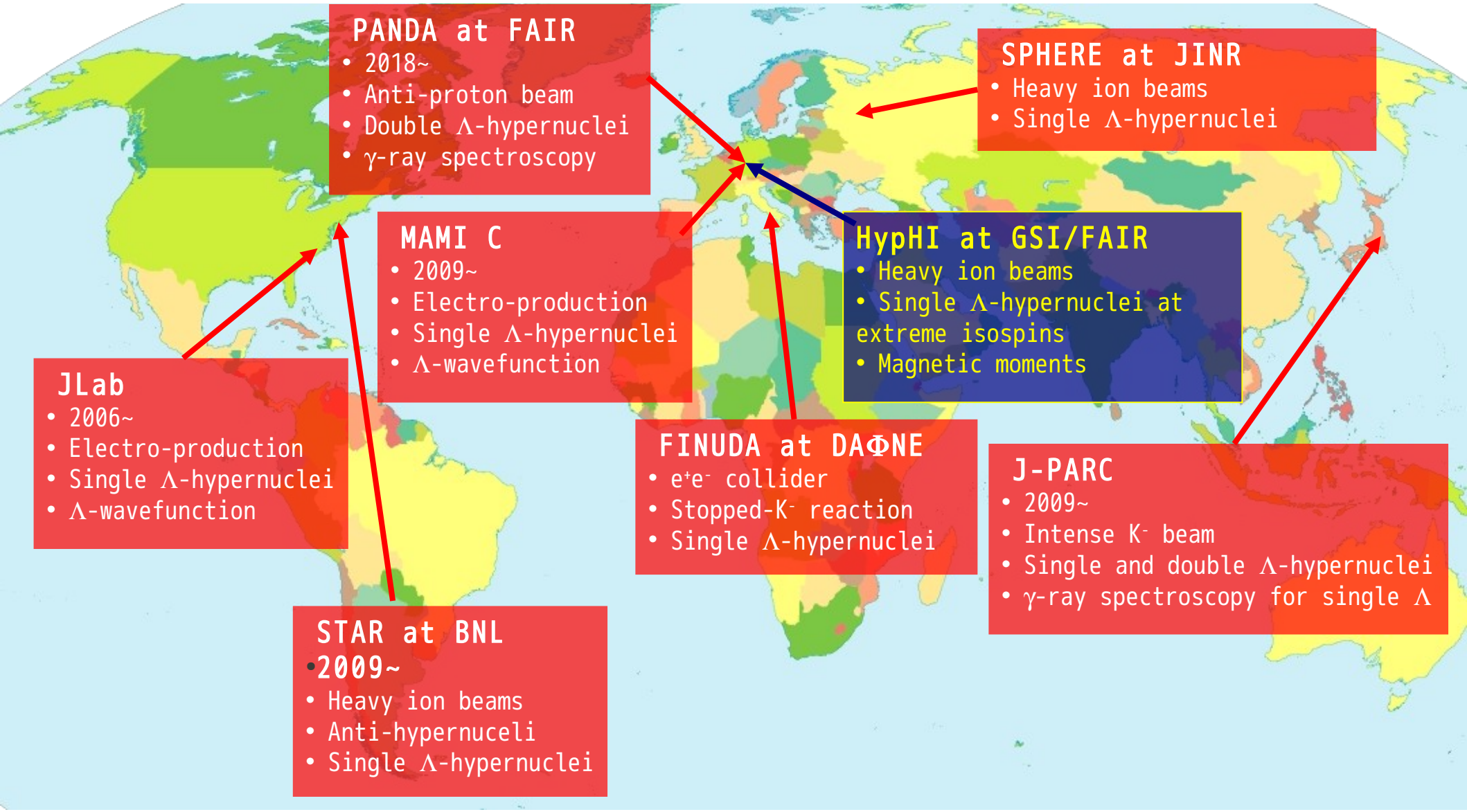
- **GSI Helmholtz-University Young Investigators Group VH-NG-239**
  - **S. Bianchin (GSI)**
  - **O. Borodina (Mainz Univ.)**
  - **V. Bozkurt (Nigde Univ.)**
  - **B. Göküzüm (Nigde Univ.)**
  - **E. Kim (Seoul Univ.)**
  - **D. Nakajima (Tokyo Univ.)**
  - **B. Özel-Tashnov (GSI)**
  - **C. Rappold (Strasbourg Univ.)**
  - **T.R. Saito (Spokes person)**
- **Mainz University**
  - P. Achenbach, J. Pochodzalla
- **GSI HP2 and Mainz University**
  - D. Khaneft, Y. Ma, F. Maas
- **GSI HP1**
  - W. Trautmann
- **GSI EE department**
  - J. Hoffmann, K. Koch, N. Kurz, **S. Minami** W. Ott, S. Voltz
- **GSI Nuclear reaction**
  - T. Aumann, C. Caeser, H. Simin
- **GSI Detector Lab.**
  - M. Träger, C. Schmidt
- **KEK**
  - T. Takahashi, Y. Sekimoto
- **KVI**
  - E. Guliev, **M. Kavatsyuk,** G.J. Tambave
- **Kyoto University**
  - Y. Hayashi, T. Hiraiwa, M. Moritsu, A. Okamura, T. Nagae, M. Sako, T. Sugimura
- **Nigde University**
  - Z.S. Ketenci, S. Erturk
- **Osaka University**
  - S. Ajimura, A. Sakaguchi, K. Yoshida
- **Osaka Electro-Communication University**
  - T. Fukuda, Y. Mizoi
- **Seoul National University**
  - H. Bhang, M. Kim, S. Kim, K. Tanida, C.J. Yoon
- **Tohoku University**
  - T. Koike, H. Tamura

Student
Postdoc
Tenure track

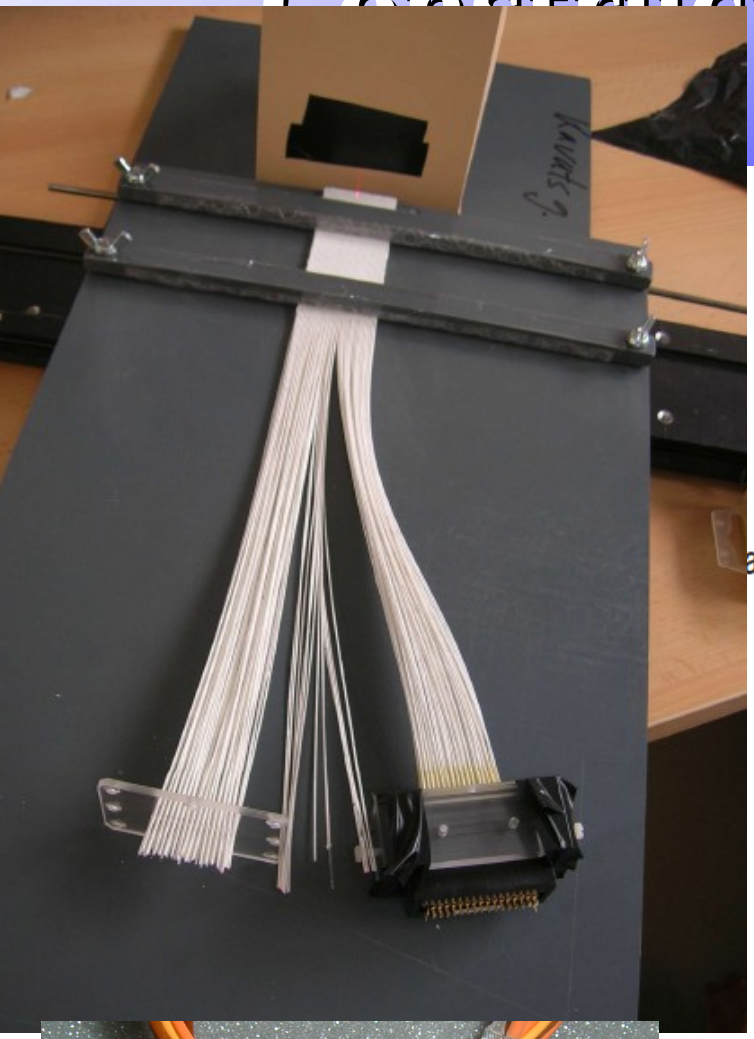
Thank you very much

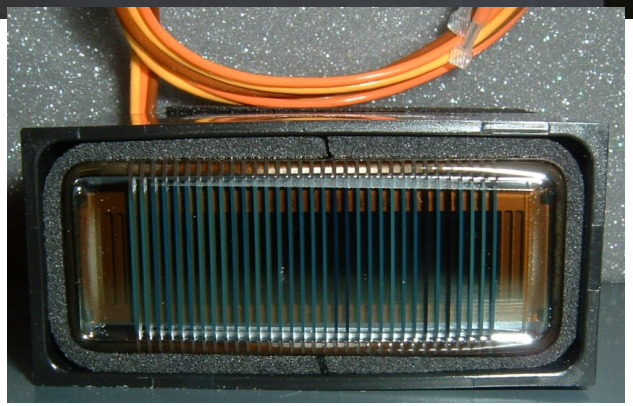
Backup

International Hypernuclear Network

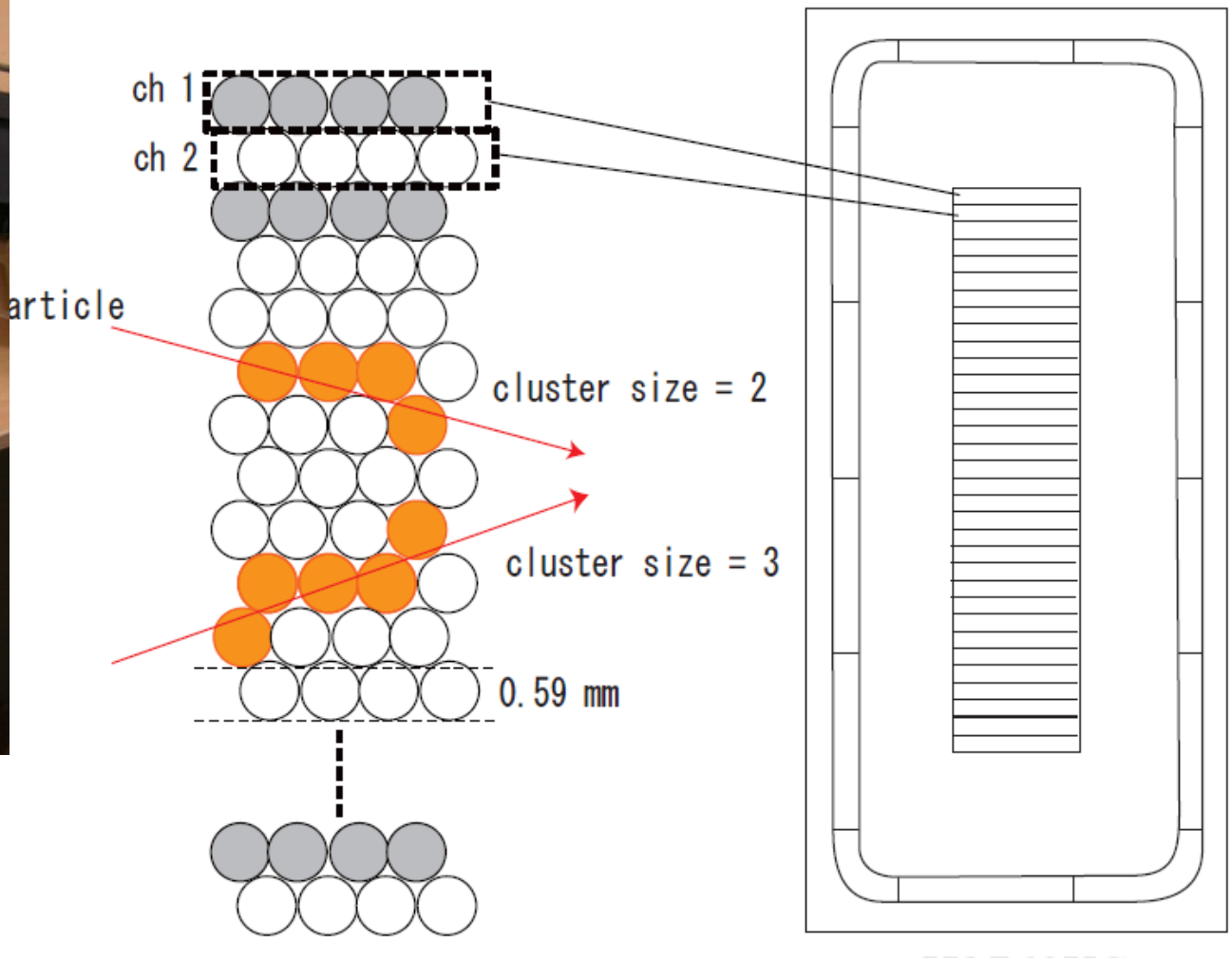


Construction of fiber detector prototype



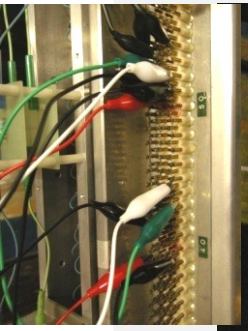


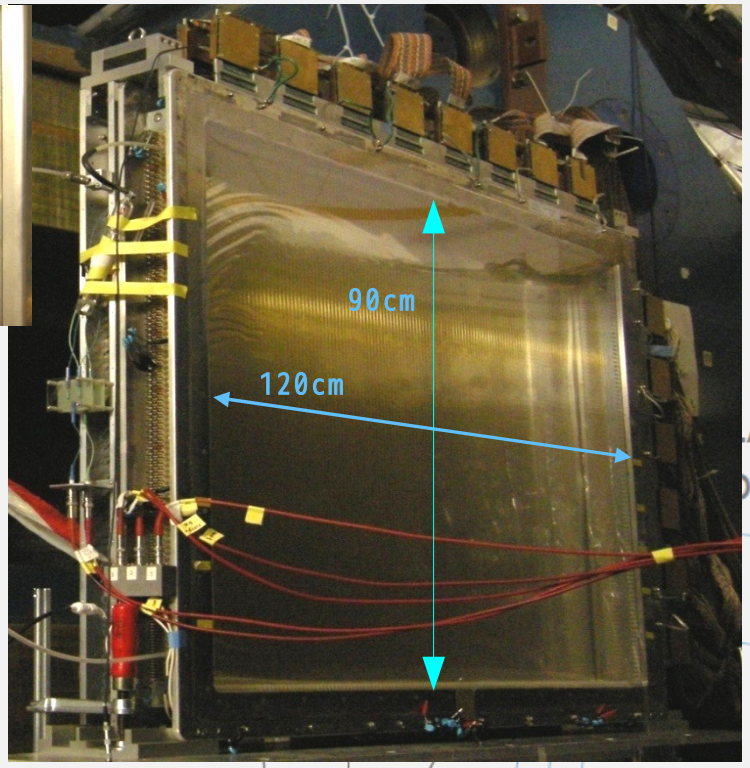
– 4 layers –



32ch multi-anode PMT

Drift Chamber : SDC





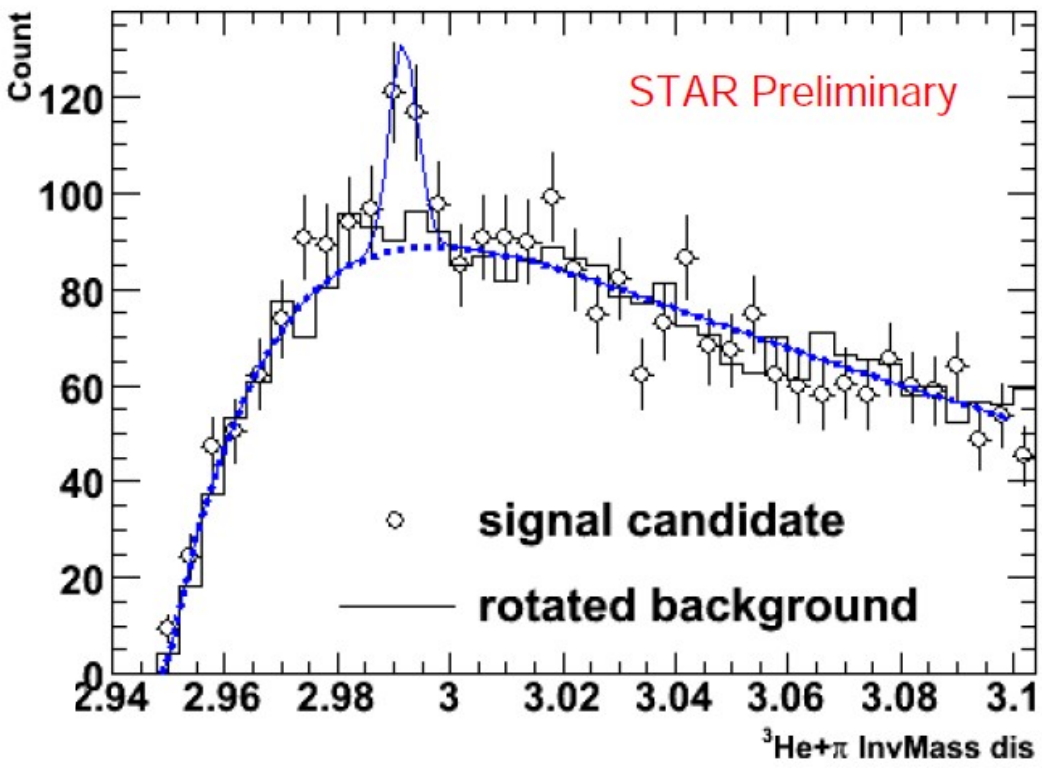
- 5 layer (0 deg, 90 deg, 45 deg)
- Gas : Ar 70% + CO_2 30 %
- Drift length : 4.5 mm
- Beam killer implimented
- Resolution ~400 μm (RMS)

Solve stereo ambiguity in traking

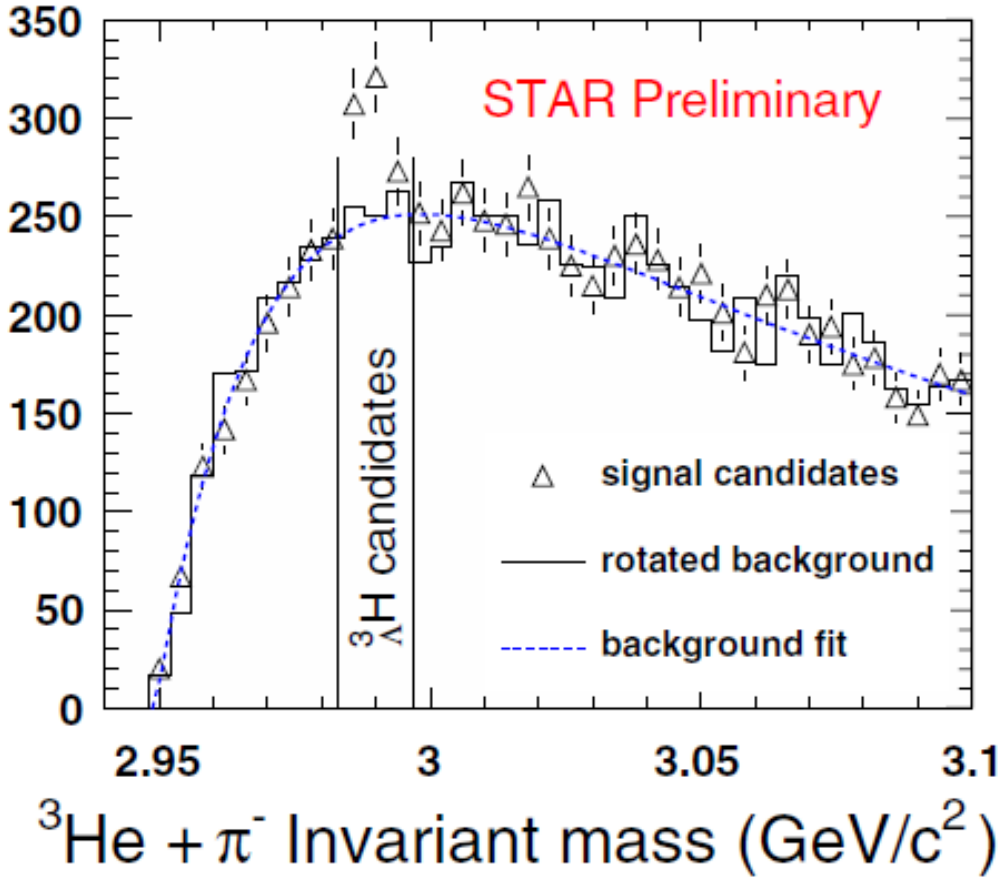
STAR at RHIC BNL

Au + Au collisions at $\sqrt{S_{NN}} = 200\,GeV$

$^{3}_{\bar{\Lambda}}\bar{H}$



$^{3}_{\Lambda}H$

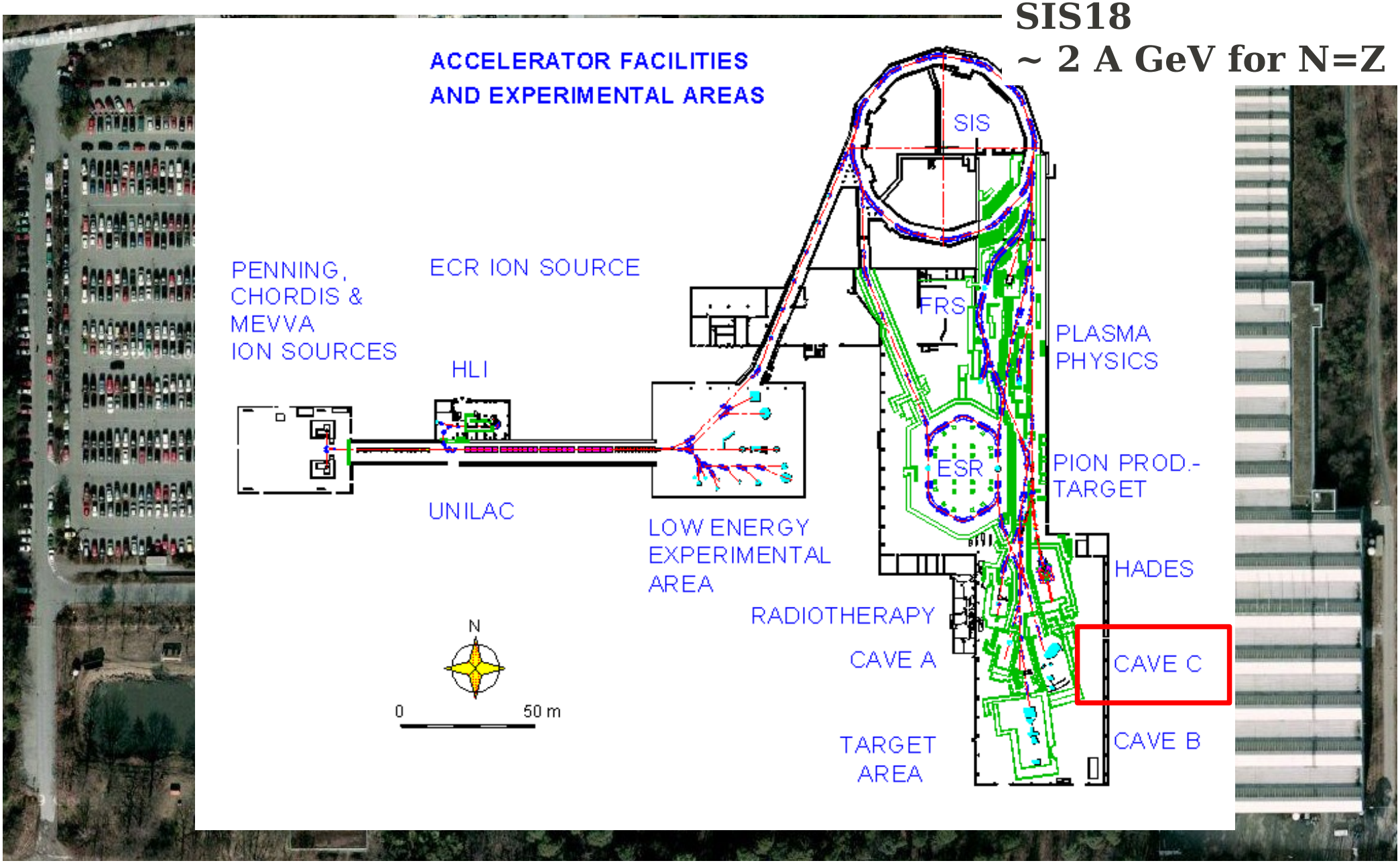


[B I Abelev et al. (STAR Collaboration)
Science. DOI: 10.1126/science.1183980.]

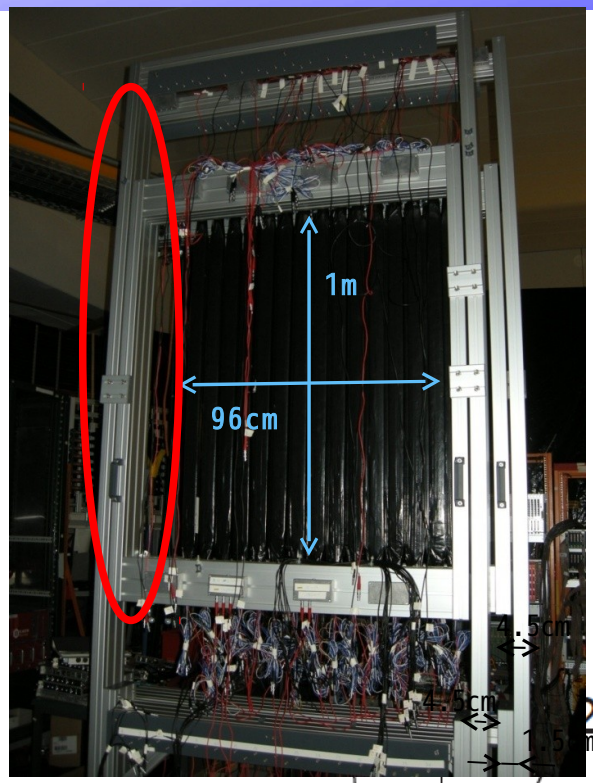
GSI , Darmstadt

GSI , Darmstadt

SIS18
~ 2 A GeV for N=Z



Scatterd particles from the Holding structure



ALADiN TOF wall

TFW

Negatively charged particle

ALADiN dipole magnet

^{6}Li Beam

Positively charged particle

TOF-start

BDC

^{12}C Target

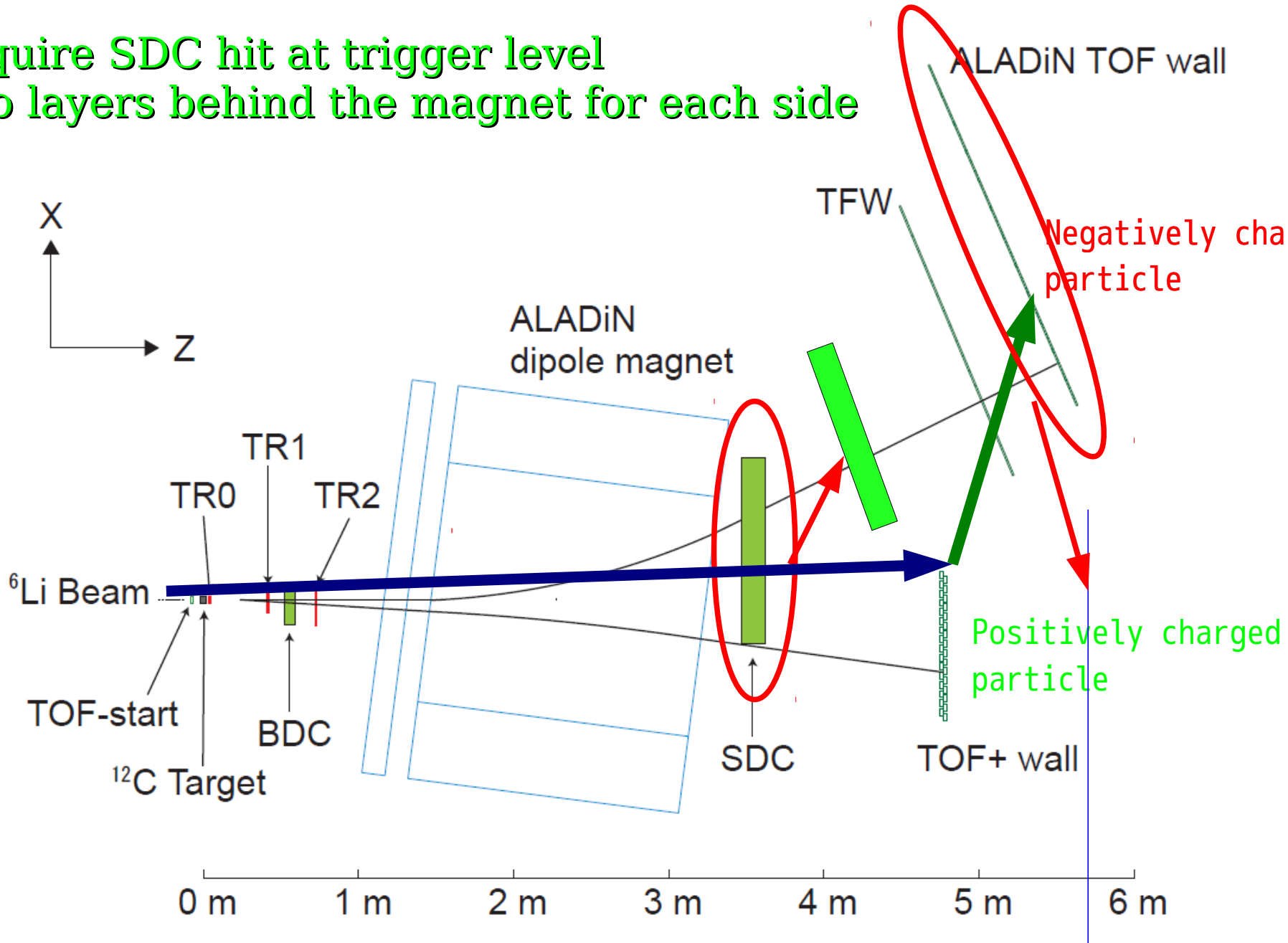
SDC

TOF+ wall

0 m 1 m 2 m 3 m 4 m 5 m 6 m

Improvement

- Require SDC hit at trigger level
- Two layers behind the magnet for each side

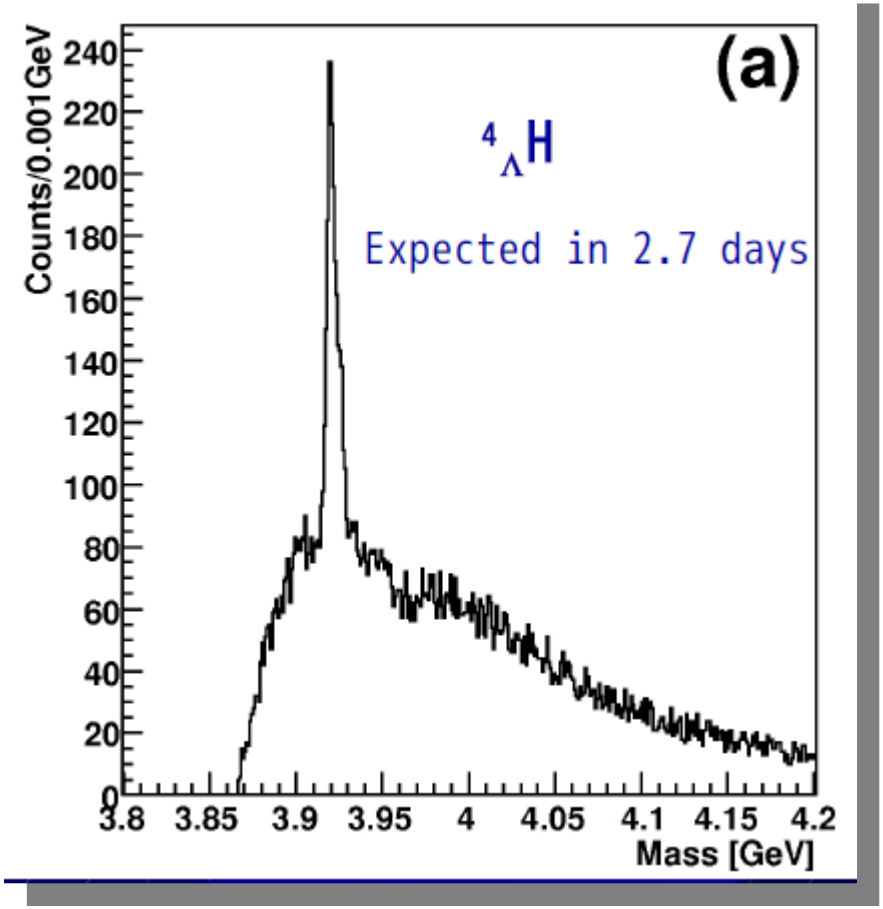


The Phase 0 and 0.5 experiment

	Phase 0	Phase 0.5
	Oct. 2009 11 days	Mar. 2010 7 days
Beam	^{6}Li at 2 A GeV	^{20}Ne at 2 A GeV
Intensity	3×10^{7} /spill	6×10^{6}/spill
Data	~800 GB (+ ~600 GB Calibration)	~700GB (+ ~200 GB Calibration)

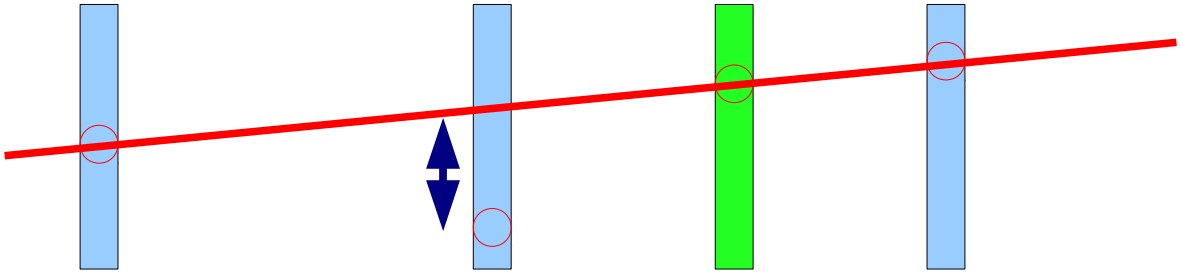
Monte-Carlo Simulation

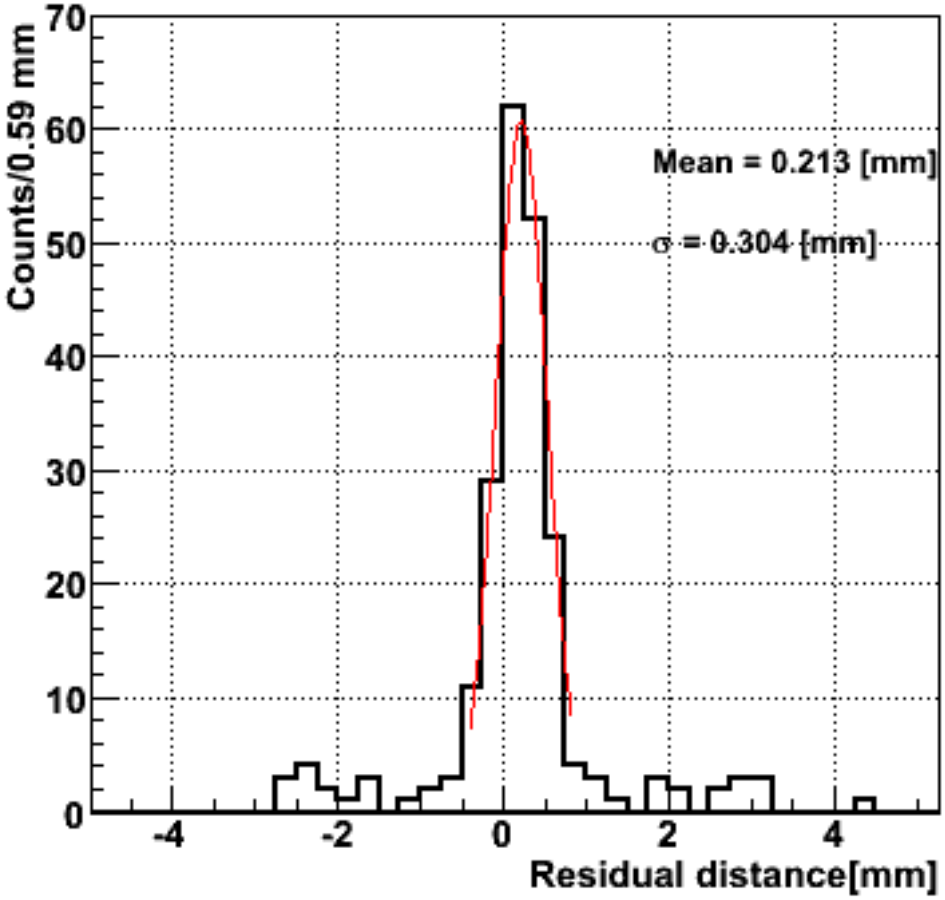
Beam : ^{6}Li beam at 2 GeV
10^{7} /sec
Target : ^{12}C

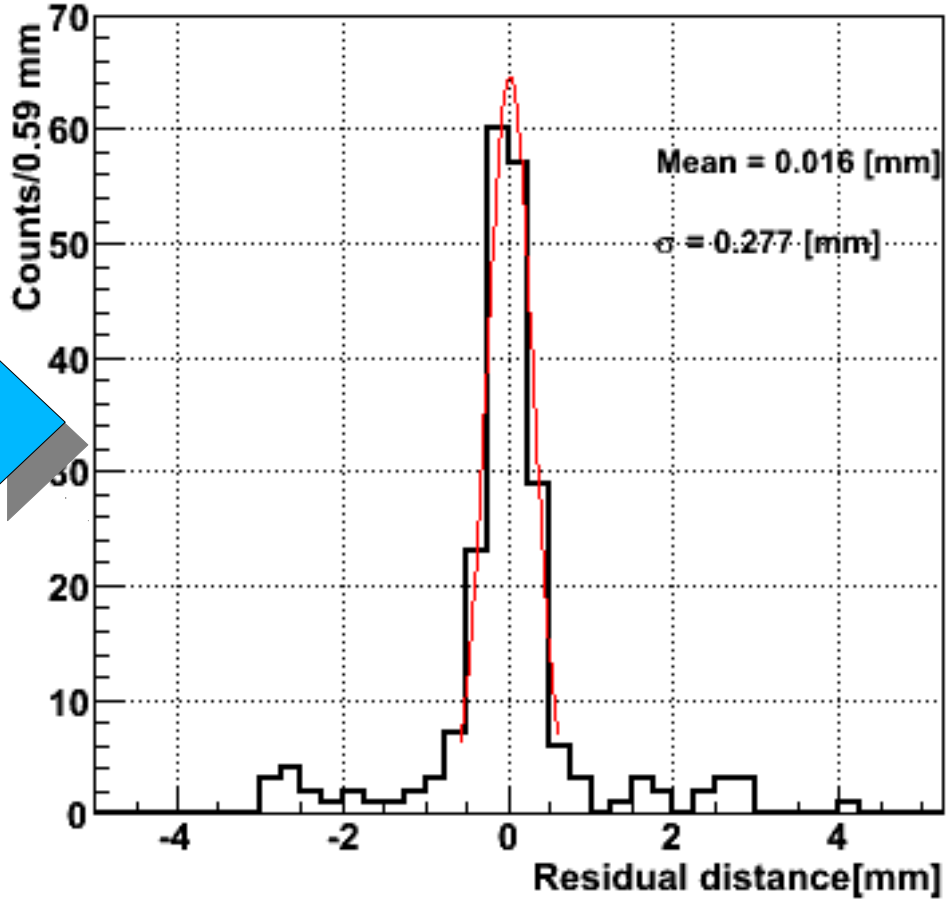


Hypernucleus	Expected cross section (μb)	Reconstructed events per week
$^{3}_{\Lambda}$H	0.1	2.8 x 10^{3}
$^{4}_{\Lambda}$H	0.1	2.6 x 10^{3}
$^{5}_{\Lambda}$He	0.5	6.3 x 10^{3}

Positin Alignment of Fiber detectors



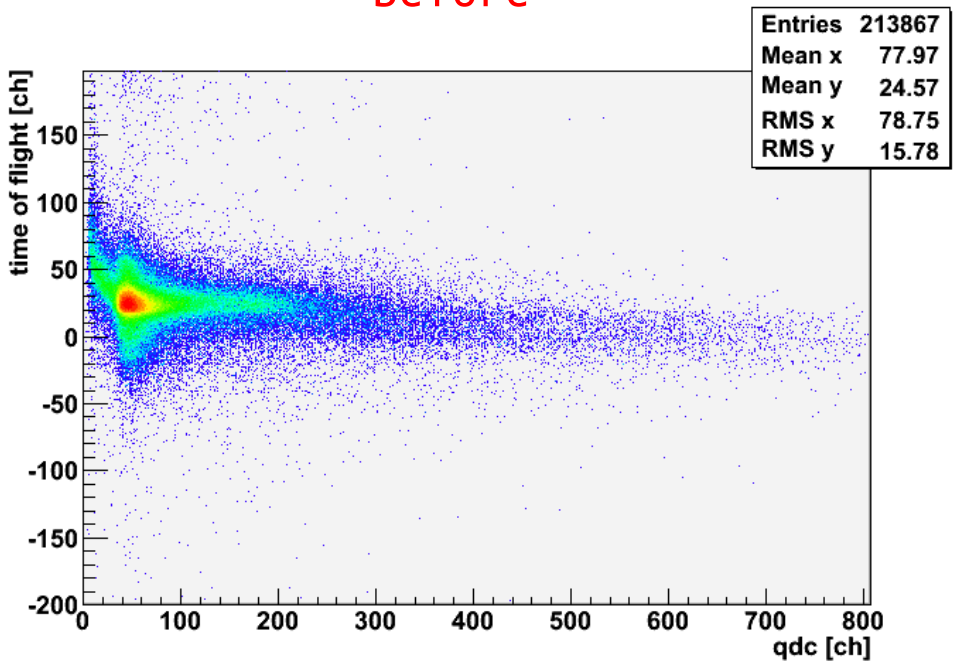




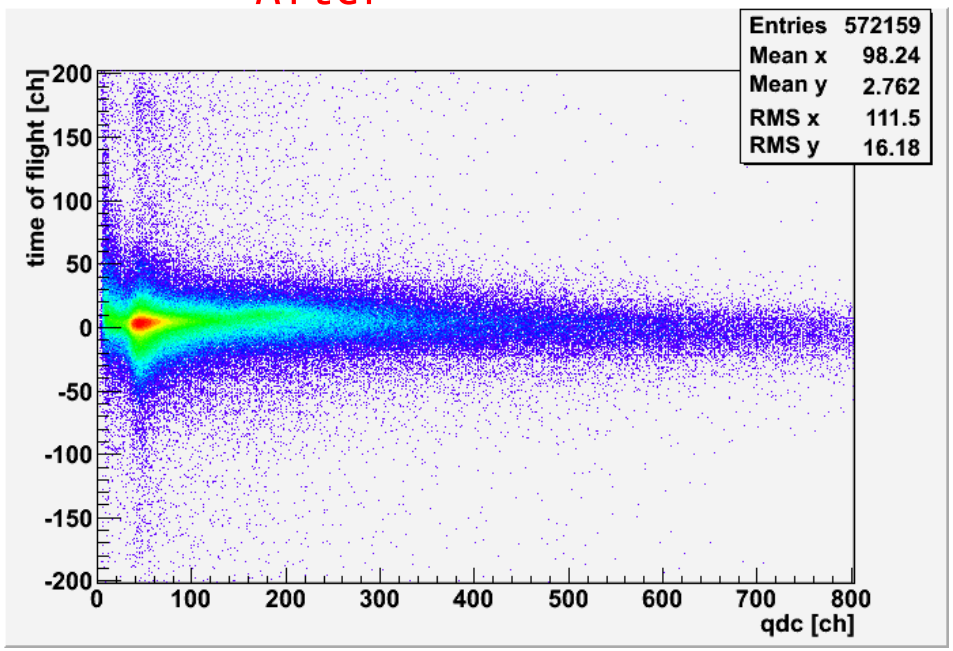
TOF corrections

Walk corrections for TOF-start and TOF+

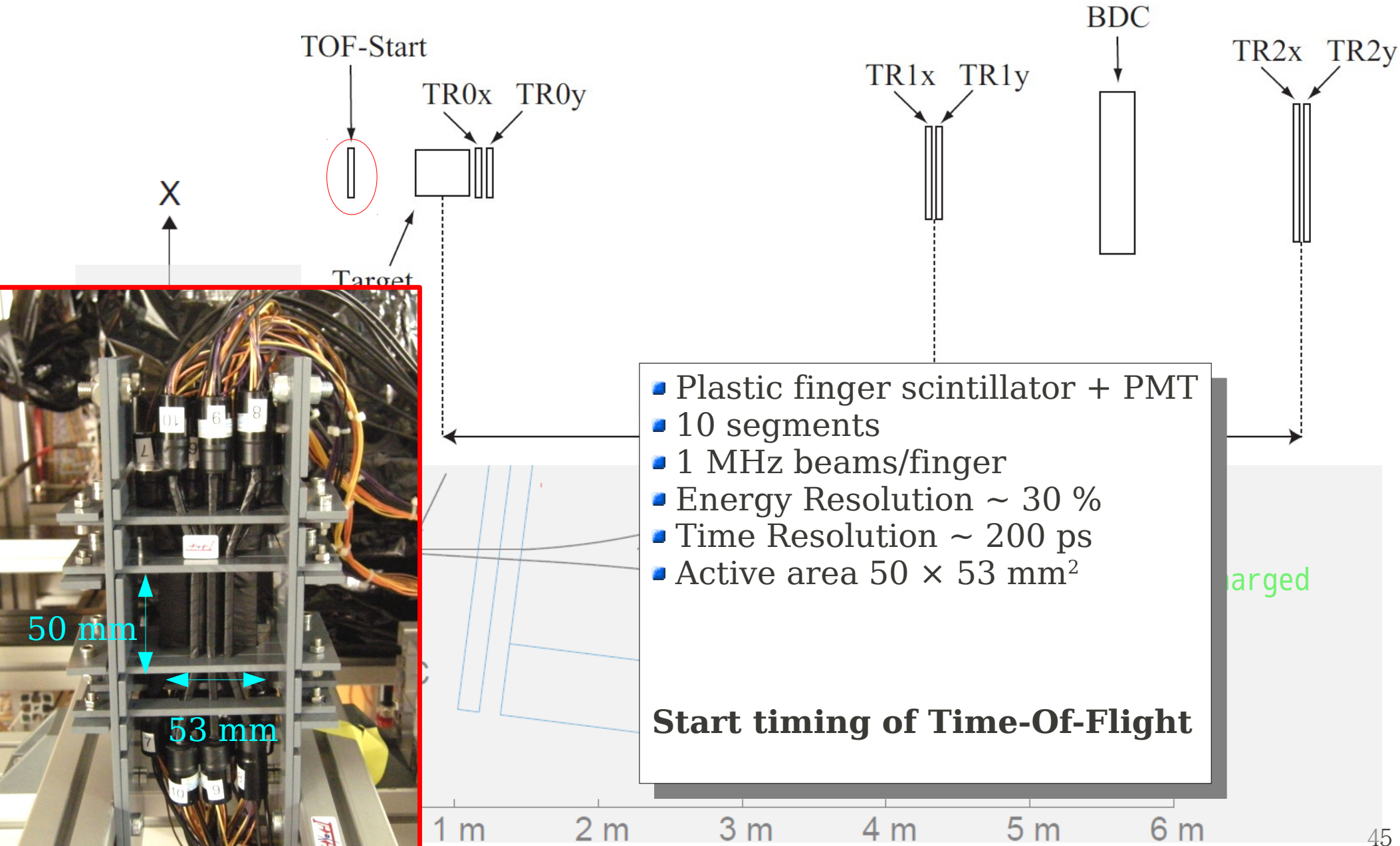
Before



After



TOF – start



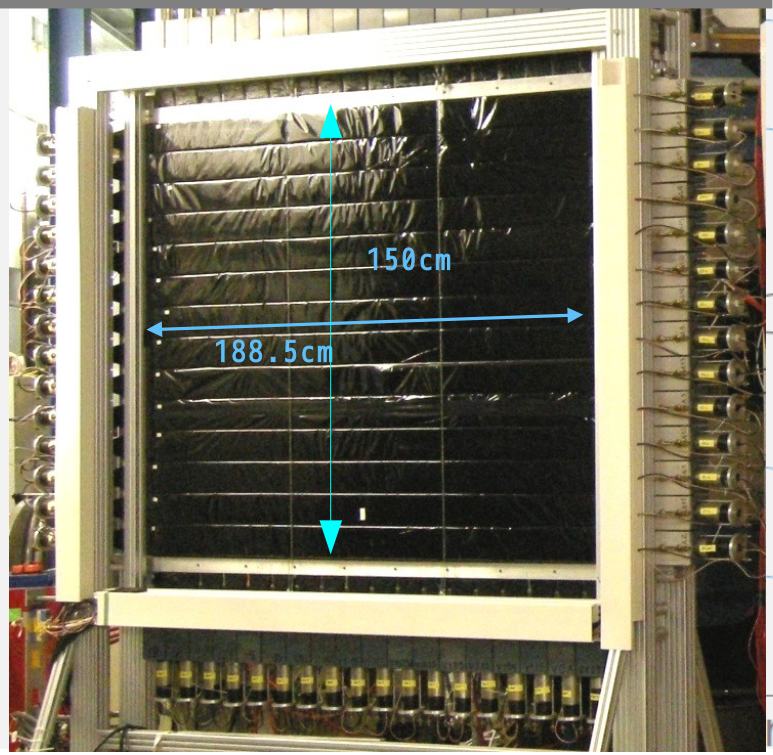
- Plastic finger scintillator + PMT
- 10 segments
- 1 MHz beams/finger
- Energy Resolution ~ 30 %
- Time Resolution ~ 200 ps
- Active area 50 × 53 mm^2

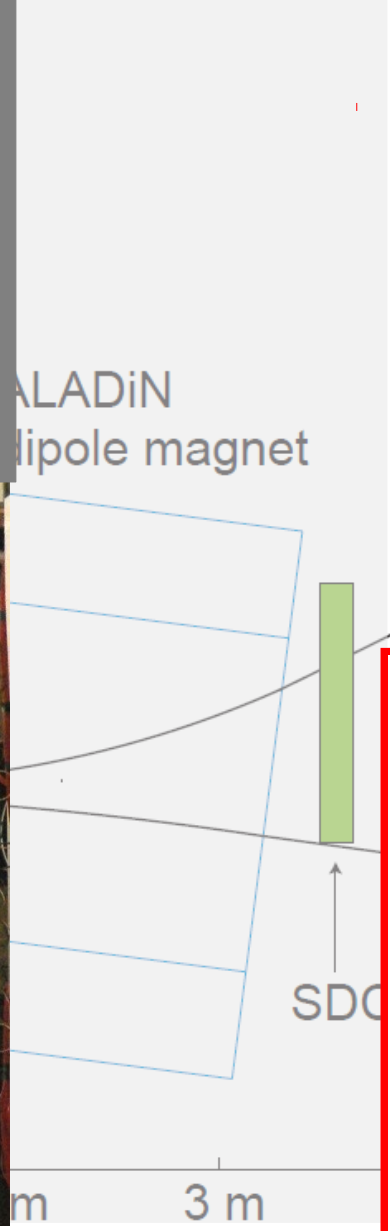
Start timing of Time-Of-Flight

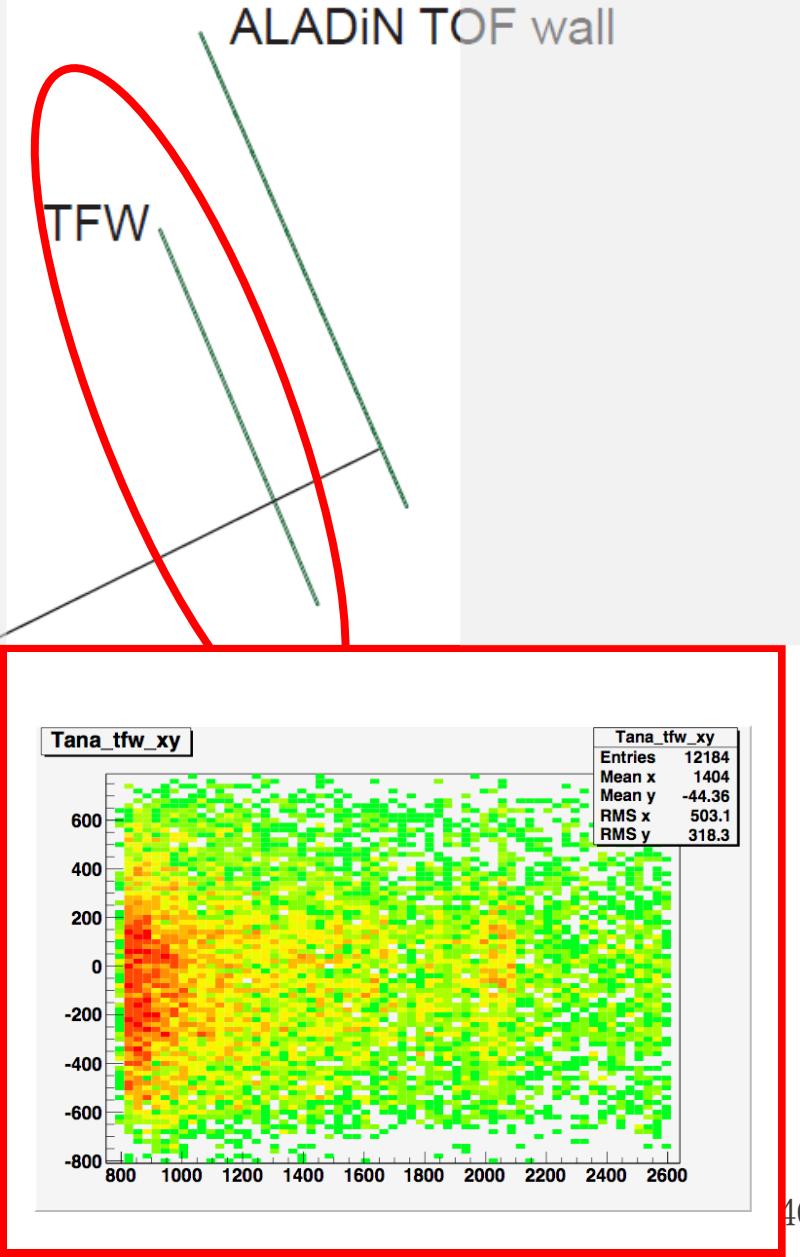
TFW

- For π-
- Plastic hodoscope + PMT
- Time resolution : ~ 400 ps
- 19 segments (horizontal)
- 18 segments (vertical)

Time Of Flight measurement
Tracking charged particles



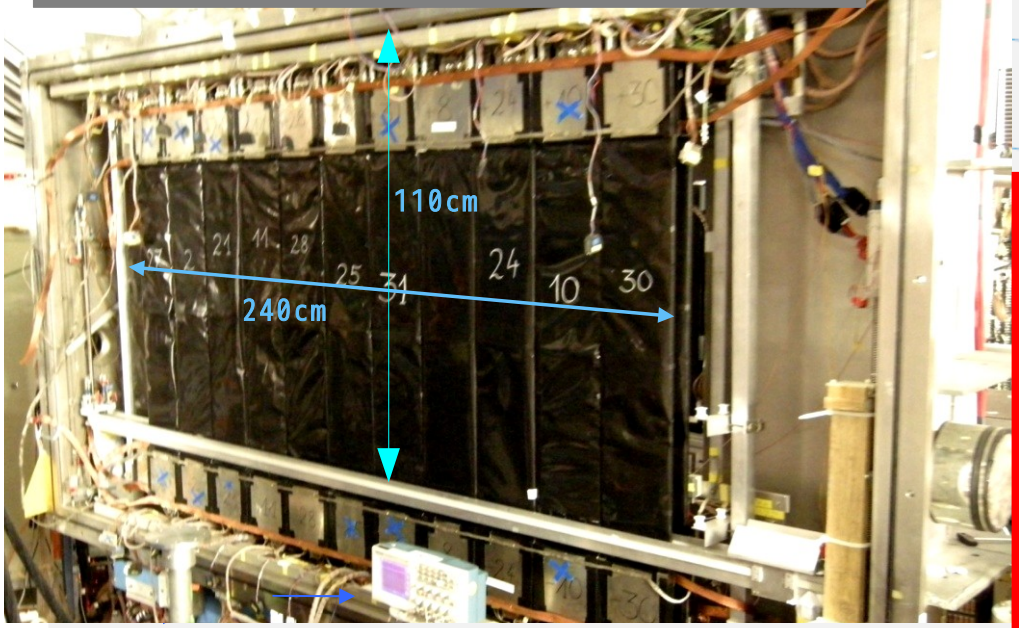


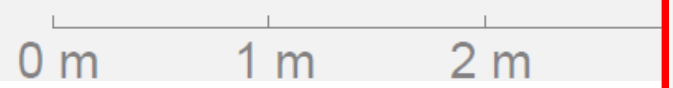


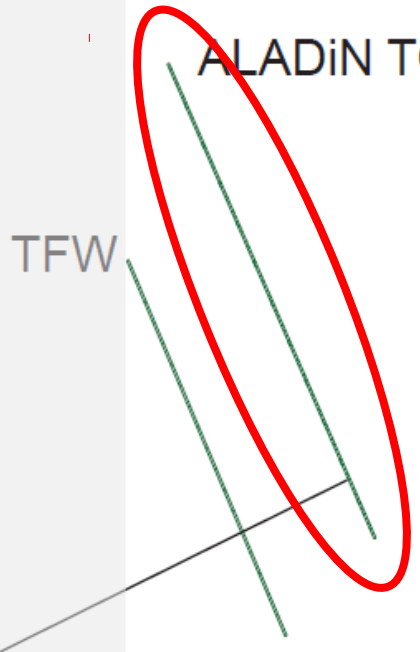
ALADiN TOF wall

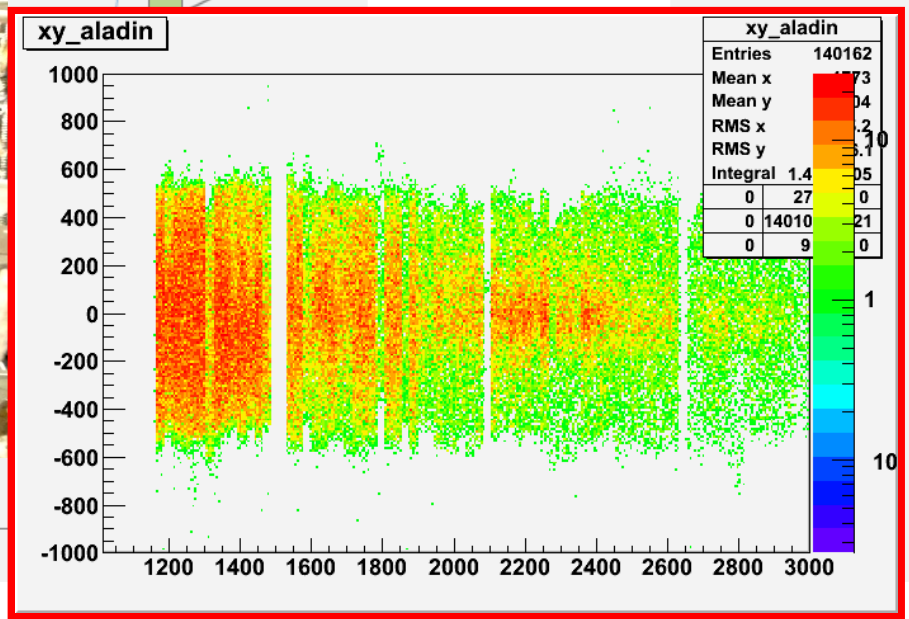
- For π-
- Plastic hodoscope + PMT
- Time resolution : ~ 500 ps
- 96 segments

Time Of Flight measurement
Tracking charged particles





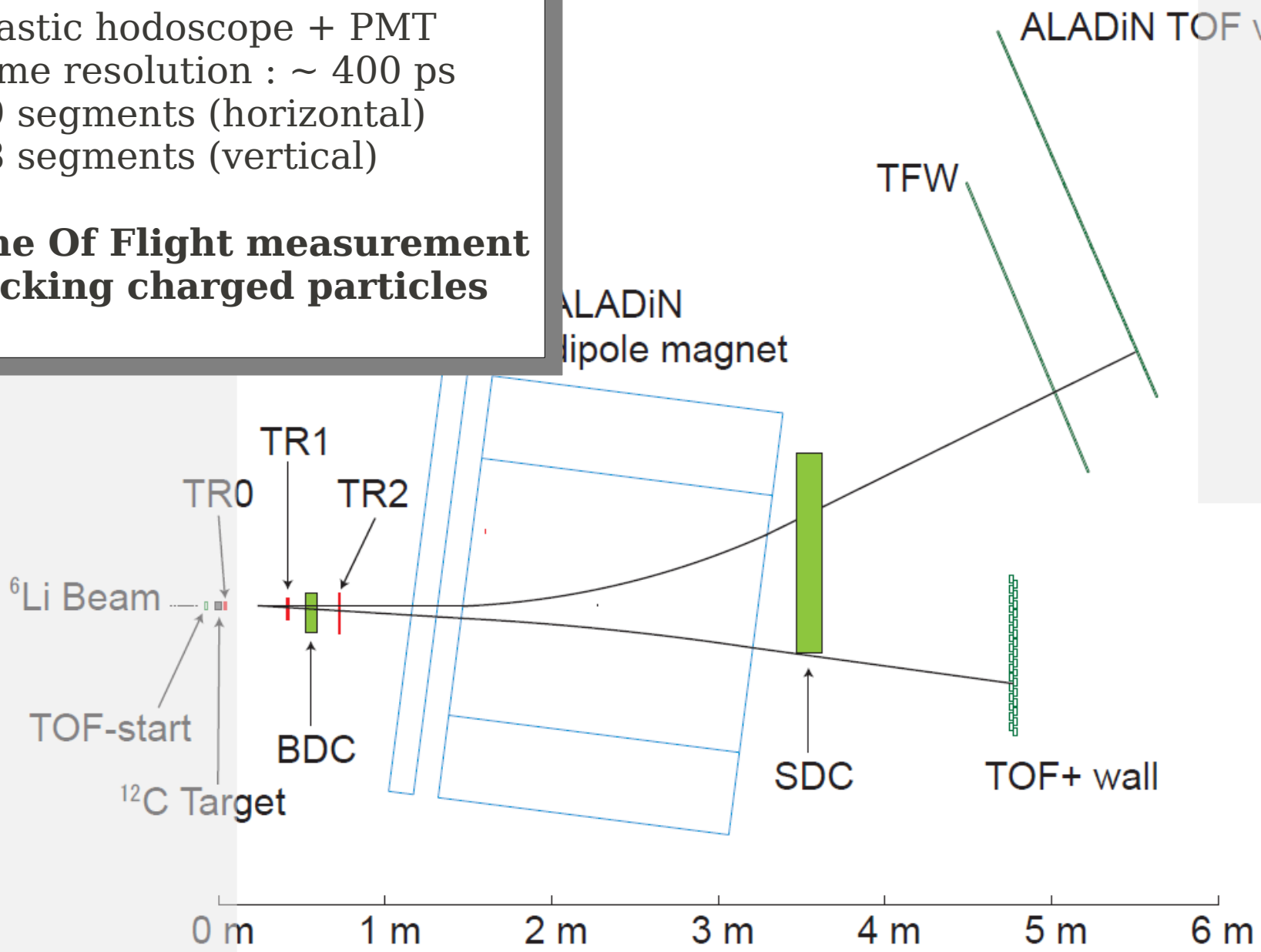




Time-Of-Flight wall for negatively charged particles

- For π-
- Plastic hodoscope + PMT
- Time resolution : ~ 400 ps
- 19 segments (horizontal)
- 18 segments (vertical)

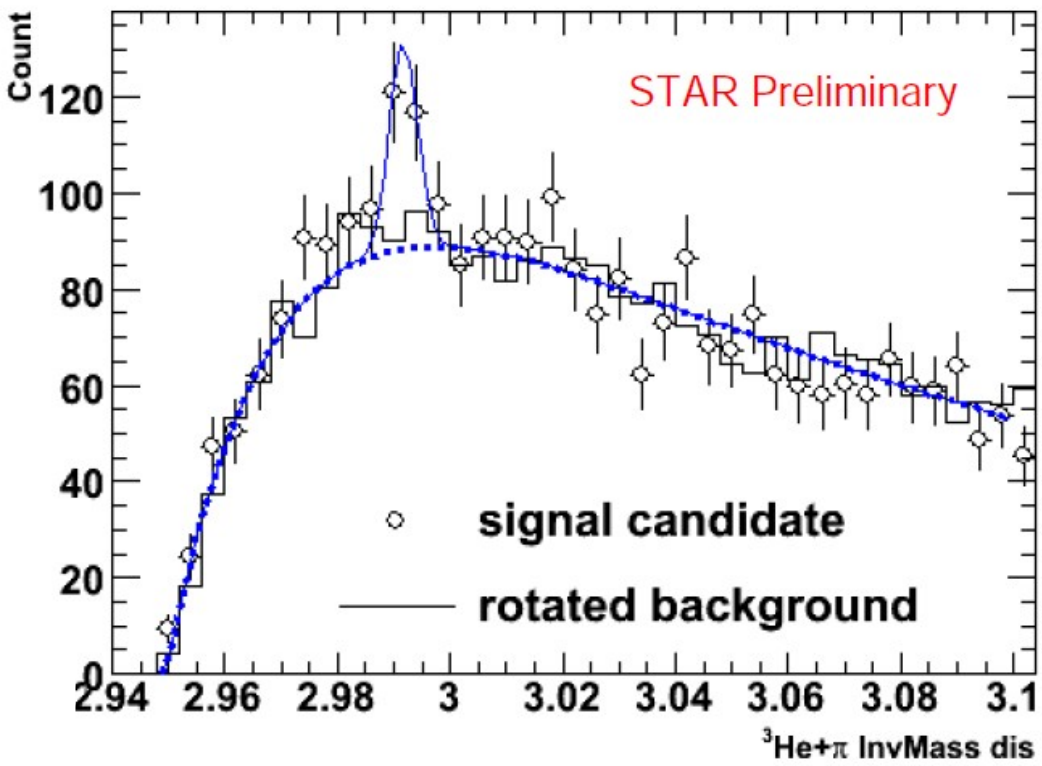
Time Of Flight measurement
Tracking charged particles



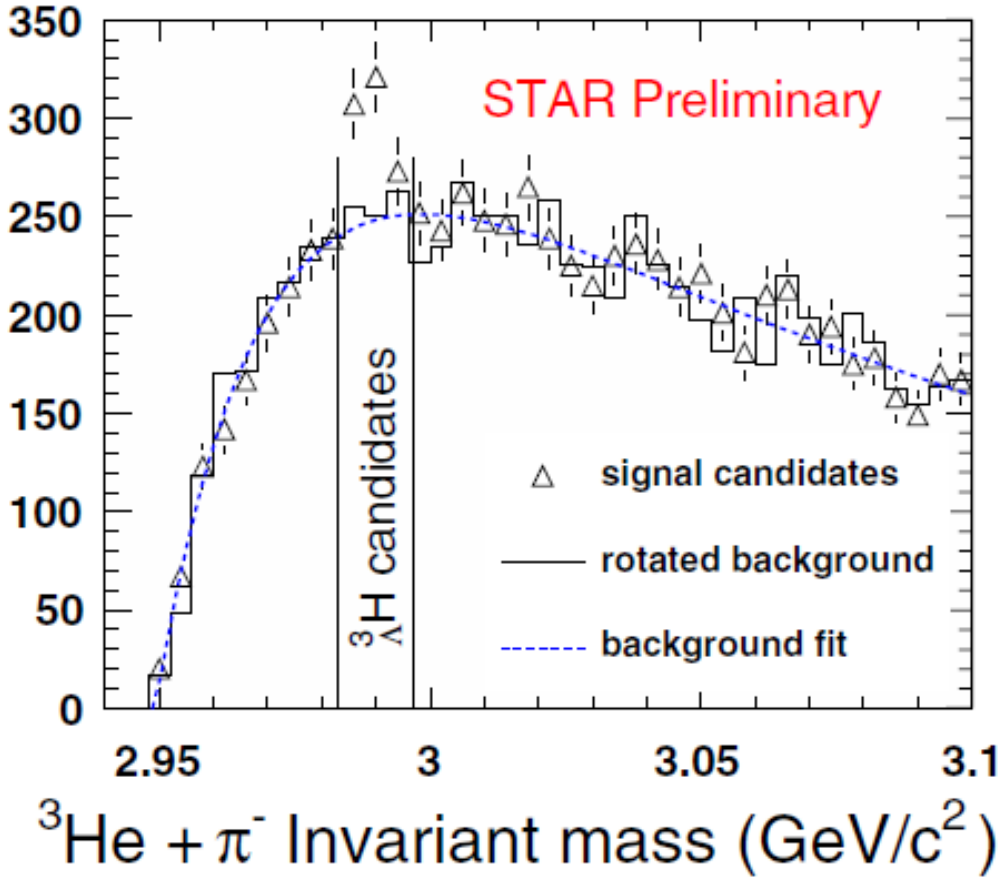
STAR at RHIC BNL

Au + Au collisions at $\sqrt{S_{NN}} = 200\,GeV$

$^{3}_{\bar{\Lambda}}\bar{H}$



$^{3}_{\Lambda}H$



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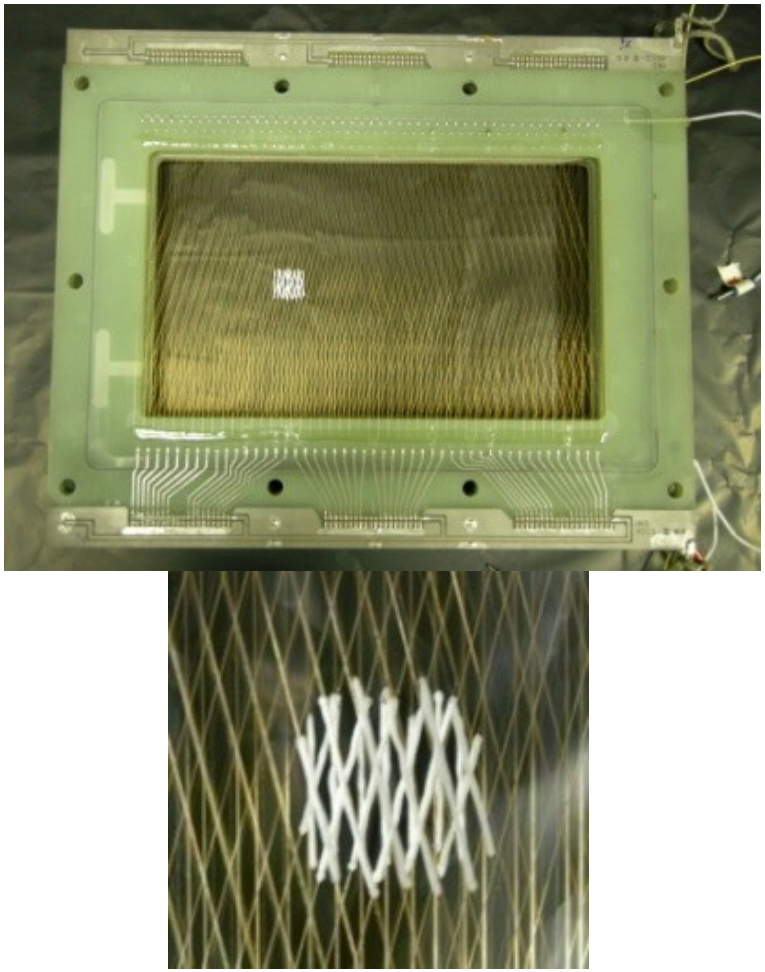
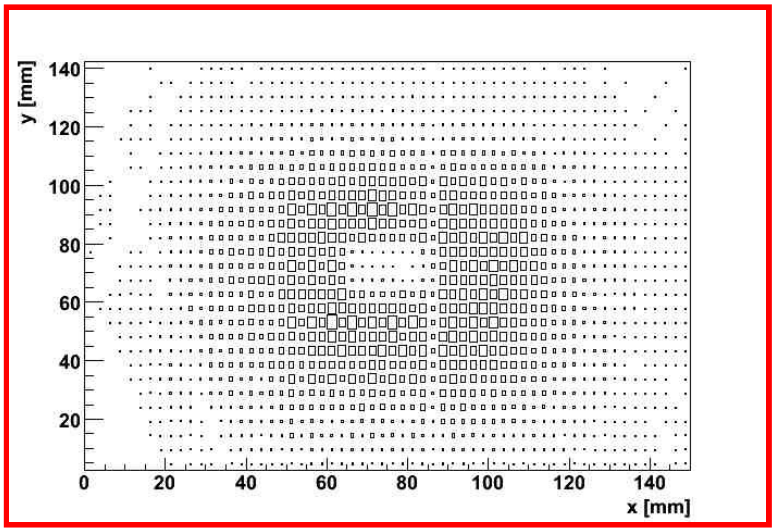
Science. DOI: 10.1126/science.1183980.]




y [mm]
140
120
100
80
60
40
20
0
20
40
60
80
100
120
140
x [mm]