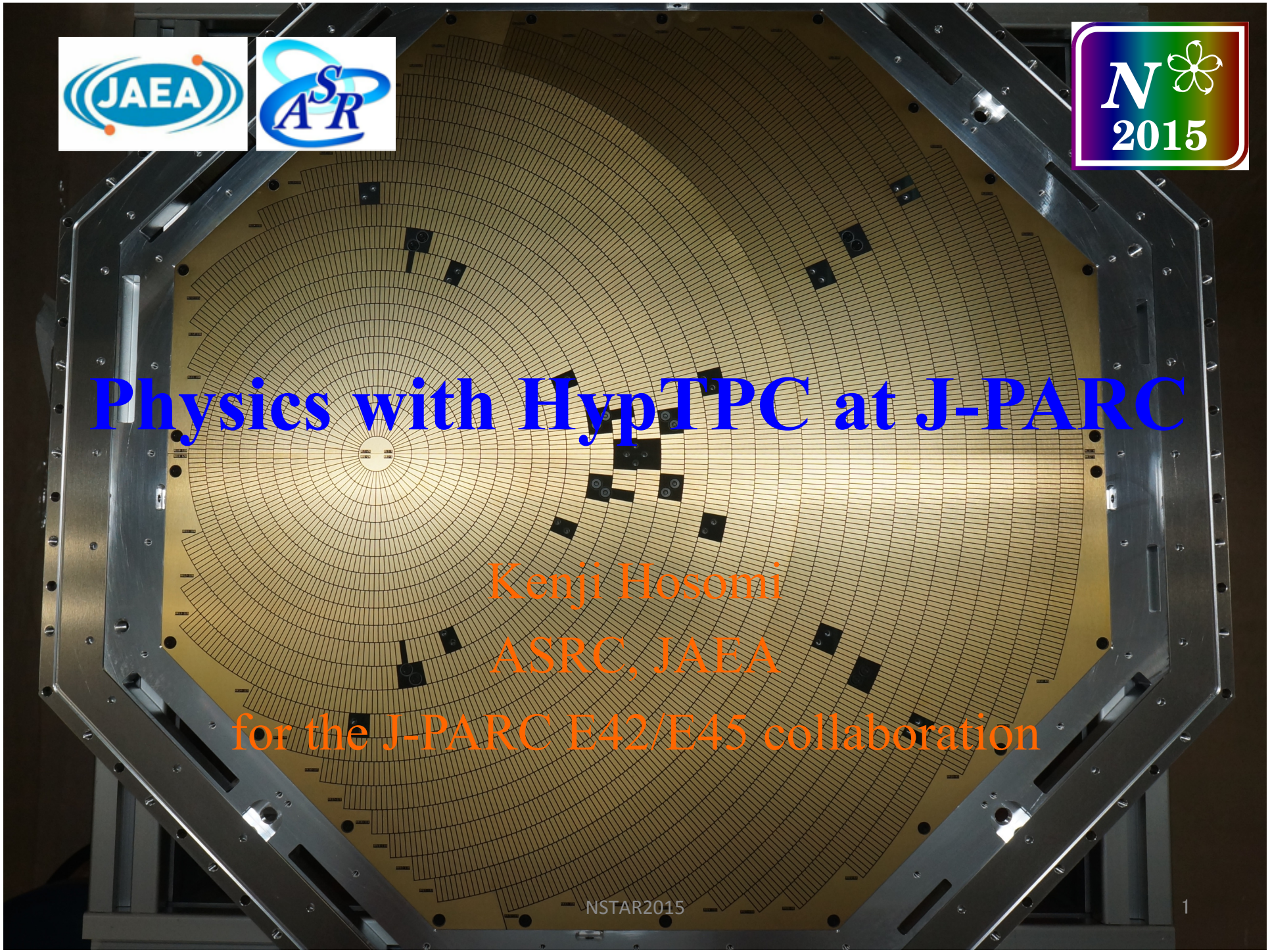


Physics with HypTPC at J-PARC

Kenji Hosomi

ASRC, JAEA

for the J-PARC E42/E45 collaboration

Contents of this talk

Hyperon Time Projection Chamber (HypTPC)

- Phyics programs with HypTPC
  - J-PARC E45 : Studies of baryon resonances in (π, 2π) rection
  - J-PARC E42 : Search for H−dibaryon
- Development status of HypTPC
- Summary

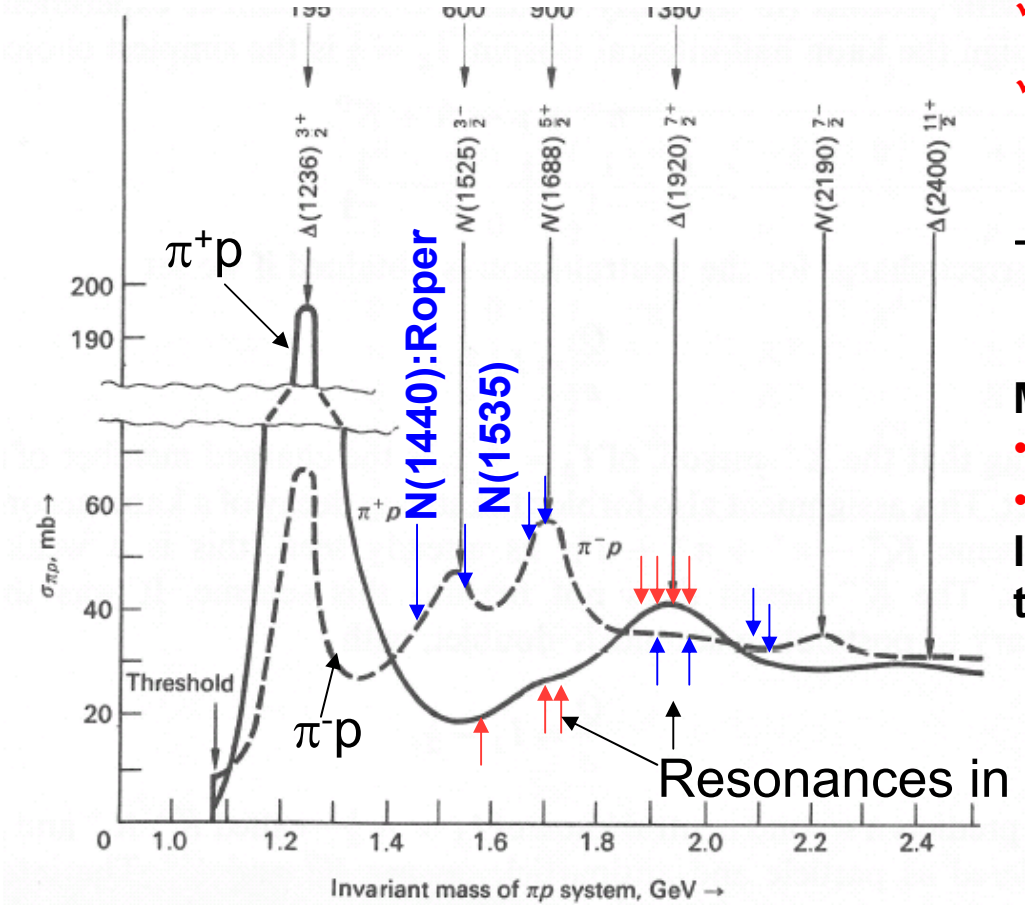
J-PARC E45

Studies of Baryon resonances in (π,2π) reaction for

- Deeper understanding of non-pertabative QCD
- Preceise measurements of baryon resonance properties
  - Many resonance have not been established experimentally
  - $\pi N \rightarrow \pi\pi N$: "Critical missing piece" for the N* spectroscopy
  - New $\pi N \rightarrow \pi\pi N$ data will provide
    1. significant modifications to the current N* mass
    2. discovery of new N* states.
- Search for new type baryon states
  - e.g. hybrid baryons (qqqg)

Baryon spectroscopy :
Physics of broad and overlapping resonances

D. H. Perkins, Introduction to High Energy Physics



- ✓ **Width: a few hundred MeV.**
- ✓ **Resonances are highly overlapped in energy except Δ(1232).**

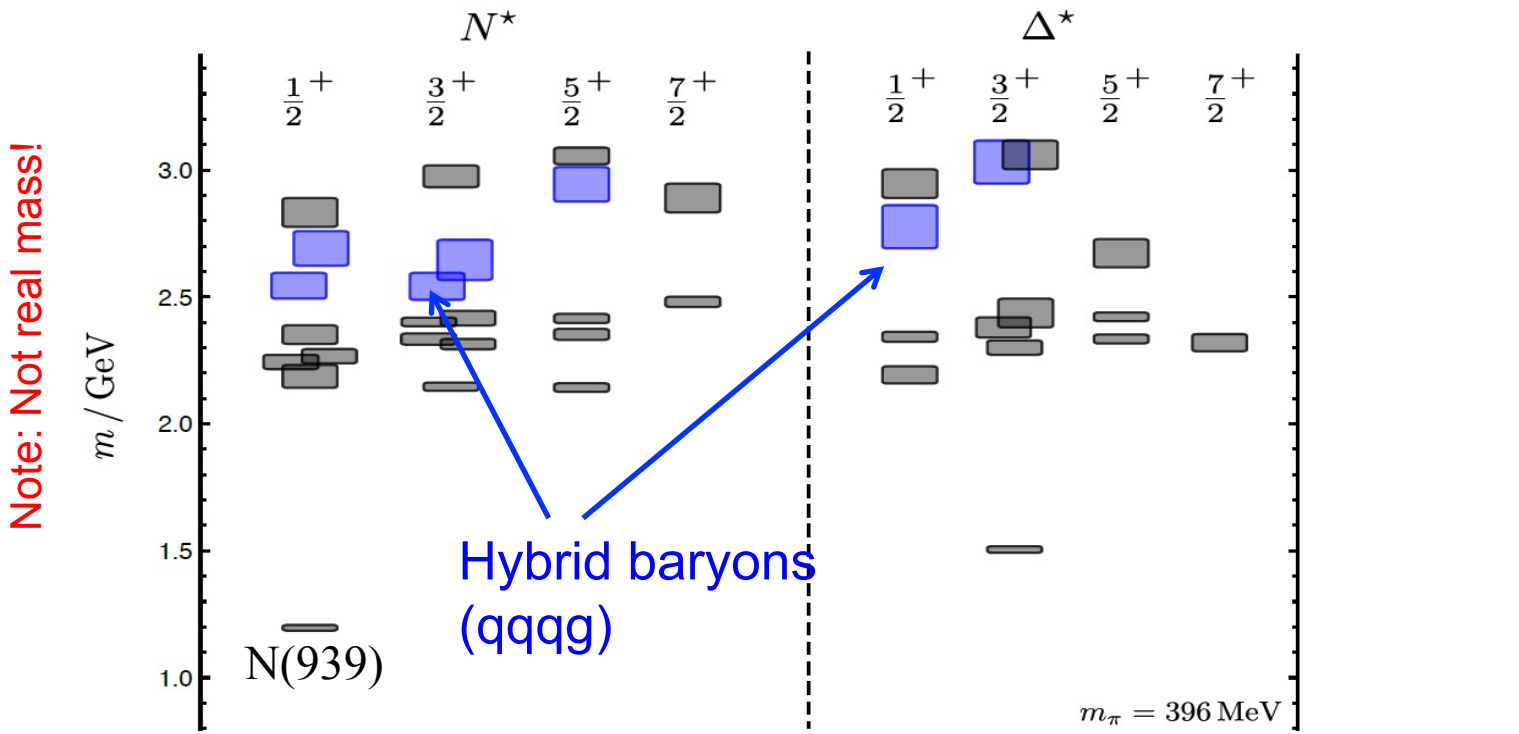
→Complicated Partial Wave Analysis to extract hidden resonances

Measure cross sections as a function of
- **incident pion energy**
- **Scattering angle**

In broad range (with fine bins) to extract resonance poles

New type baryon states

- Recent Lattice QCD calcurations show a new aspect in the nucleaon resonance spectrum.
  - They predict hybrid baryons (gluonic excitations).



J. Dudek et al., PRD85 (2012) 054016

Status of $N*$ resonance

PDG2014

Particle	J^P	Status overall	Status πN	Status γN	Status as seen in — $N\eta$	$N\sigma$	$N\omega$	ΛK	ΣK	$N\rho$	$\Delta\pi$
N	$1/2^+$	****									
$N(1440)$	$1/2^+$	****	****	****		***				*	***
$N(1520)$	$3/2^-$	****	****	****	***					***	***
$N(1535)$	$1/2^-$	****	****	****	****					**	*
$N(1650)$	$1/2^-$	****	****	***	***			***	**	**	***
$N(1675)$	$5/2^-$	****	****	***	*			*		*	***
$N(1680)$	$5/2^+$	****	****	****	*	**				***	***
$N(1685)$	$?^?$	*									
$N(1700)$	$3/2^-$	***	***	**	*			*	*	*	***
$N(1710)$	$1/2^+$	***	***	***	***		**	***	**	*	**
$N(1720)$	$3/2^+$	****	****	***	***			**	**	**	*
$N(1860)$	$5/2^+$	**	**							*	*
$N(1875)$	$3/2^-$	***	*	***			**	***	**		***
$N(1880)$	$1/2^+$	**	*	*		**		*			
$N(1895)$	$1/2^-$	**	*	**	**			**	*		
$N(1900)$	$3/2^+$	***	**	***	**		**	***	**	*	**
$N(1990)$	$7/2^+$	**	**	**					*		
$N(2000)$	$5/2^+$	**	*	**	**			**	*	**	
$N(2040)$	$3/2^+$	*									
$N(2060)$	$5/2^-$	**	**	**	*				**		
$N(2100)$	$1/2^+$	*									
$N(2150)$	$3/2^-$	**	**	**				**			**
$N(2190)$	$7/2^-$	****	****	***			*	**		*	
$N(2220)$	$9/2^+$	****	****								
$N(2250)$	$9/2^-$	****	****								

more than *** : 15/45
tentative : 10/45

Many of the nucleon resonances predicted by QM were not found by PWA of old hadronic beam data.

"Missing resonance" problem

(This has not been solved yet)

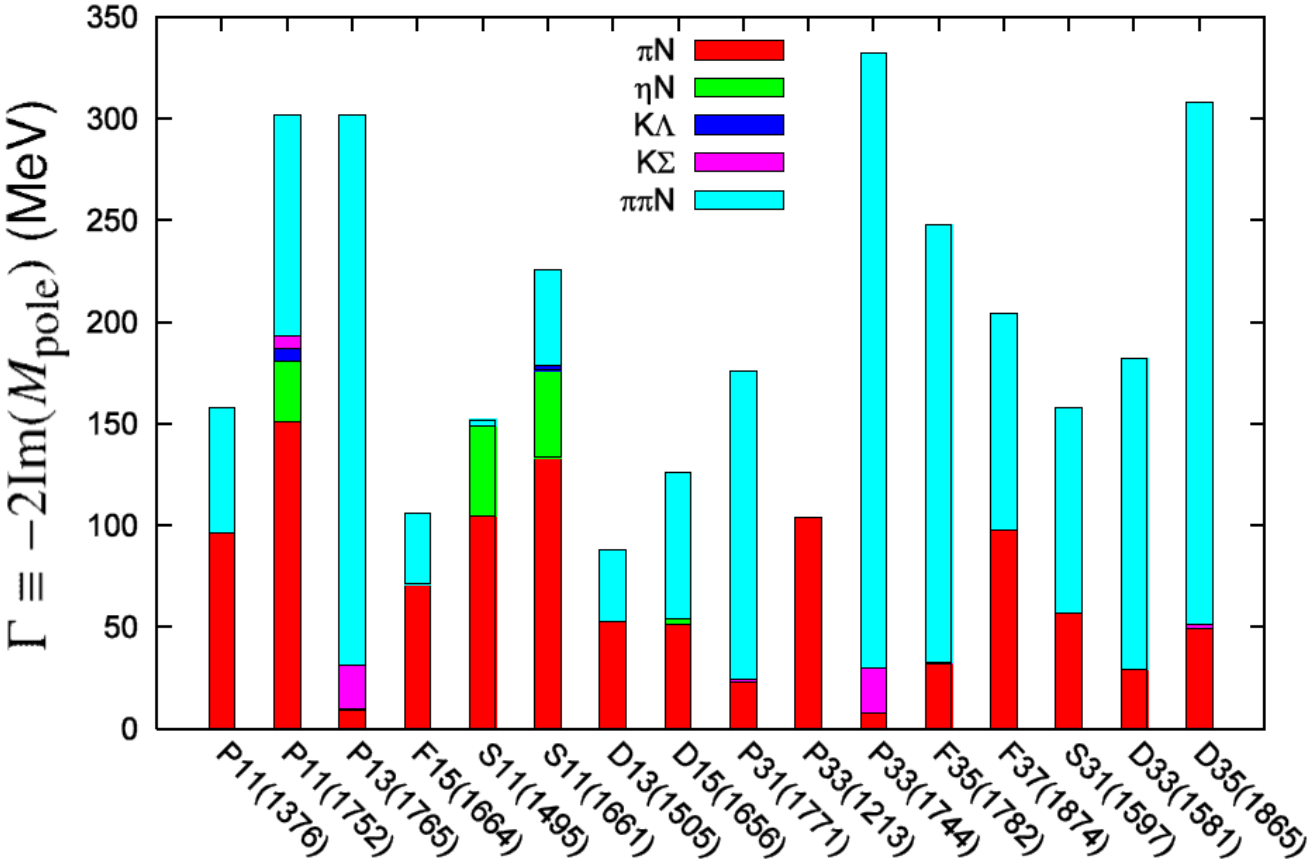
Most of the N resonance were primary determined from $\pi N \rightarrow \pi N$ data. But, many of high mass resonances has strong coupling to $\pi\pi N$ final states.

Precise new data on phtonproduction is available from (Bonn, Mainz, Jlab, Spring-8,…)

Good data for $\pi N \rightarrow \pi\pi N$ is still highly desirable to search for missing resonances.

Importance of ππN (Width of *N** resonances)

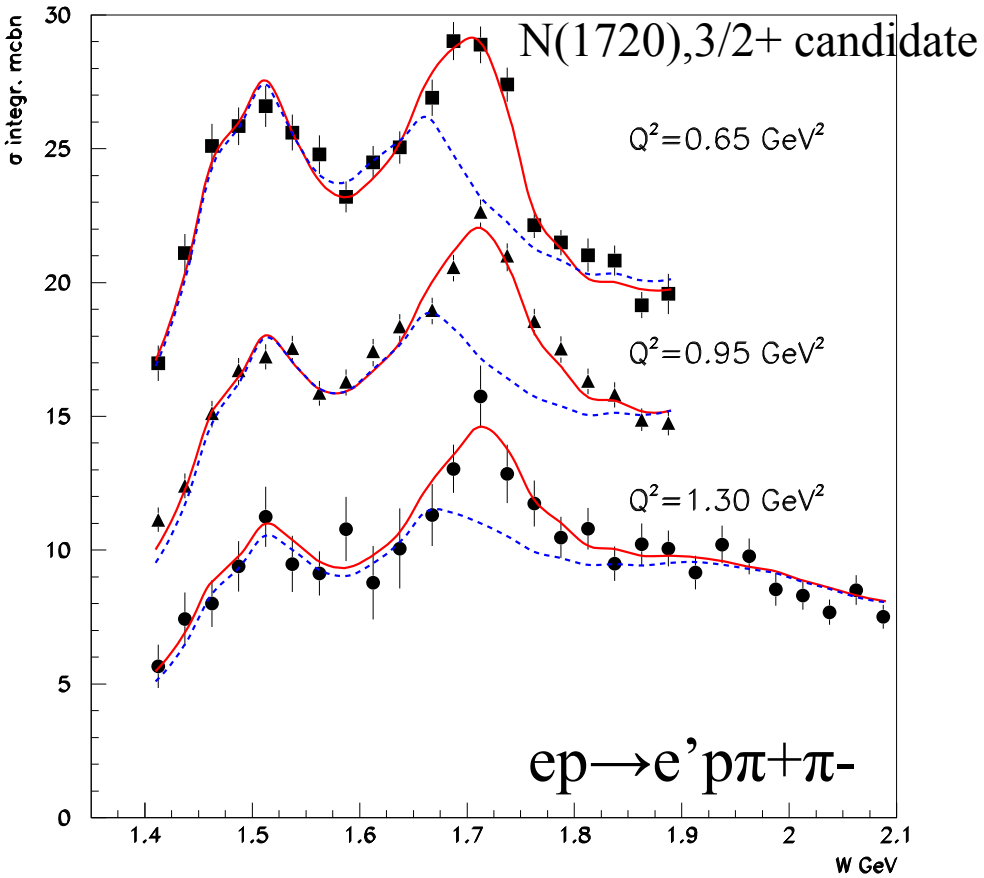
Over half of the decay branchig fraction goes into 2π channel.



Kamano, Nakamura, Lee, Sato, 2012

Importance of ππN
(Two pion production from CLAS)

Journal of Physics: Conference Series 299 012008



The blue dotted curve use only the known resonances from the PDG.

The red solid curve includes extra resonance not seen from the PWA of πN data alone.

Two pion production can see new resonance!!

World's πN→ππN data

Only 240K events is abailable at present.
These data were taken in bubble-chamber experiments in 1970's.

TABLE I. Summary of the number of events analyzed at each energy.

W (MeV)	$\pi^+\pi^-n$	$\pi^0\pi^-p$	$\pi^0\pi^+p$	$\pi^+\pi^+n$	Total
1340±20	1664	11	0	0	1675
1375±15	3893	145	15	2	4055
1400±10	3646	826	63	15	4550
1440±10	3790	1339	207	48	5384
1460±10	2074	971	152	36	3233
1480±10	7246	3776	537	128	
1500±10	6224	4055	1160	250	
1520±10	5650	4671	795		
1540±10	6230	5320			12 848
1565±15	2237	1598		481	7020
1595±15	3065			483	8374
1620±10	0		4203	621	4824
1640±10			7939	1013	20 566
1660±10		4273	4071	752	16 507
		5340	4999	847	19 970
	8377	5394	5375	1007	20 153
	6265	4594	5679	524	17 062
1755±15	5442	4200	1316	18	10 976
1790±20	1966	1352	4715	228	8261
1830±20	3543	2223	2322	0	8088
1870±20	4342	3382	8190	557	16 471
1910±20	6036	4081	6445	0	16 562
Total	105 322	63 690	64 866	7336	241 214

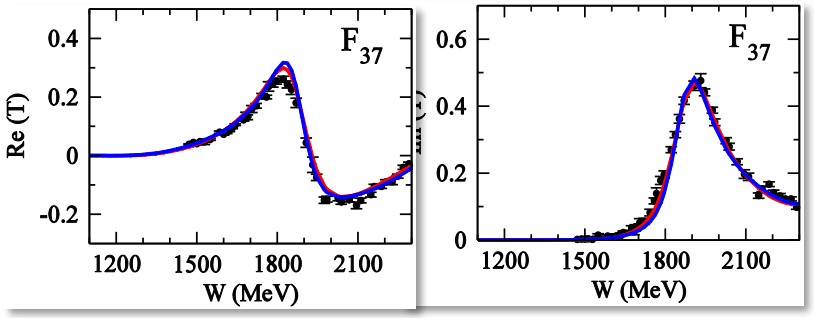
Statistics are insufficient for multi-dimensional bining analysis.

D. Mark Manley et al., Phys. Rev. D 30 904

World's πN→ππN data

Only 240K events is abailable at present.
These data were taken in bubble-chamber experiments in 1970's.

Kamano, ELPH workshop C005

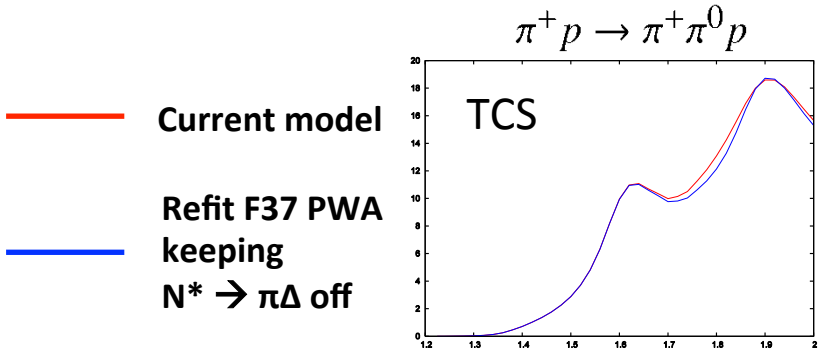


Muti−dimentional analyses are essential to determine DCC parameters

M(π0 p)

M(π+ p)

M(π+ π0)

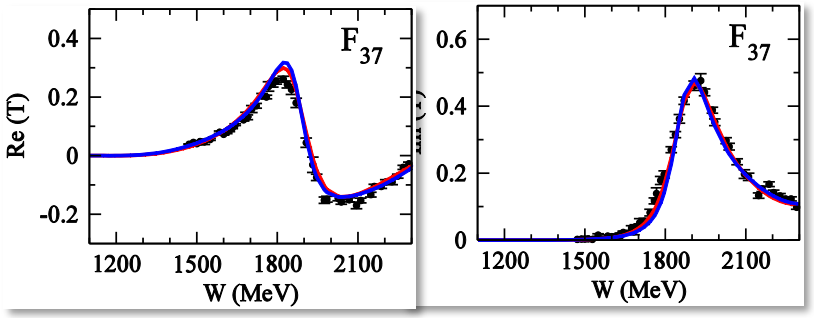


VERY PRELIMINARY

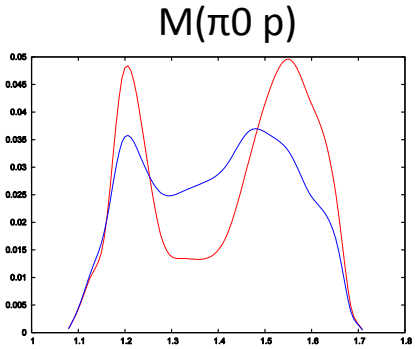
World's πN→ππN data

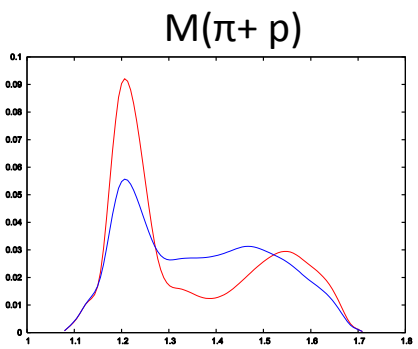
Only 240K events is abailable at present.
These data were taken in bubble-chamber experiments in 1970's.

Kamano, ELPH workshop C005



Muti−dimentional analyses are essential to determine DCC parameters

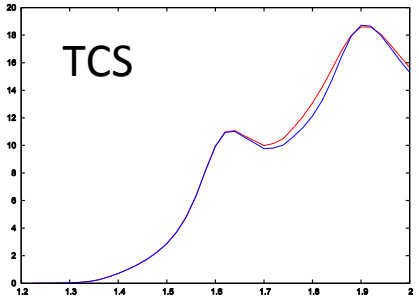




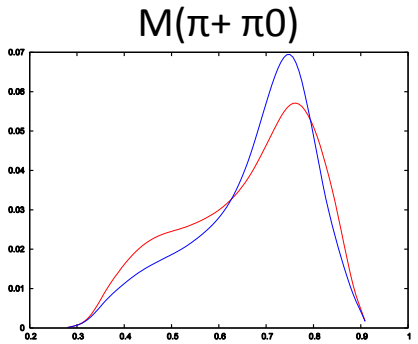
Current model

Refit F37 PWA keeping N* → πΔ off

$\pi^+ p \to \pi^+ \pi^0 p$



VERY PRELIMINARY



Outputs from E45

Improvement of the world's $\pi N \rightarrow \pi\pi N$ data by factor of 100 times.
Uniform coverage of the wide W range of the nucleon resonance.

TABLE I. Summary of the number of events analyzed at each energy.

W (MeV)	$\pi^+\pi^-n$	$\pi^0\pi^-p$	$\pi^0\pi^+p$	$\pi^+\pi^+n$	Total
1340±20	1664	11	0	0	1675
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1480±10	7246	3776	537	128	11 687
1500±10	6224	4055	1160	250	11 689
1520±10	5650	4671	795	143	11 259
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1870±20	4342	3382	8190	557	16 471
1910±20	6036	4081	6445	0	16 562
:					
2100					
2125					
2150					

Momentum range of incident π beam (GeV/c) : 0.73 – 2.0

for higher W

Total ~10k events/ ΔW

Now, J-PARC is the only facility that can address this deficiency.

~1M events / ΔW

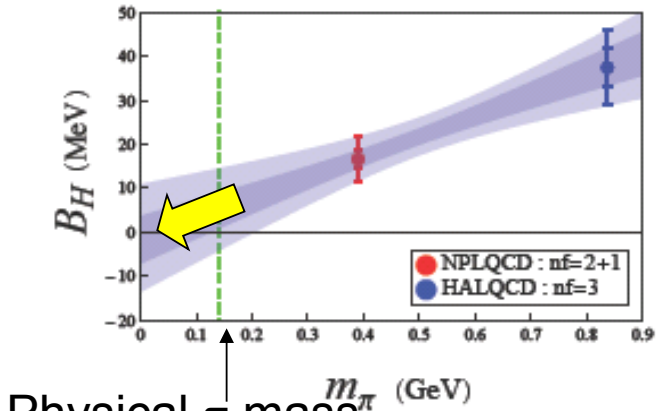
J-PARC E42: Search for H-dibaryon

Stable and compact 6-quark state (*uuddss*)

Lattice-QCD calculations

Binding energy : -13 ~ +7 MeV

H may be slightly bound or unbound

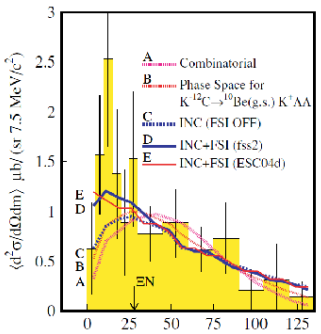


Experimental search

- Peaks observed at KEK-E224, E522 around ΛΛ mass threshold
  - Indication of H?
  - Statistics not enough

KEK-E522

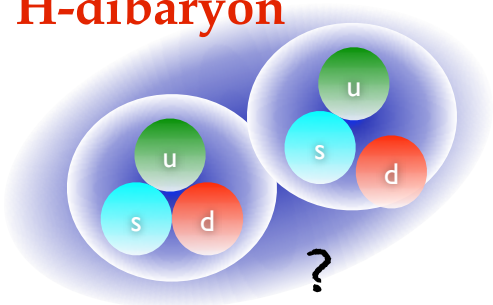
90 ΛΛ



High statics experiment at J-PARC

J-PARC E42: Search for H-dibaryon

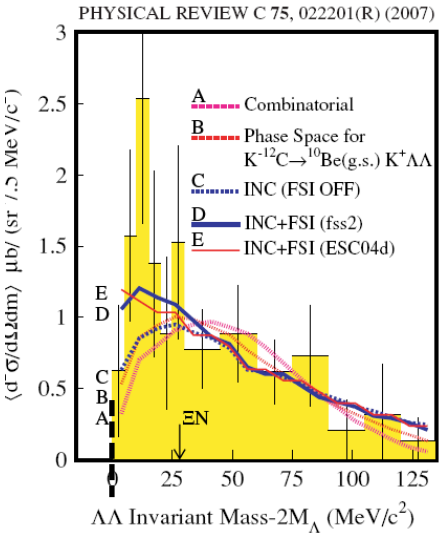
H-dibaryon



R. L. Jaffe, Phys. Rev. Lett. 38, 195 (1977)

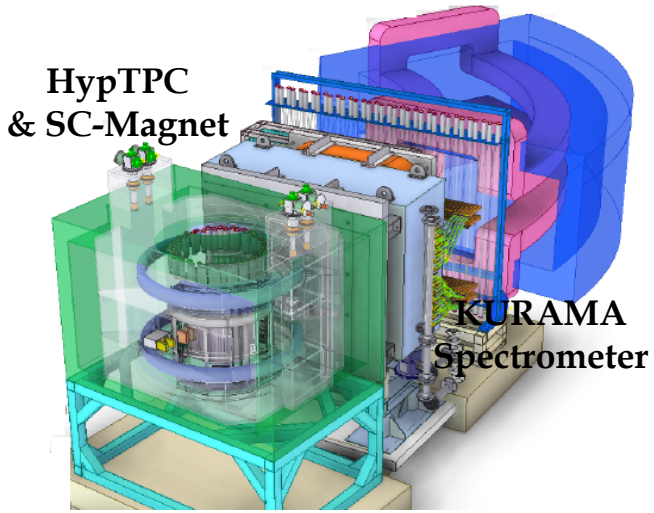
- Weakly-bound : $H \rightarrow \Lambda p\pi$ weak decay Lower Limit: 7 MeV ($^{6}_{\Lambda\Lambda}$He)
- Virtual state : $\Lambda\Lambda$ threshold effect
- Resonance : Breit-Wigner peak in the $\Lambda\Lambda$ mass spectrum.

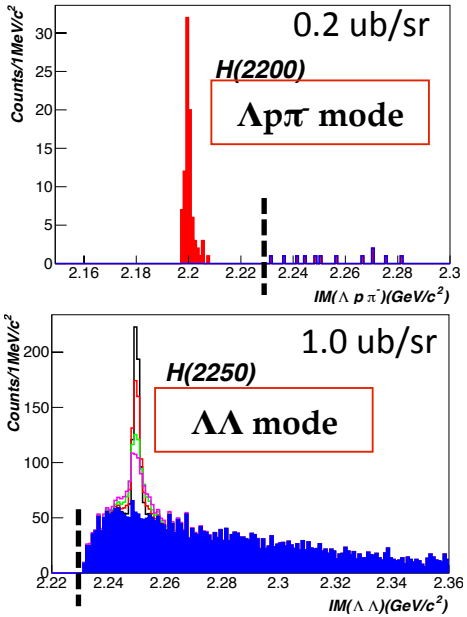
E522 @ KEK

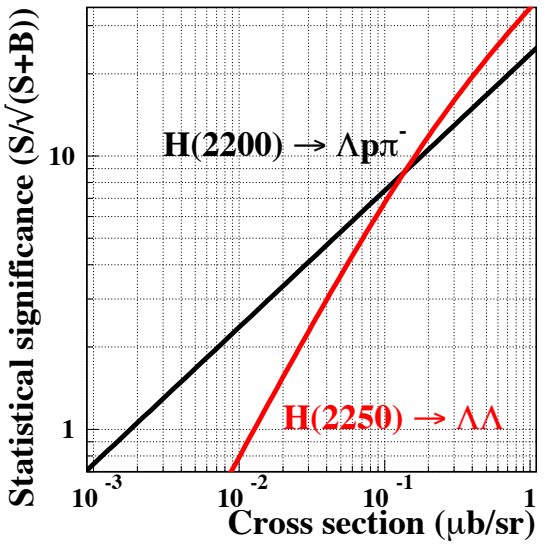


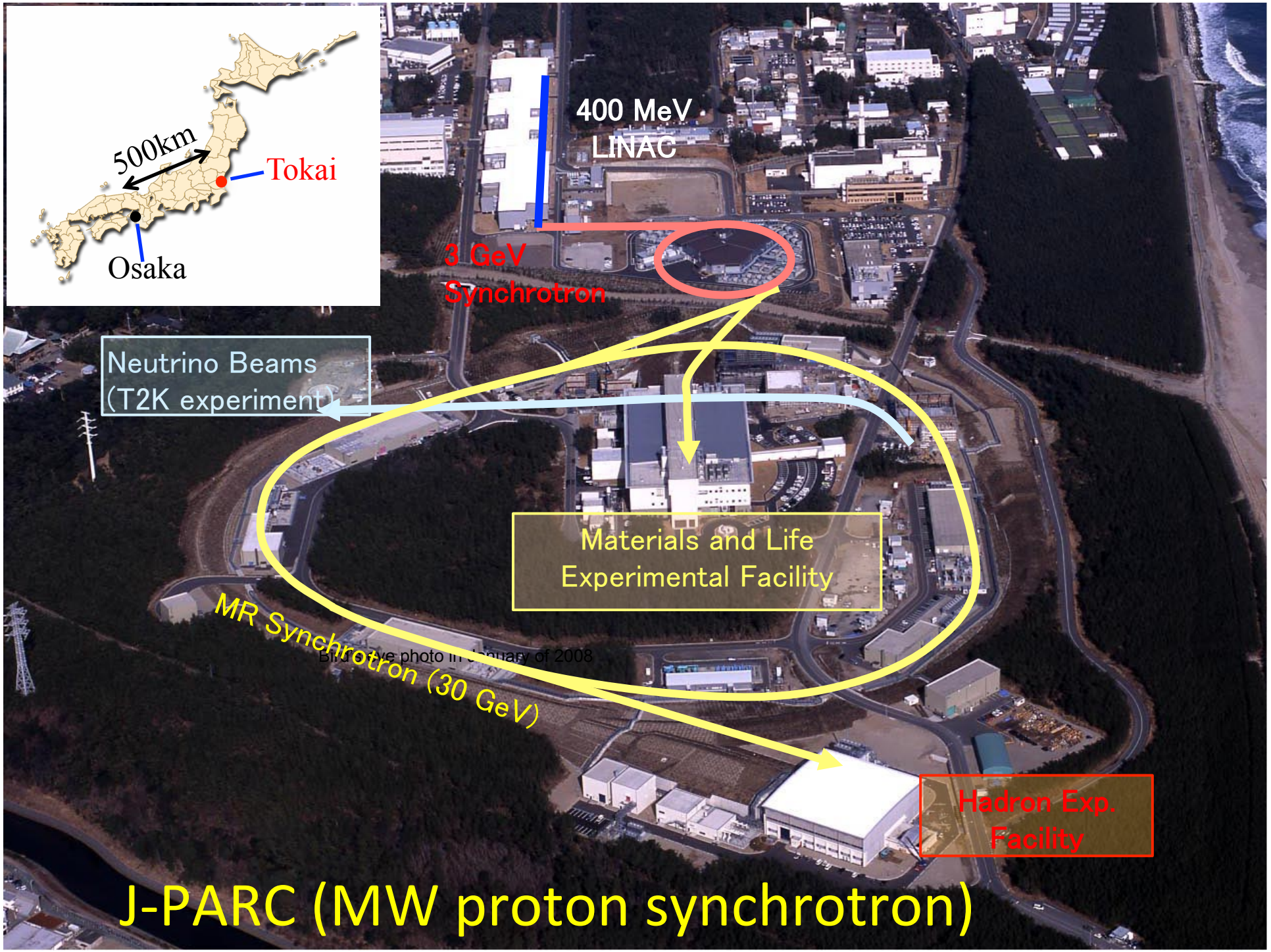
^{12}C(K-,K+)X at 1.6 GeV/c
H→2Λ→ppπ-π-

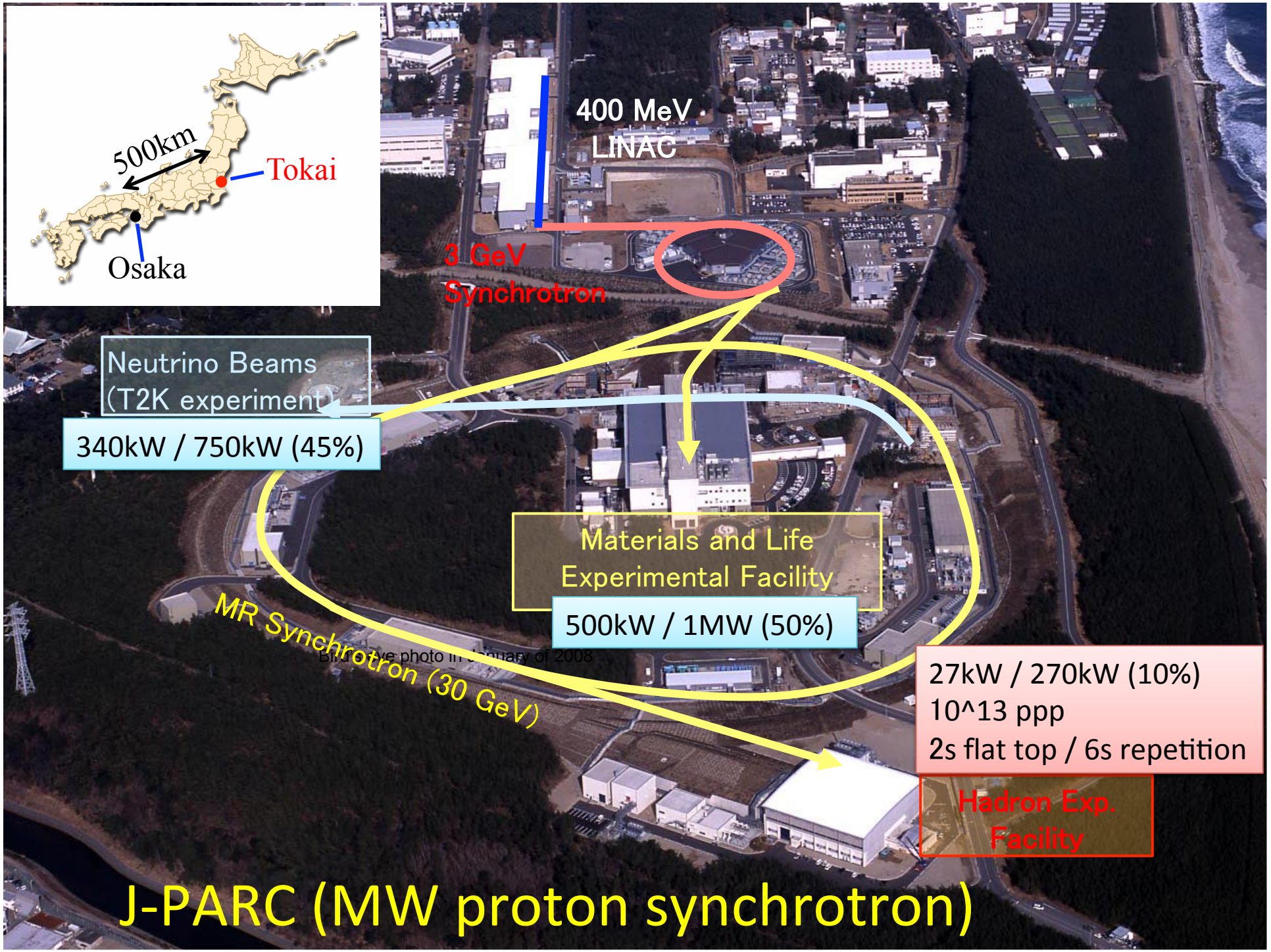
measure 11000 $\Lambda\Lambda$ events and 1440 H(2250) events for 1.0 μb/sr







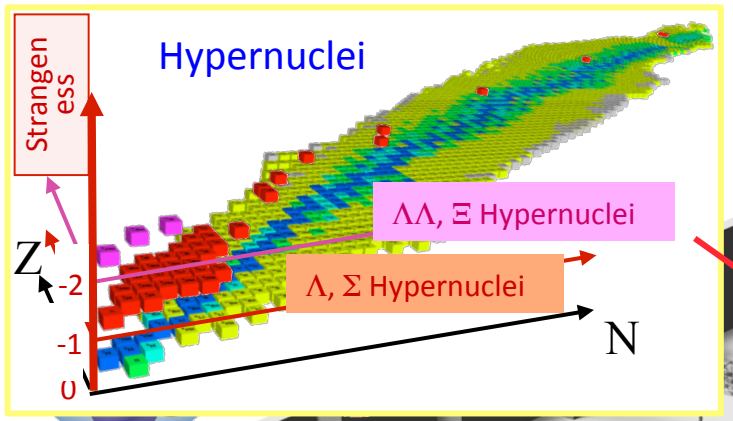

500km
Tokai
Osaka
400 MeV
LINAC
3 GeV
Synchrotron
Neutrino Beams
(T2K experiment)
Materials and Life
Experimental Facility
MR Synchrotron (30 GeV)
Hadron Exp.
Facility
J-PARC (MW proton synchrotron)

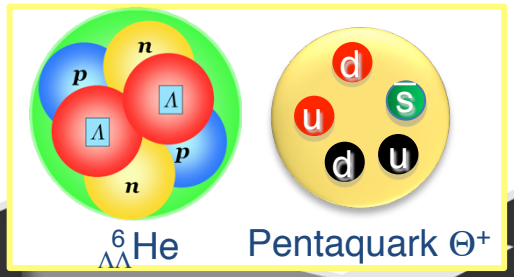

500km
Tokai
Osaka
400 MeV
LINAC
3 GeV
Synchrotron
Neutrino Beams
(T2K experiment)
340kW / 750kW (45%)
Materials and Life
Experimental Facility
500kW / 1MW (50%)
MR Synchrotron (30 GeV)
27kW / 270kW (10%)
10^13 ppp
2s flat top / 6s repetition
Hadron Exp.
Facility
J-PARC (MW proton synchrotron)

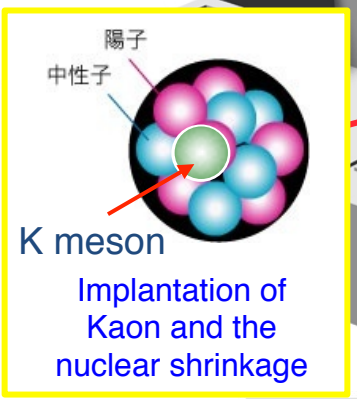
Hadron Experimental Facility

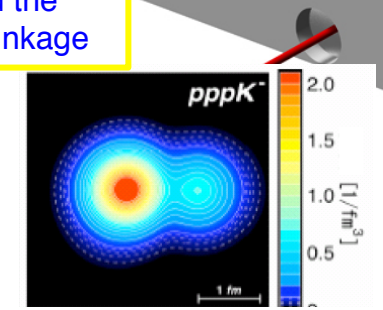
Details of Hadron Physics Programs:
Kiyoshi TANIDA, Pleanary 28-2

2015 (cycle ~ 6s)
10^{13}/cycle p beams
10^{7}/cycle π beams
10^{5}/cycle K beams
E45 : 1M pion ✔
E42 : 1M Kaon









E45 HypTPC Spectrometer

Measure (π,2π) in large acceptance TPC in dipole magnetic field

$\pi^- p \to \pi^+ \pi^- n$, $\pi^0 \pi^- p$

$\pi^+ p \to \pi^0 \pi^+ p$, $\pi^+ \pi^+ n$

2 charged particles + *1 neutral particle*

→*missing mass technique*

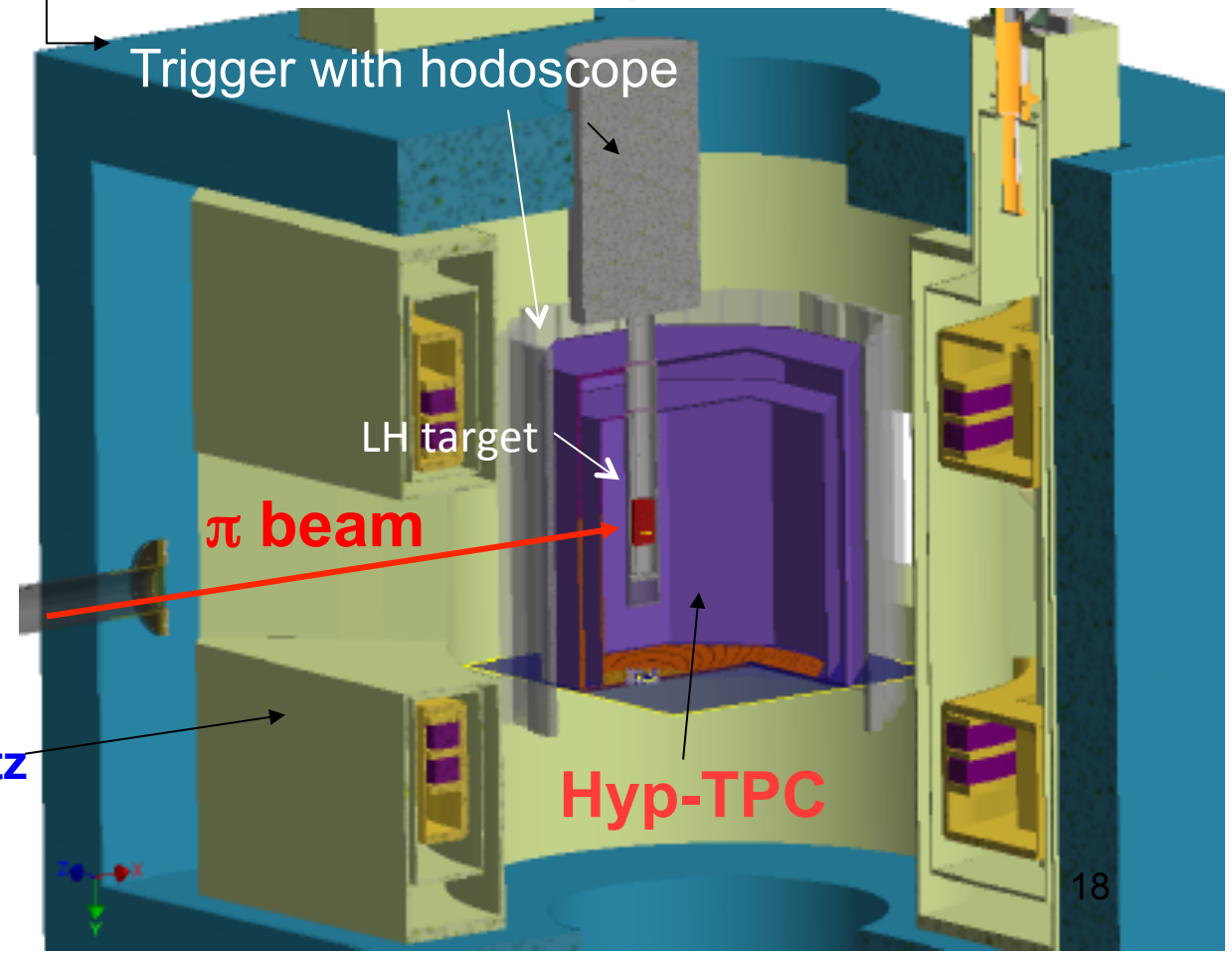
$\pi N \to KY$ *(2-body reaction)*

$\pi^- p \to K^0 \Lambda$,

$\pi^+ p \to K^+ \Sigma^+$ *(I=3/2, Δ*)*

π^{+-} beam on liquid-H target
(p= 0.73 – 2.0 GeV/c
W=1.5-2.15 GeV)

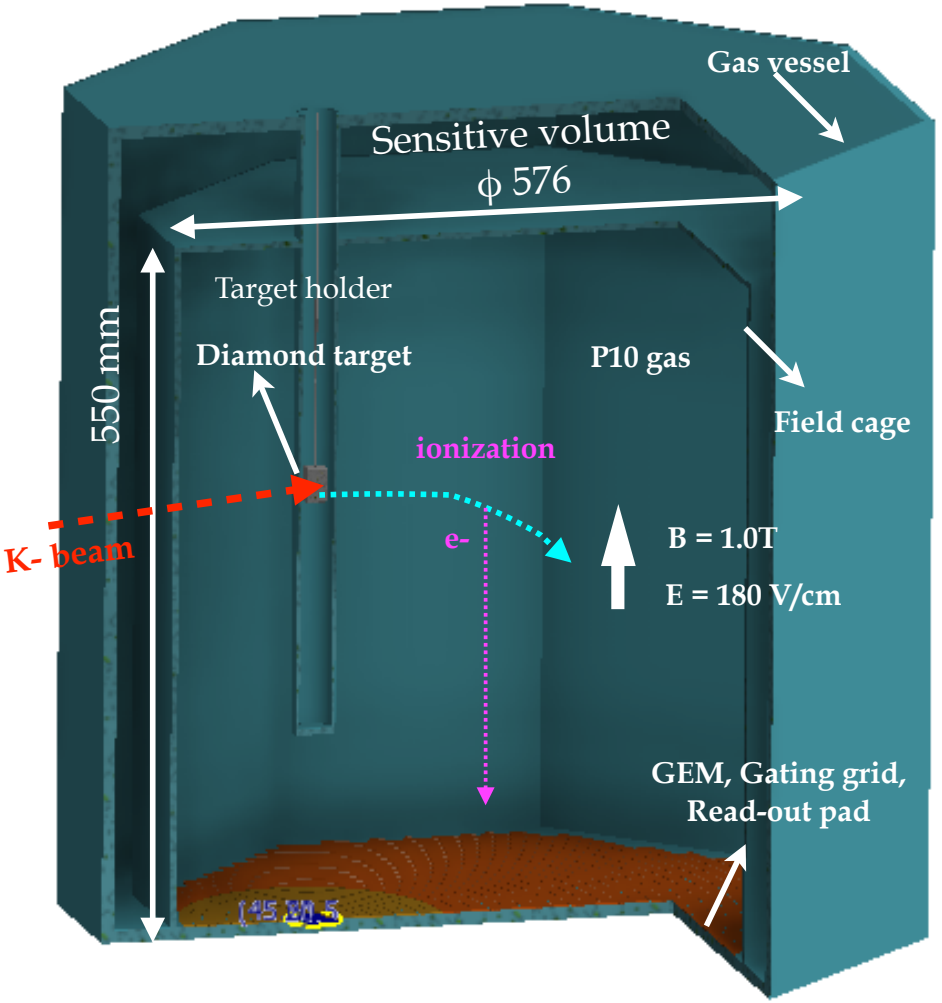
LH target: Φ5cm



Superconducting Helmholtz Dipole magnet (1.5 T)

Hyperon Time-Projection-Chamber

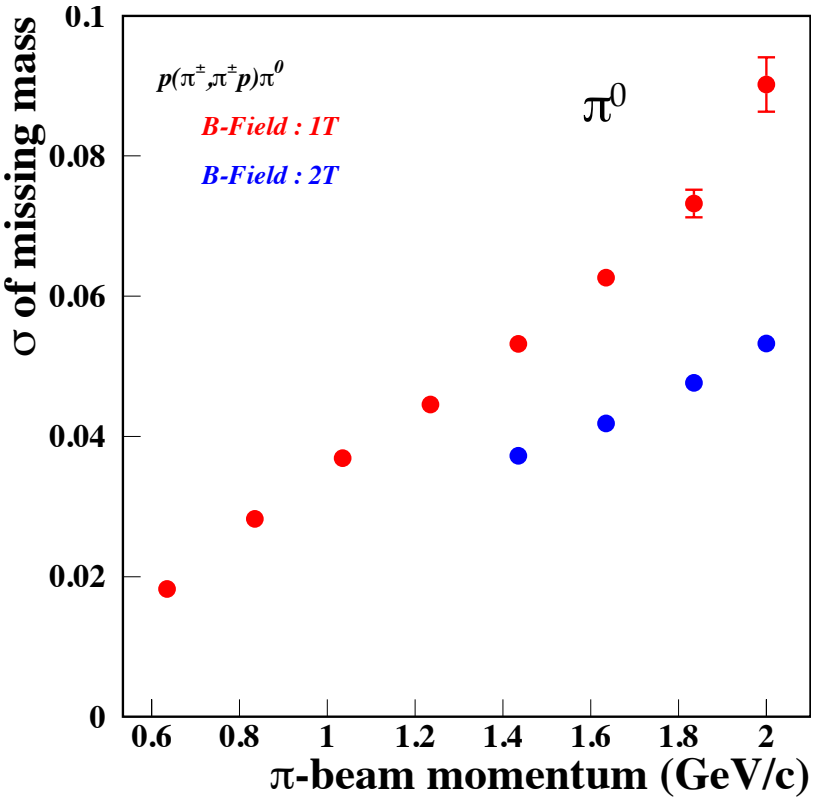
3D rendering view of HypTPC

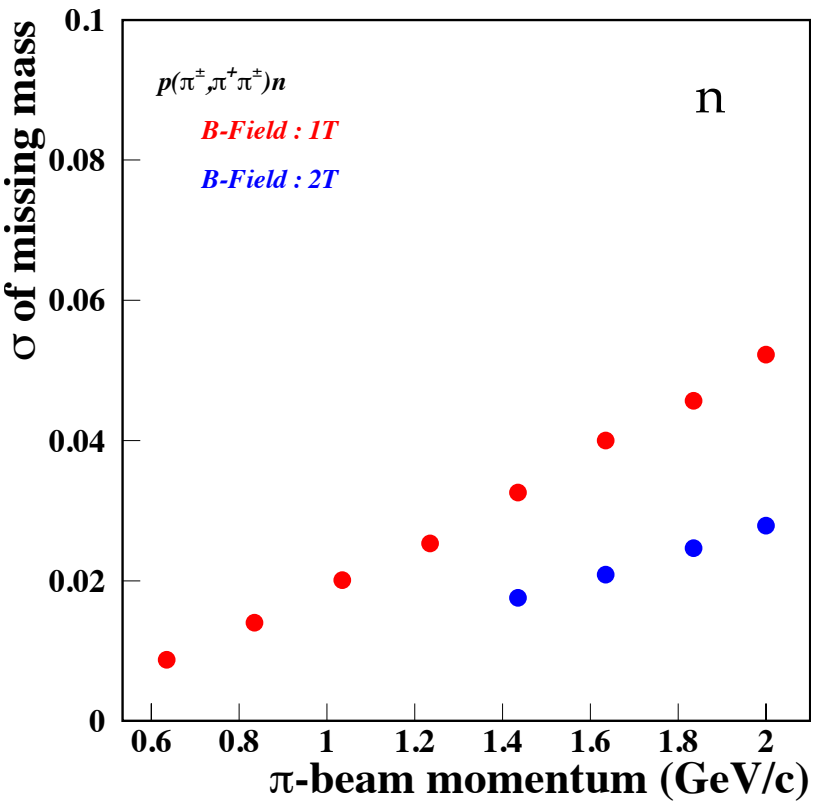


- GEM amplification
  (High count rate, 10^6)
- Large Acceptance
  (almost 4π)
- Target is inside TPC
  (Detection of short lived particle)
- High resolution.
  position : 300um, $\Delta p/p$: 2-6 % (π,p)
- Long term operation

Missing mass resolution

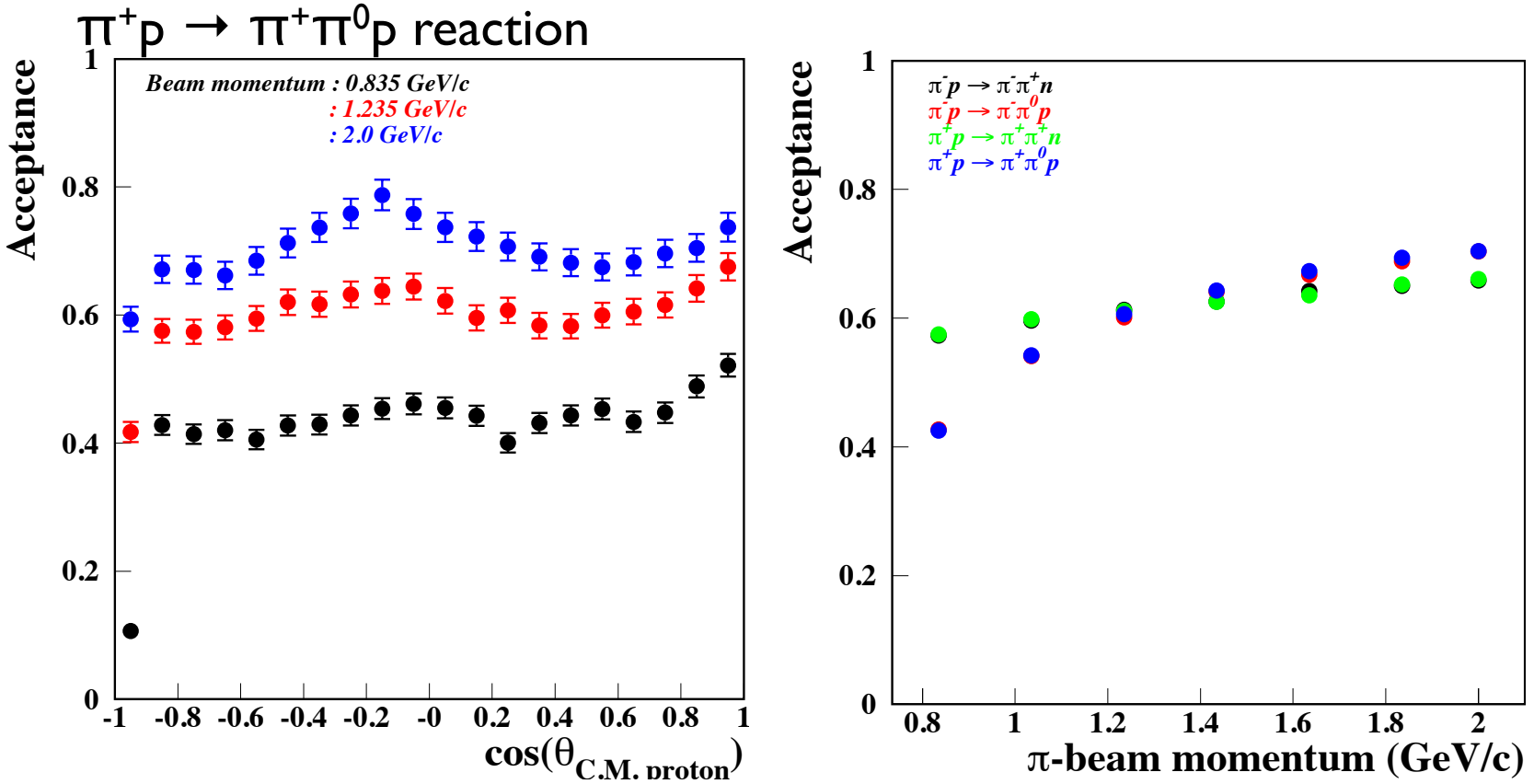
σ of MM is ~ 50 MeV/c^2, (Mass π0: 134, neutron: 940)





Missing mass technique and coplanarity can identify neutral particles.

Acceptance



Momentum of Proton > 300 MeV/c (energy lose in target is large)

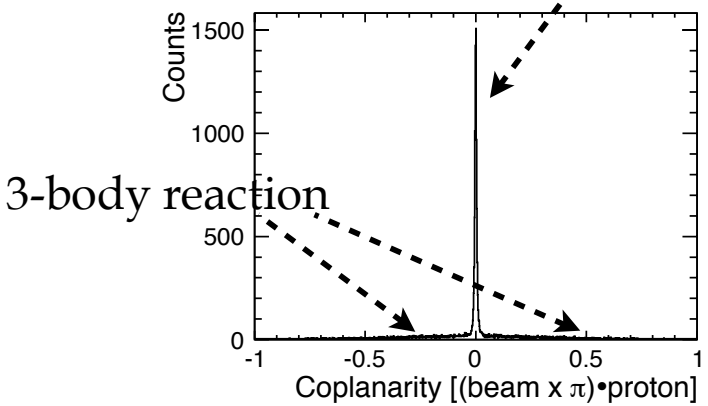
Background

πp: σ_{total} = 40 mb

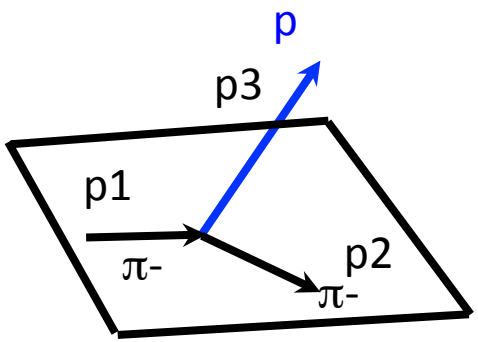
(π,2π) cross section : 2 - 10 mb

elastic scattering : 10 – 30 mb
(Dominant background)

Elastic scattering
(Same trigger condition)



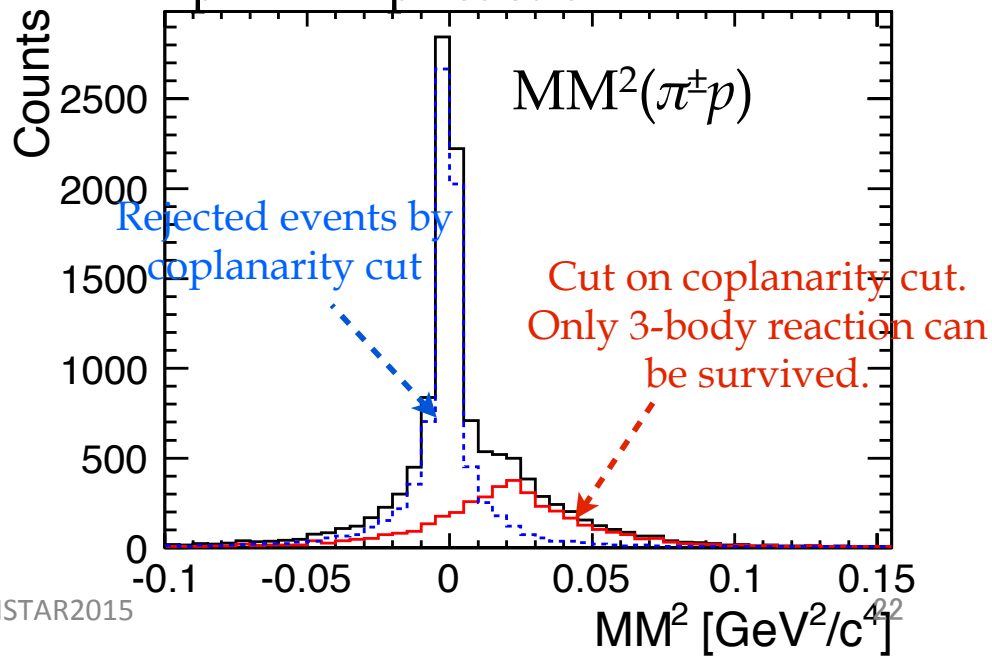
3-body reaction



coplanarity
=cosine of angle
Between p1 and
(p2xp3)

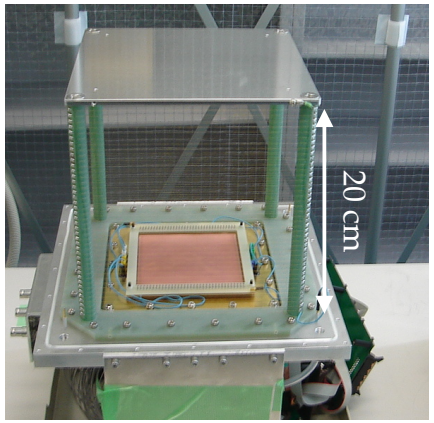
0: p1,p2,p3re in
the same plane

$\pi p \rightarrow \pi\pi^0 p$ reaction



Milestones

1st prototype TPC



2011. 1. Beam test of the prototype TPC at ELPH

Stable operation

2011. 11. High rate beam test of the prototype TPC at RCNP

Confirmed high counting rate operation 10^6

2013. 3. Begin of the fabrication of the HypTPC

2013. 4. Operation test with B-field at J-PARC (FM magnet)

2014. 4. GEM and readout pad were ready.

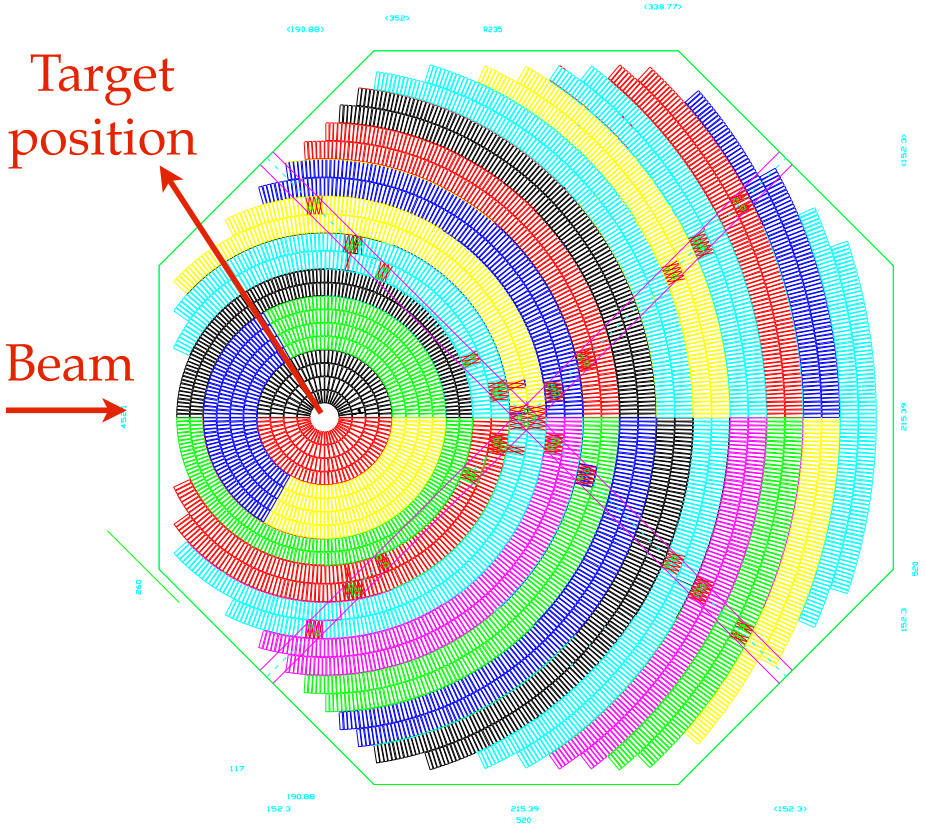
2015. 2. Full readout pad of the HypTPC was ready.

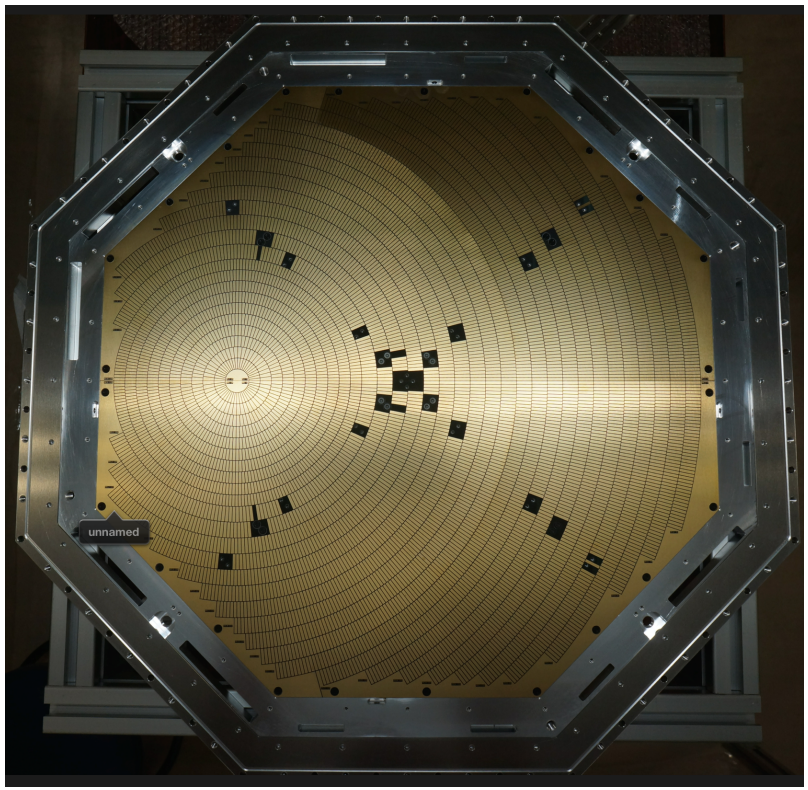
2015. 3. 256/5768 ch (5%) readout with 10cm drift volume was ready.

2016. 3. 100 % readout with 55cm (full size) drift will be ready.

Configuration of Readout-PAD

Colours show read-out channels for each AsAd board.

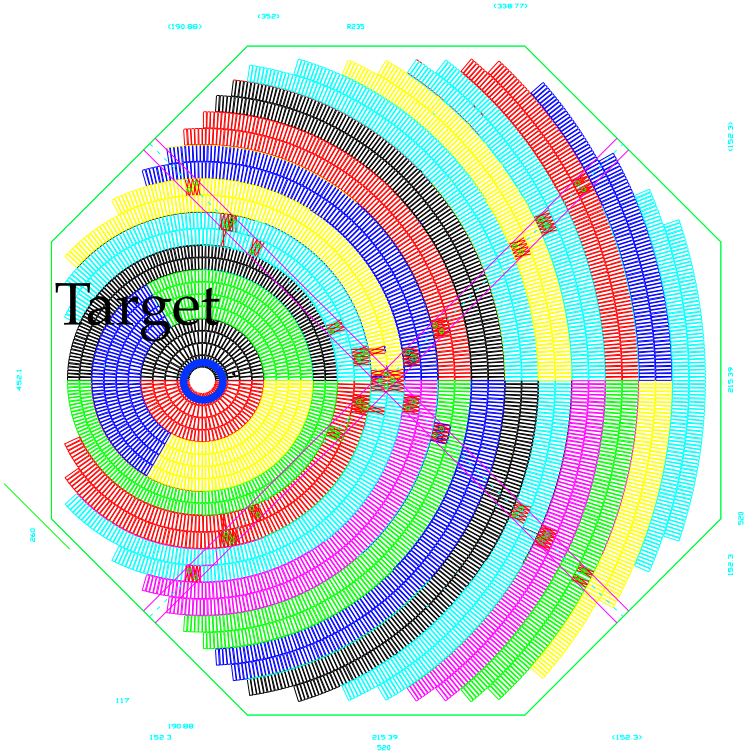




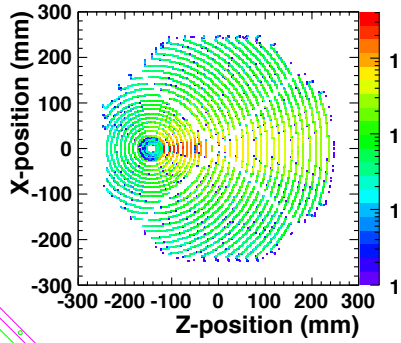
Inner pad : 10 layers, 2.1 - 2.7 x 9 mm^2
Outer pad : 23 layers, 2.3 - 2.4 x 12.5 mm^2
Read-out pad :5768

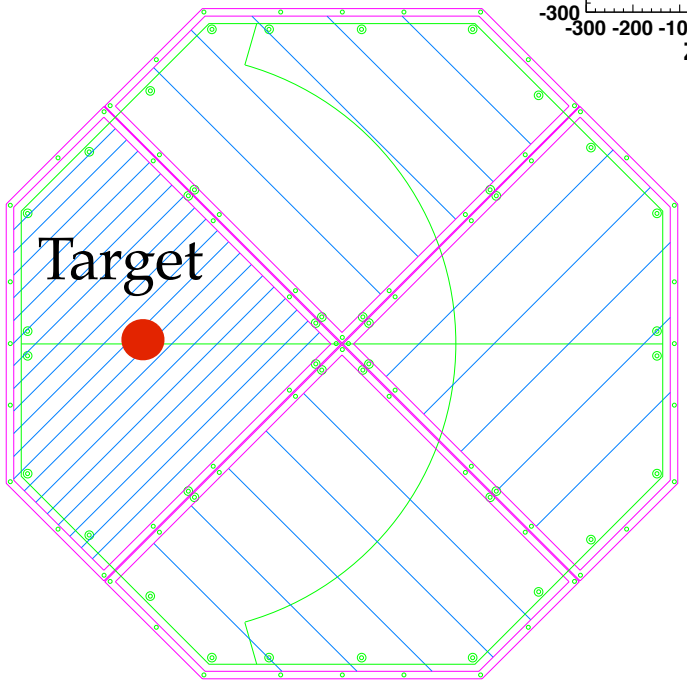
Readout PAD and GEM electrode

Readout PAD



GEM electrode



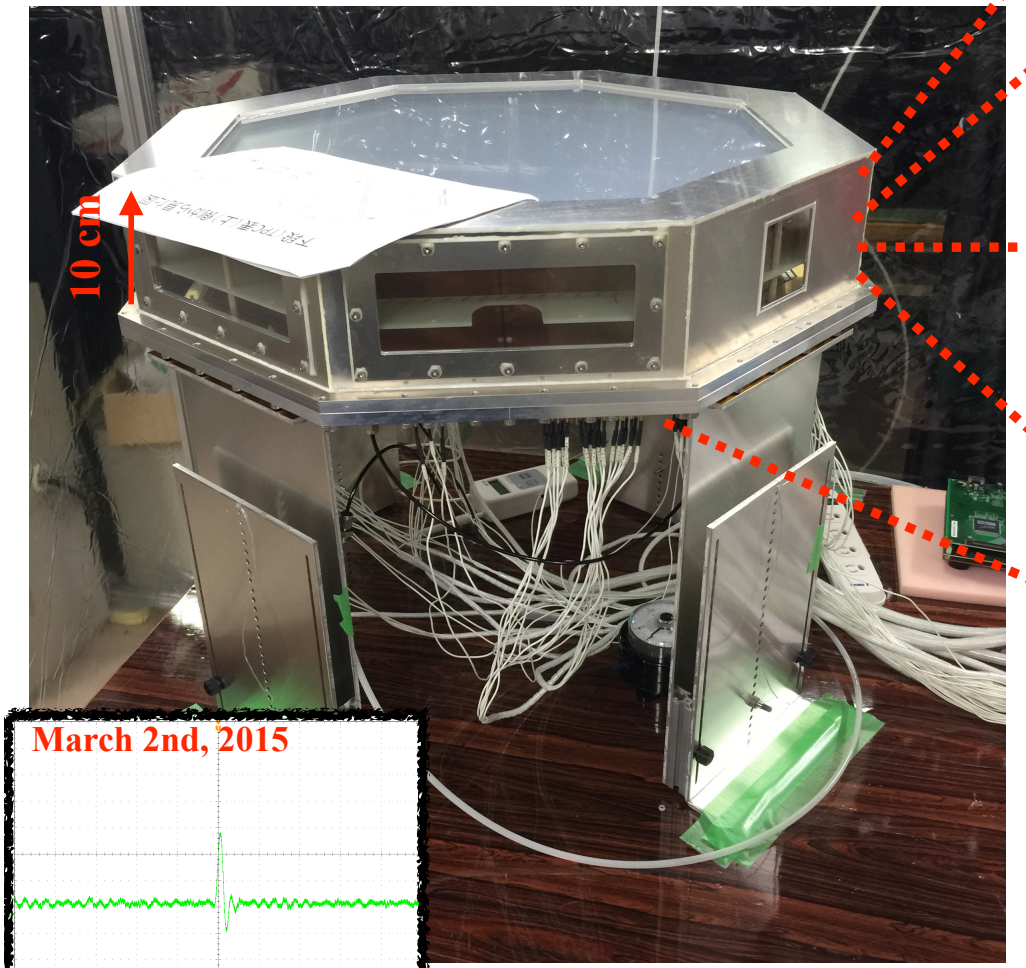


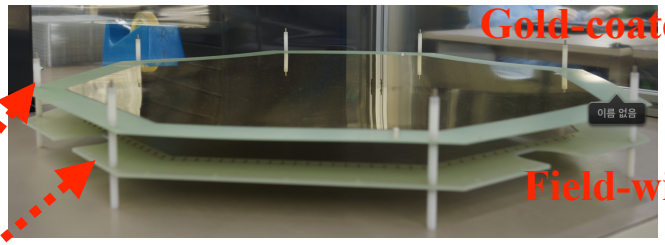
Number of pads : 5768
Inner PAD : (2.1-2.7) x 9 mm^2
Outer PAD : (2.3-2.4) x 12.5 mm^2

The GEM electrode has a small devision in target section, due to the large multiplicity.

Construction of the HypTPC

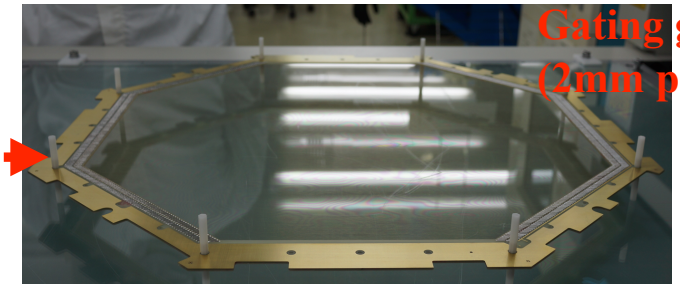
- HypTPC is ready with full size of read-out pad



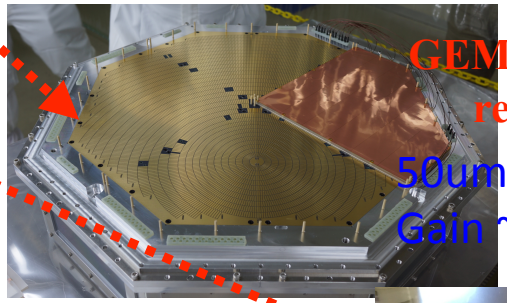


Gold-coated Cathode

Field-wire plane



Gating grid
(2mm pitch)

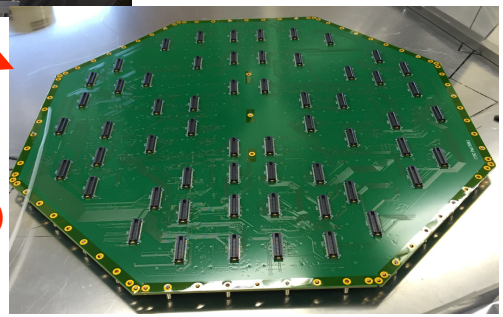


GEM (3 layers) &
read-out PAD

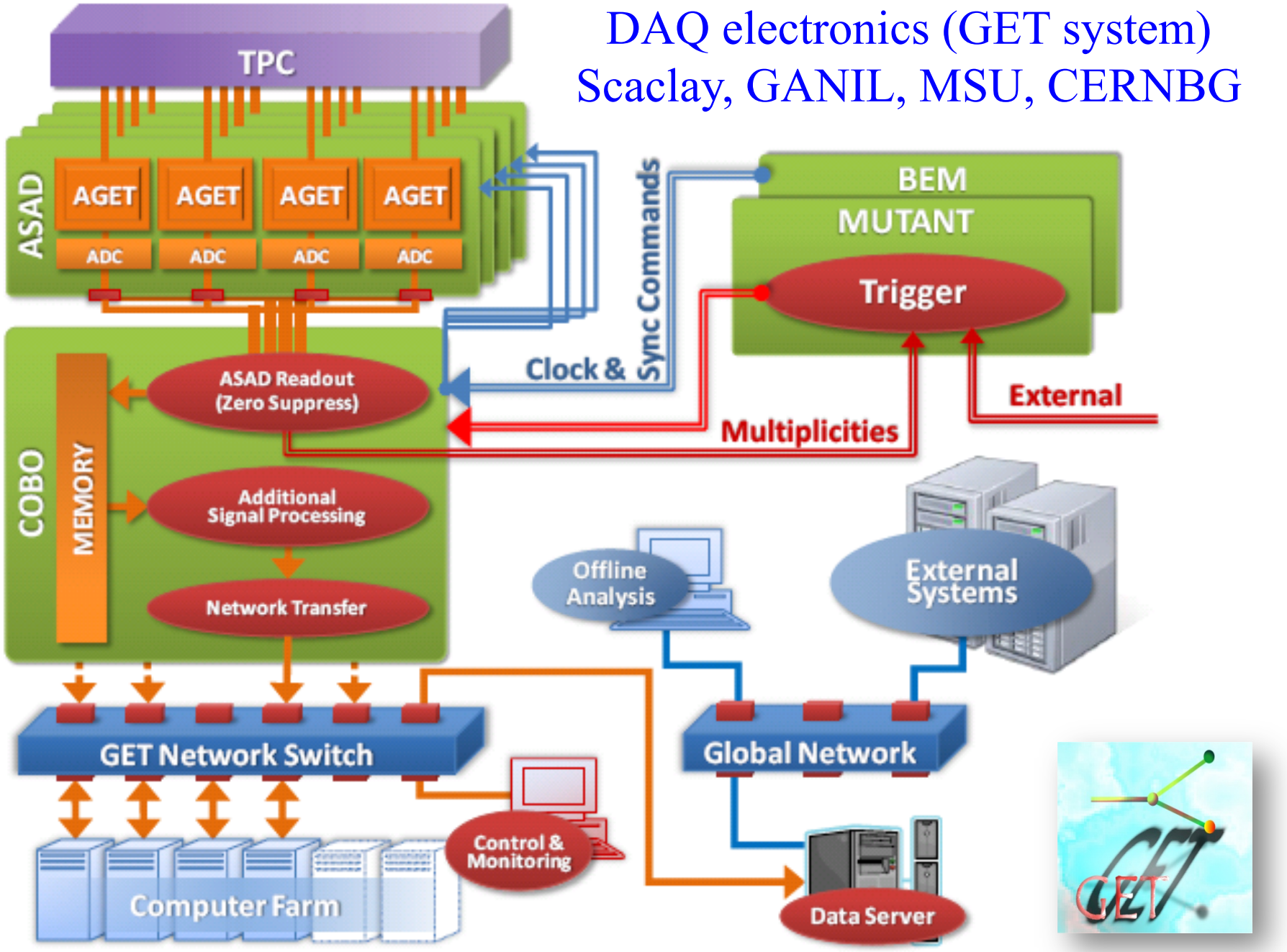
50um + 50um + 100um

Gain ~10^4

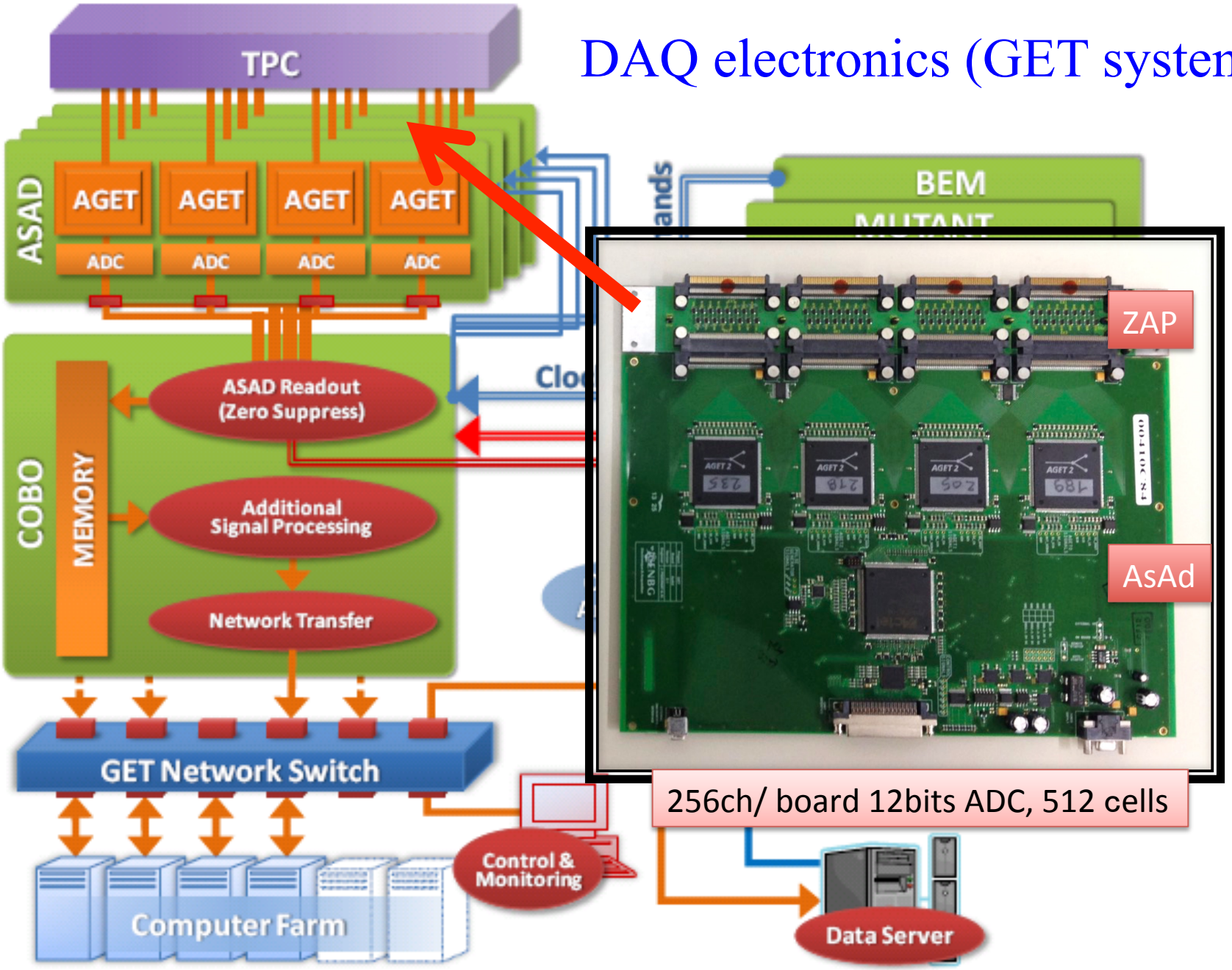
Conversion board
(read-out pad to
read-out circuit)



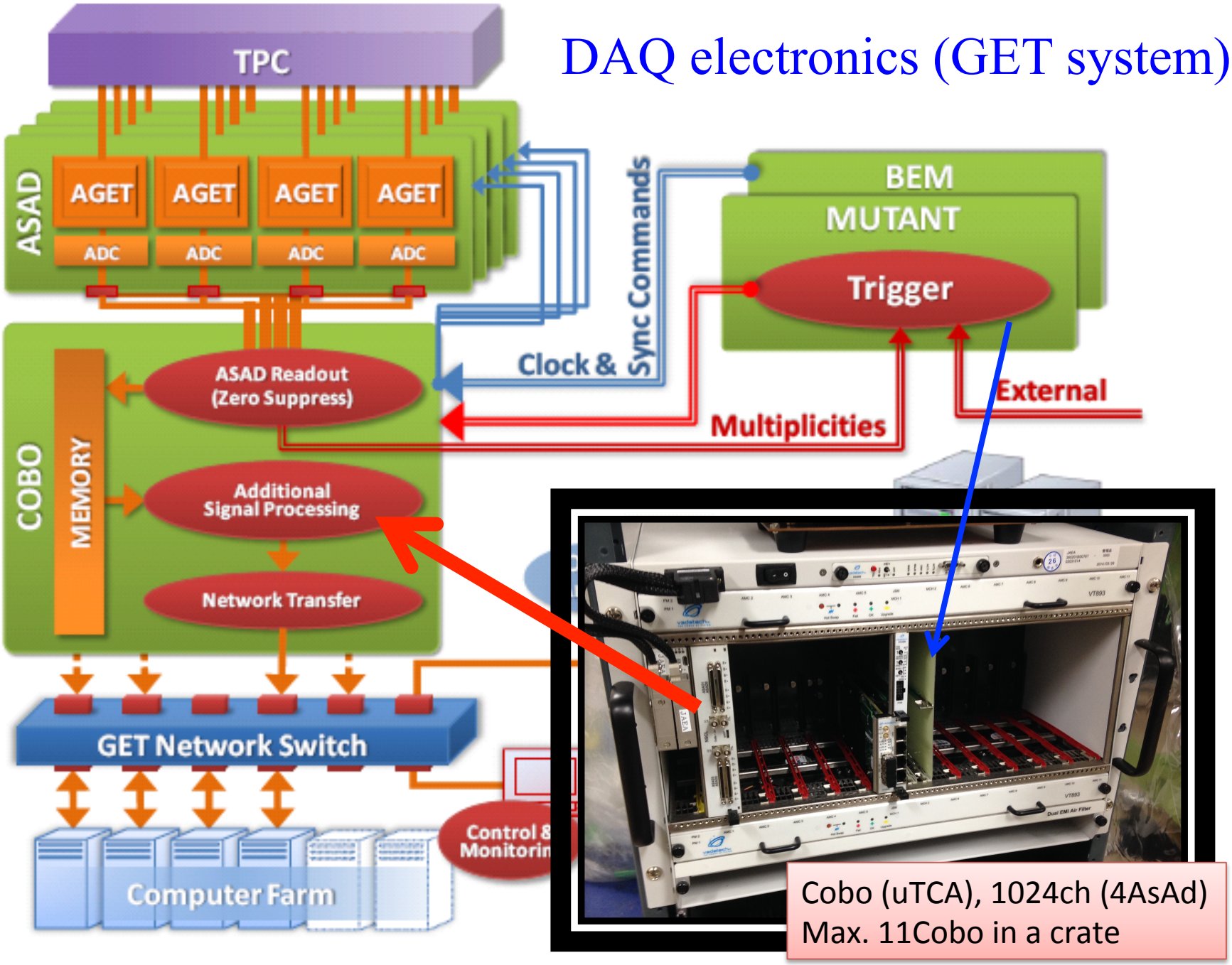
DAQ electronics (GET system)
Scaclay, GANIL, MSU, CERNBG



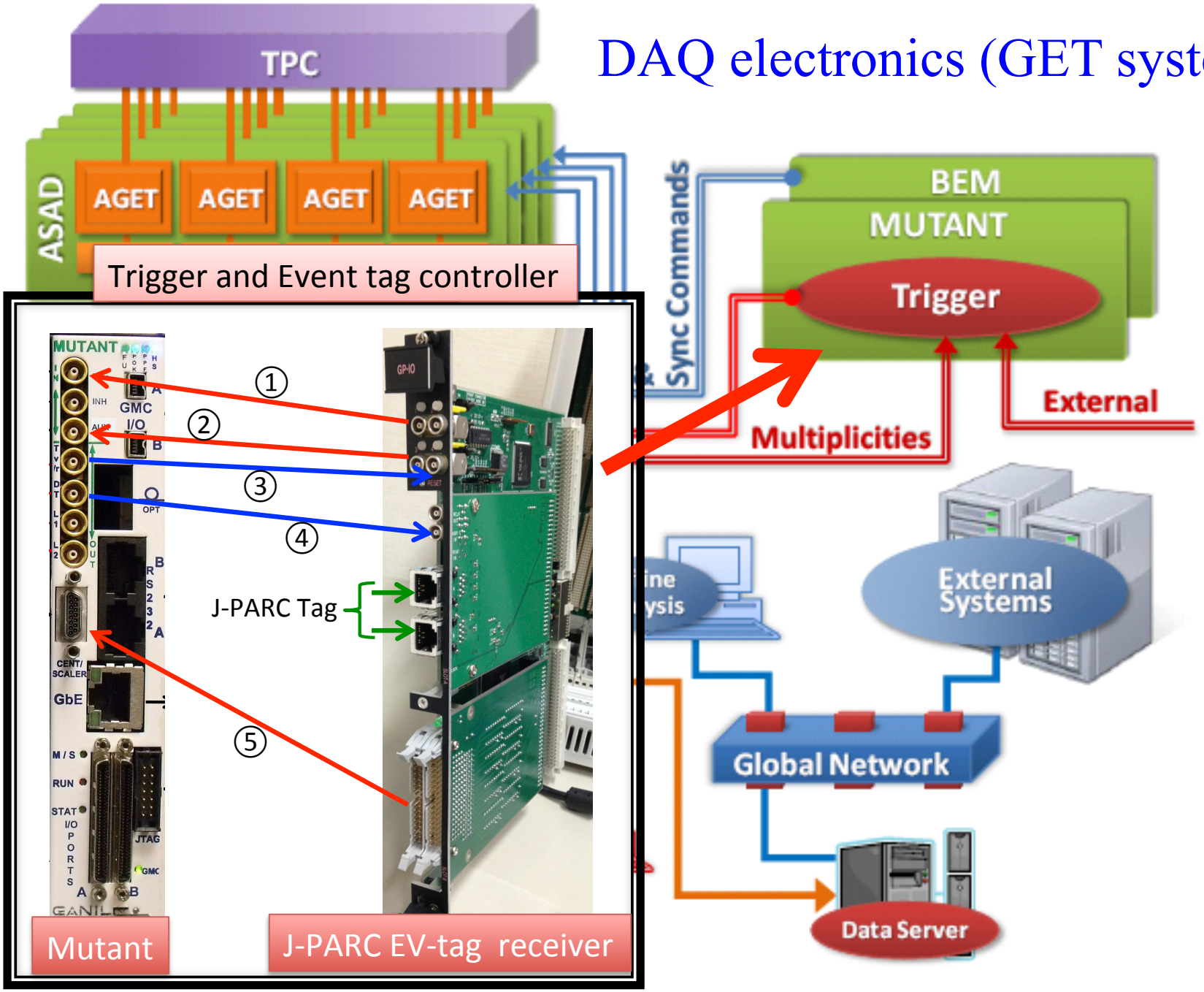
DAQ electronics (GET system)



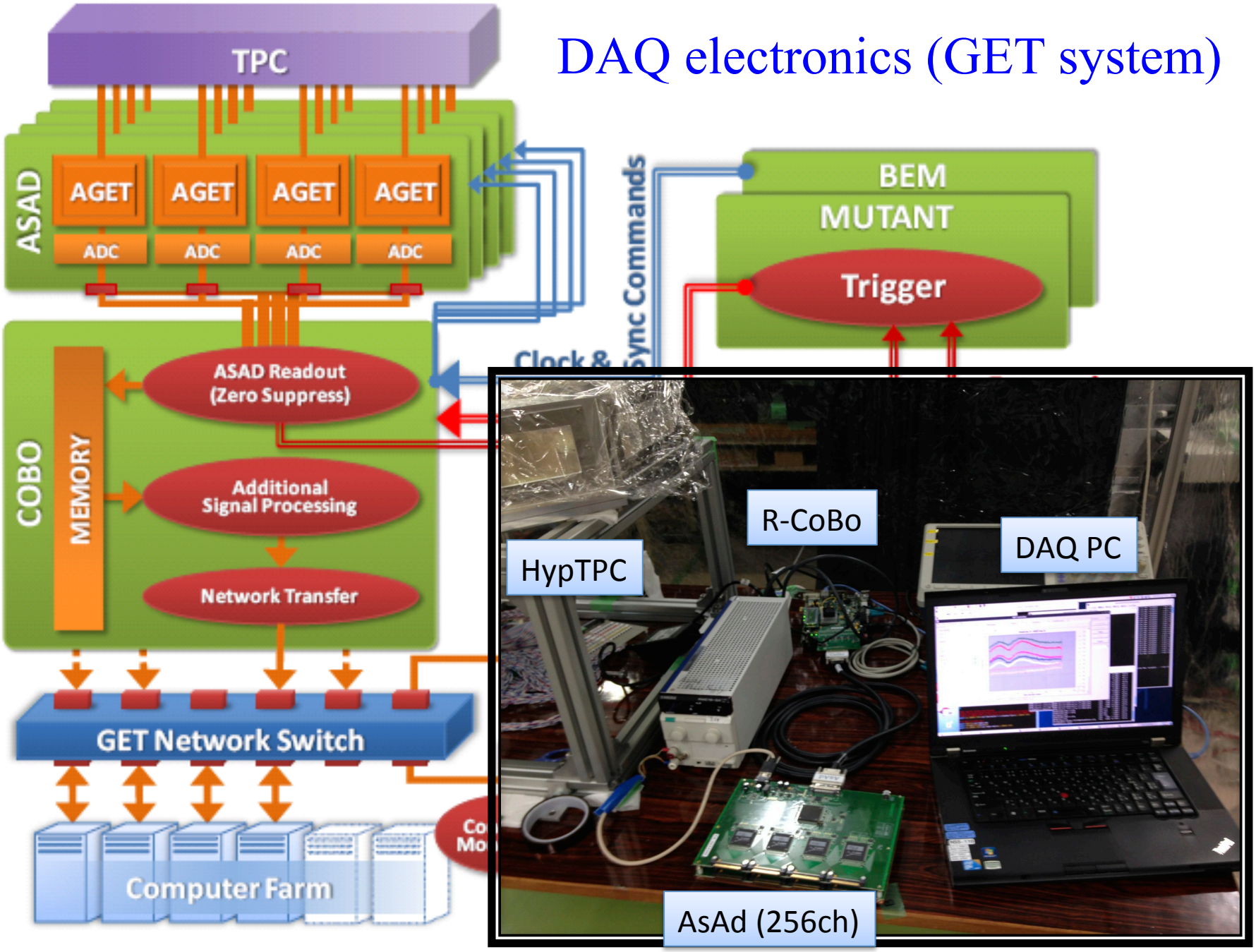
DAQ electronics (GET system)



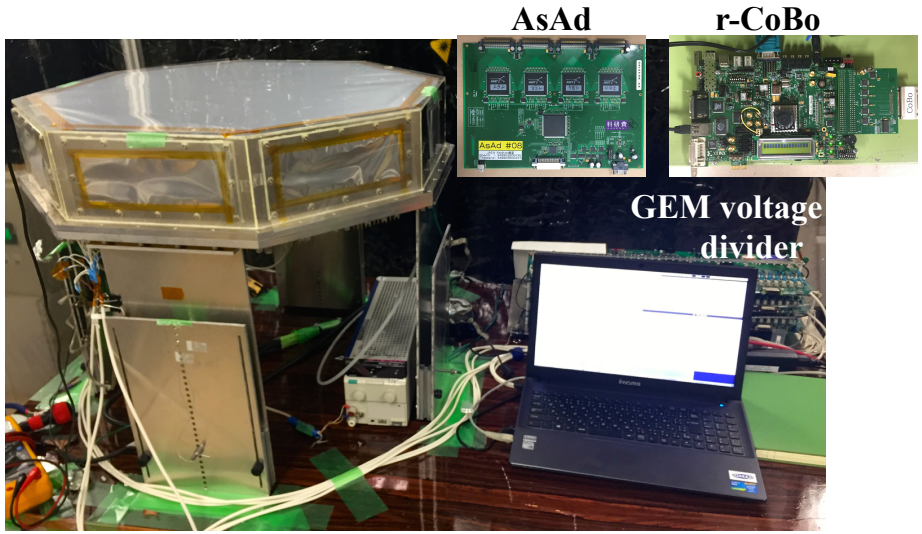
DAQ electronics (GET system)

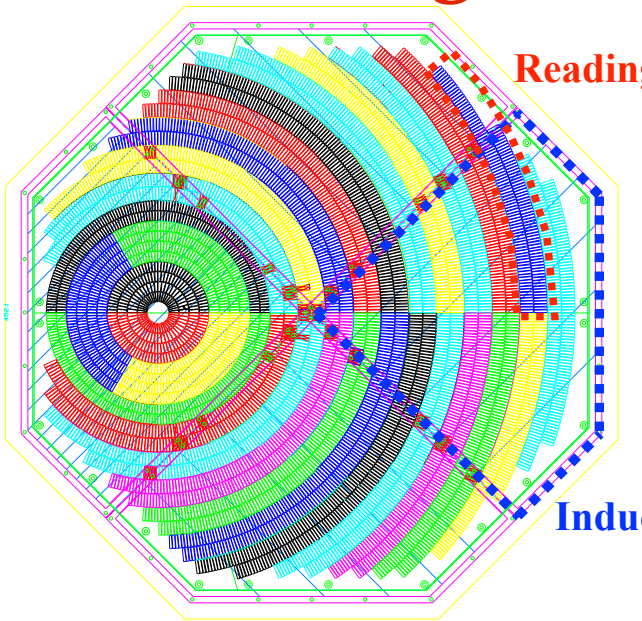


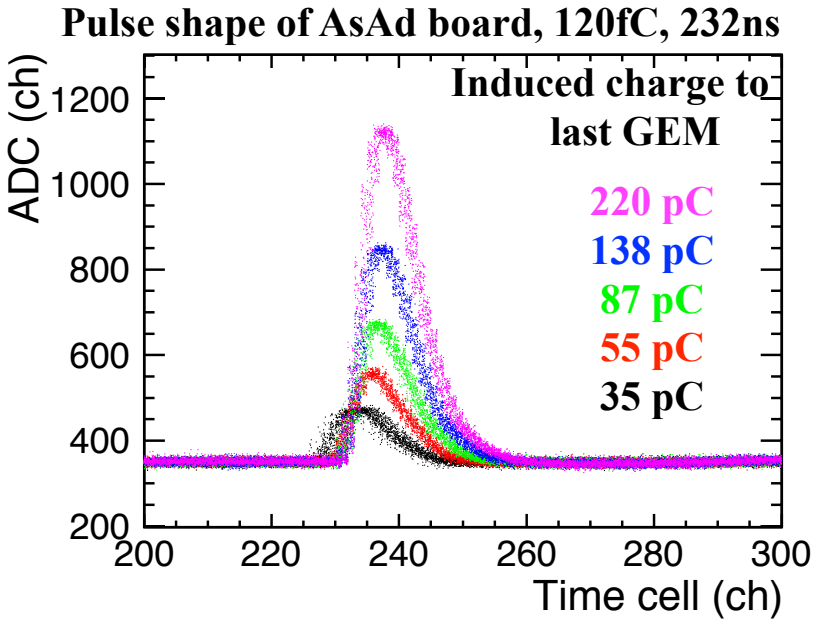
DAQ electronics (GET system)

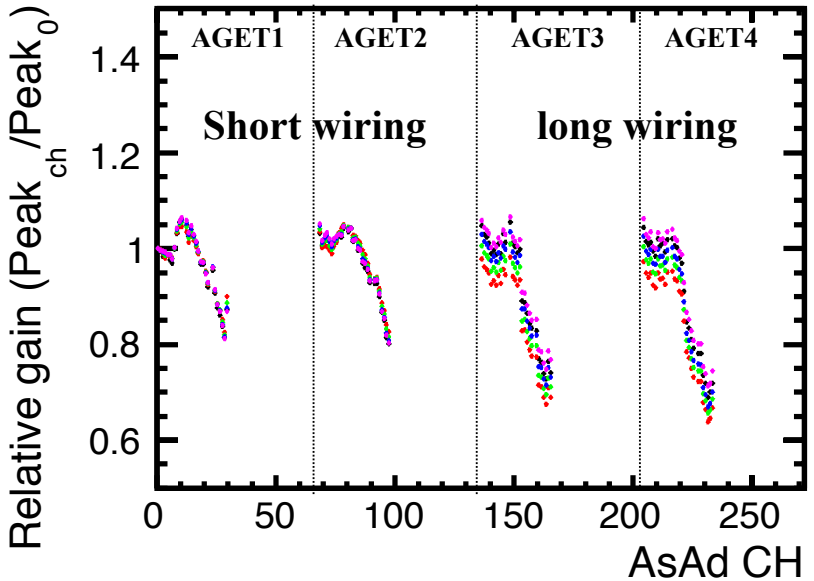


Gain test with an induced charge



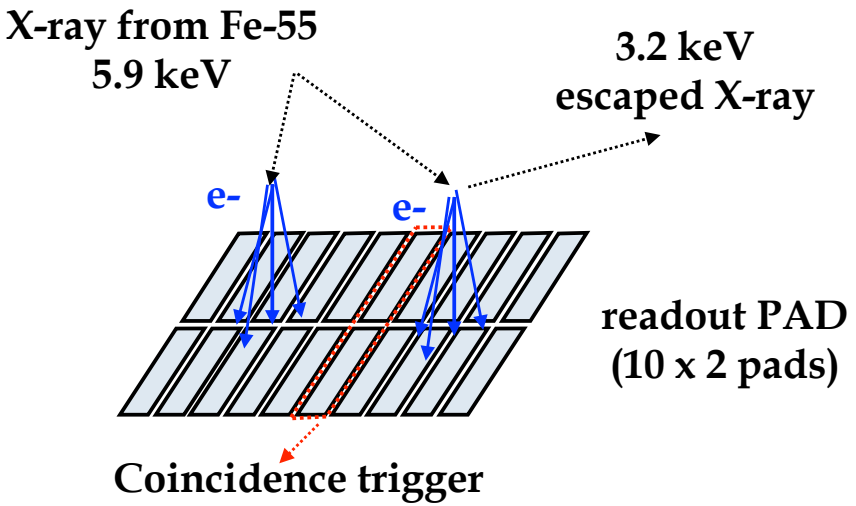




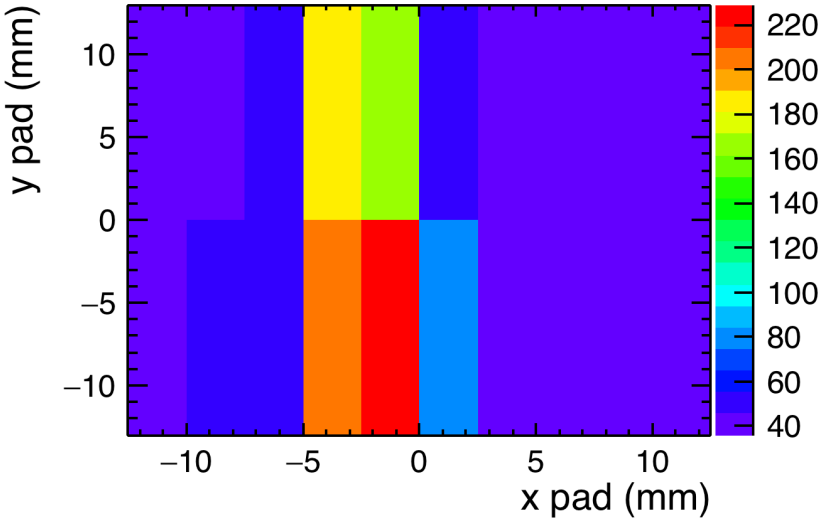


Gain uniformity is good.

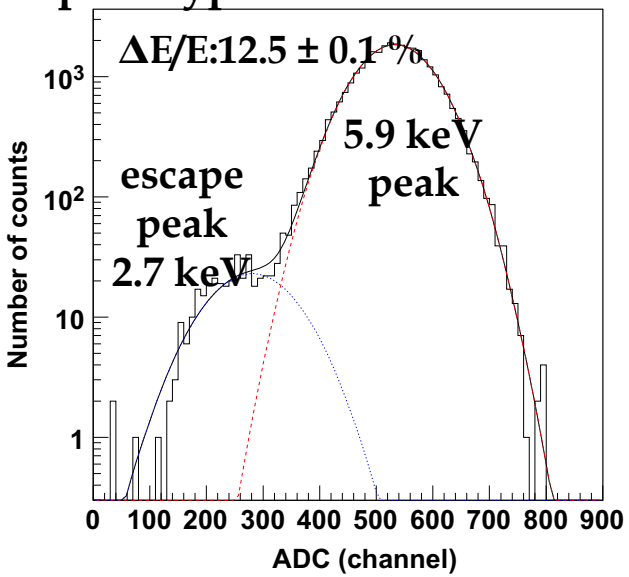
X-ray measurements



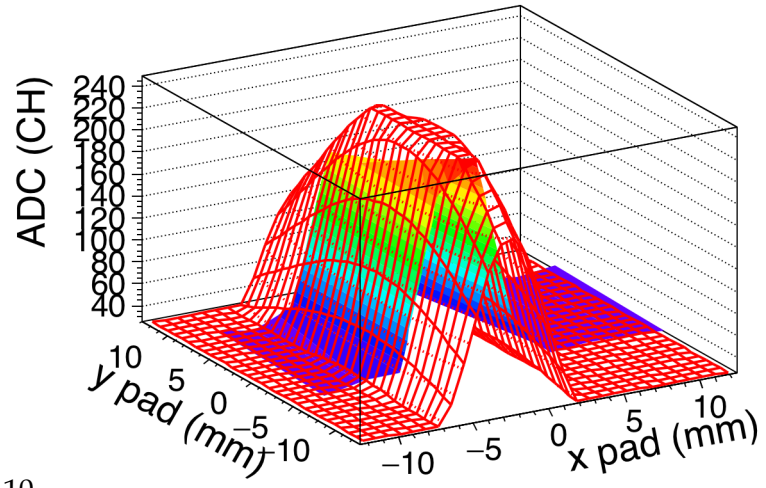
ADC distribution



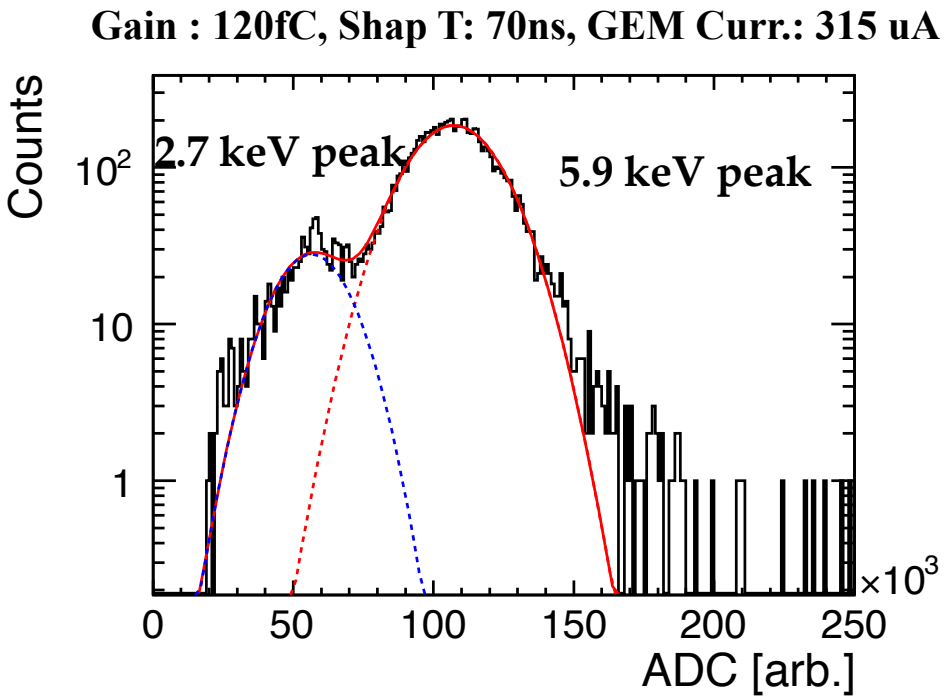
prototype TPC

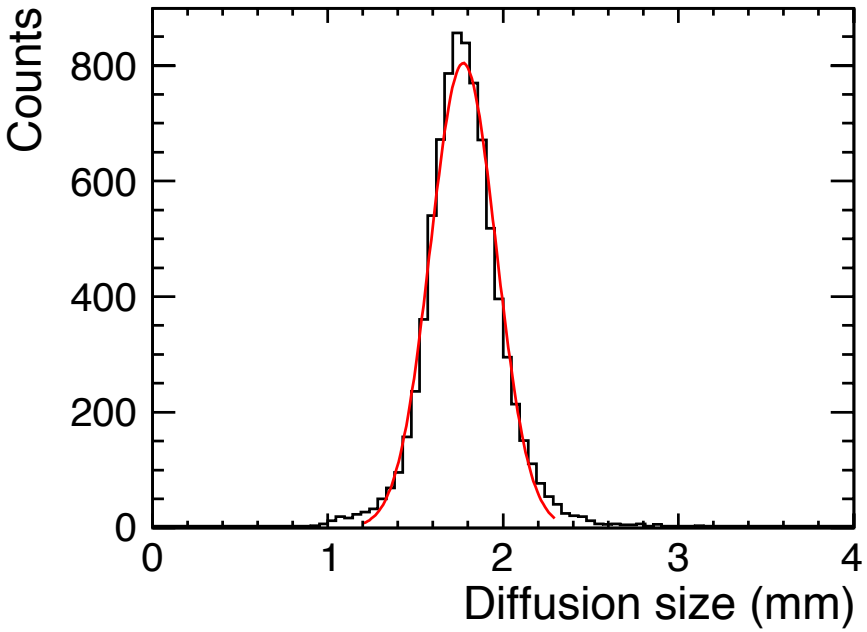


2D-gaussian fitting



X-ray spectrum





ΔE/E :14.3 ± 0.2 %
(Peak)/(Esp. Peak): 0.52 ± 0.01

Diffusion size : 1.87 ± 0.02 mm
cf. prototype TPC(5 cm to 10 cm)
: 1.7 ~ 2.0 mm

The TPC operation is consisted with the prototype TPC!!

Summary

- Phyics programs with HypTPC
  - J-PARC E45 : Studies of baryon resonances in (π,2π) rection

    $\pi^- p \rightarrow \pi^+ \pi^- n$, $\pi^0 \pi^- p$, $\pi^+ p \rightarrow \pi^0 \pi^+ p$, $\pi^+ \pi^+ n$

    $\pi N \rightarrow KY$ ($\pi^- p \rightarrow K^0 \Lambda$, $\pi^+ p \rightarrow K^+ \Sigma^+$)

    → 100 times improved (π,2π) data
  - J-PARC E42 : Search for H−dibaryon

    $^{12}C(K^-,K^+)X$, *resonance* $H \rightarrow \Lambda\Lambda$、*bound* $H \rightarrow \Sigma^- p$, $\Lambda p \pi^-$

    → 11000 ΛΛ events (1440 H resonance, 1ub/sr)

    KEK-E522 90ΛΛ events
- Spectrometer system including HypTPC will be ready for beams in 2016.