

IN2P3 : Réunion Détecteur Gazeux 29 Oct 2013

LLR Ecole Polytechnique and CNRS/IN2P3

Denis Bernard

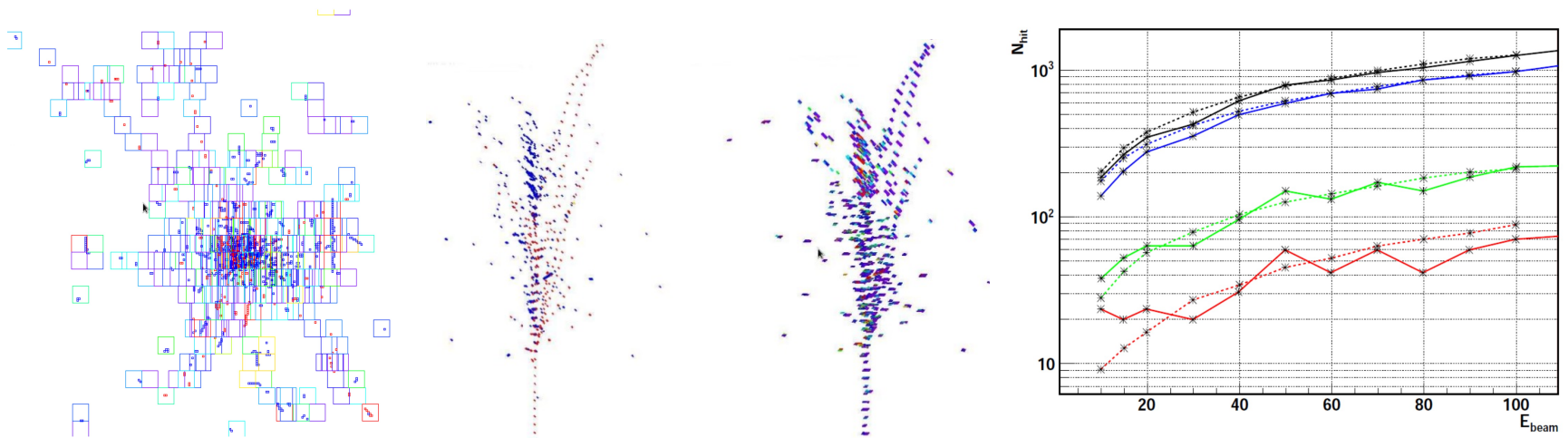
Le Menu

– ILC

– HARPO

ILC - SDHCAL

- Within the SDHCAL (Semi-Digital Hadron Calorimeter) Collaboration, develop a small cell digitization :
G2CD : General Gaseous Calorimeter Digitizer



- Cell size $(10 \text{ mm})^2$ (π beam, threshold 0.113, 5, 15 pC)
- Tested on SDHCAL prototype data (CERN 2012, CALICE collaboration)

Yacine HADDAD, MPGD2013, July 2013 Zaragoza

*HARPO, polarimétrie et astronomie d'excellente
résolution angulaire et sensibilité par création de paires
 e^+e^-*

Emploi d'une cible active fine (TPC) en astronomie γ non polarisée
et polarimétrie γ

- Micro rappel sur le science case
- Le projet HARPO
 - objectifs
 - collaboration
 - résultats récents
 - financements, manpower

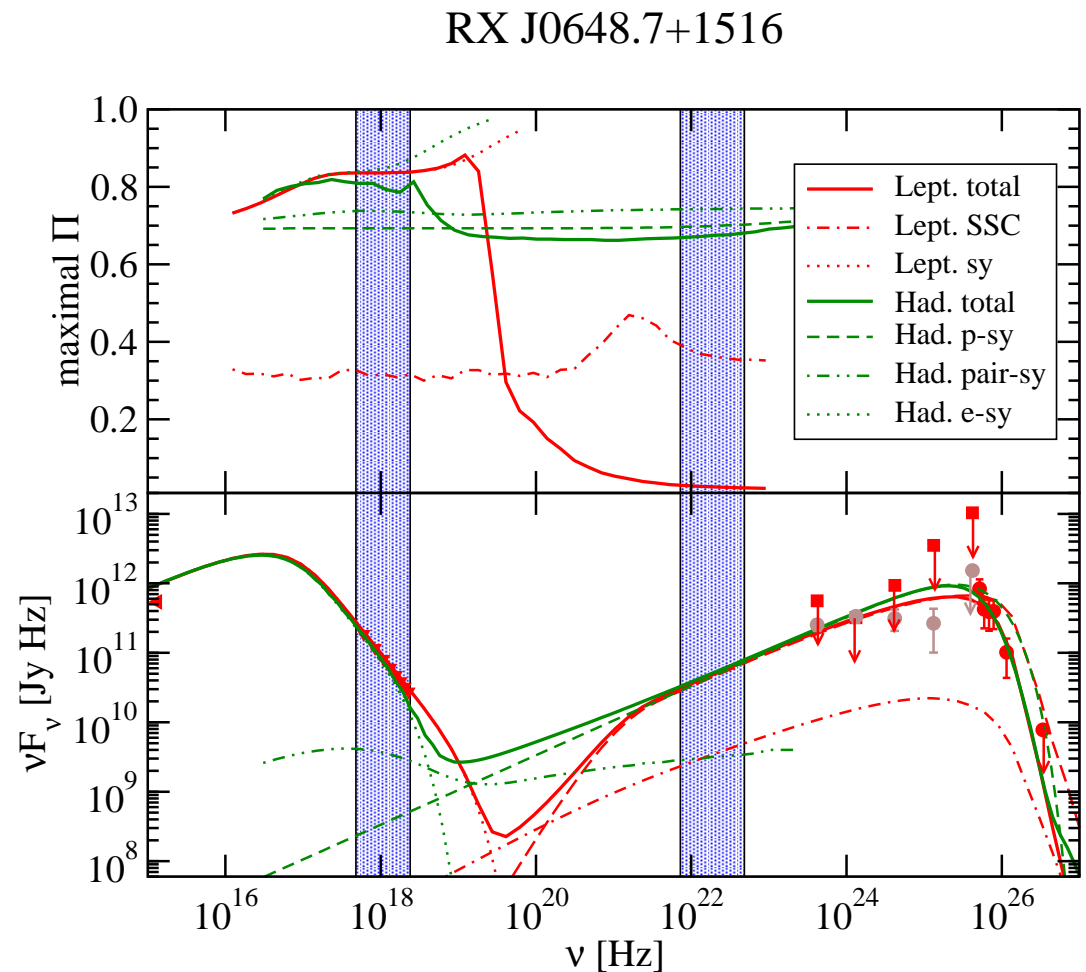
Science case

- Non polarized astronomy
 - Improve angular resolution – crowded sky regions
 - Solve sensitivity gap between Compton and pair telescopes
- Polarimetry
 - Astrophysics : understand the nature / working mechanism(s) of γ emitting cosmic sources
 - Pulsars : decipher geometry of emitting region
 - AGN : decipher leptonic (SSC) against hadronic (proton-synchrotron) models
 - GRB : decipher models / tests global order of magnetic field
 - Cosmo / New Physics
 - LIV : Search for Lorentz Invariance Violation
 - Search for axion or ALP Axion-like-particles.

Science case : Polarimetry : Astrophysics

- Today just one example : AGN : decipher leptonic synchrotron self-Compton (SSC) against hadronic (proton-synchrotron) models
 - high-frequency-peaked BL Lac (HBL)
 - X band : 2 -10 keV
 - γ band : 30 - 200 MeV
- SED's indistinguishable
- X-ray : $P_{\text{lept}} \approx P_{\text{hadr}}$
- γ -ray : $P_{\text{lept}} \ll P_{\text{hadr}}$

H. Zhang and M. Böttcher,
A.P. J. 774, 18 (2013)



LIV : Search for Lorentz Invariance Violation

- Particle (photon) dispersion relations modified in LIV effective field theories (EFT)
- Additional term to the QED Lagrangian parametrized by ξ/M , M Planck mass.
- ξ bounds :
 - time of flight from the Crab : $\Delta t = \xi(k_2 - k_1)D/M$, $\xi \leq \mathcal{O}(100)$.
 - birefringence $\Delta\theta = \xi(k_2^2 - k_1^2)D/2M$
LIV induced birefringence would blurr the linear polarization of GRB emission.
 $\xi \leq 3.4 \times 10^{-16}$ with IBIS on Integral (250 – 800 keV)
D. Götz, *et al.*, MNRAS 431 (2013) 3550
- Bound $\propto 1/k^2$!

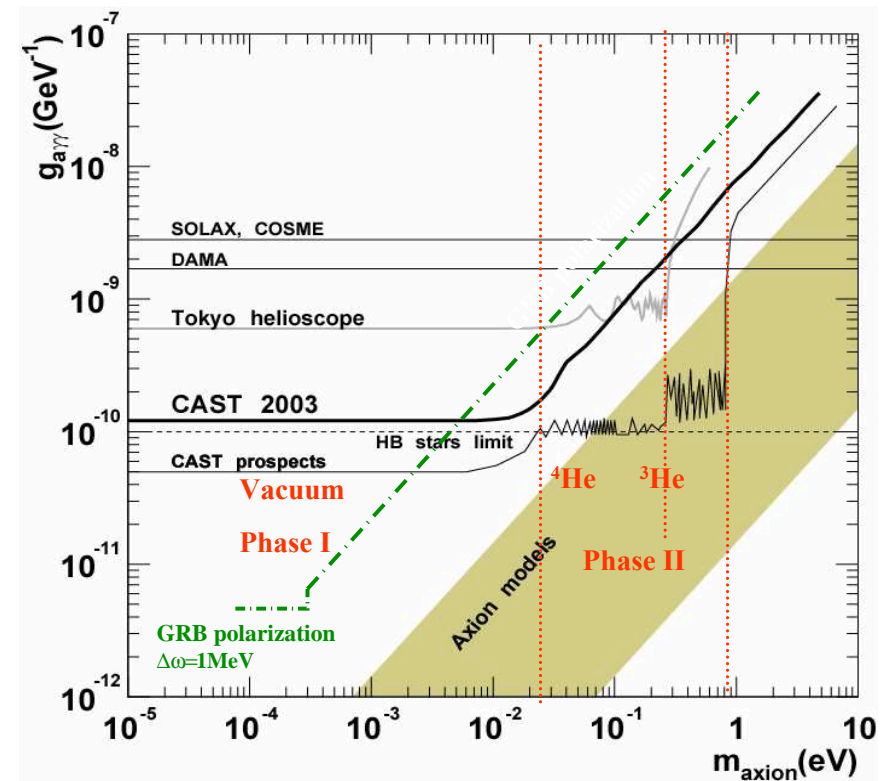
Search for Axions

- Scalar field associated with $U(1)$ symmetry devised to solve the strong CP problem.
- Couples to 2 γ through triangle anomaly.
- γ propagation through $B \Rightarrow$ Dichroism $\Rightarrow E$ dependant rotation of linear polarization \Rightarrow linear polarization dilution.

$$g_{a\gamma\gamma} \leq \pi \frac{m_a}{B \sqrt{\Delta\omega L_{GRB}}}$$

- Saturation over $L = 2\pi\omega/m_a^2 > L_{GRB}$ for $m_a \leq \sqrt{\frac{2\pi\omega}{L_{GRB}}}$

and the limit $g_{a\gamma\gamma}$ reaches a ω -independent constant.



A. Rubbia and A. S. Sakharov, *Astropart. Phys.* 29, 20 (2008)

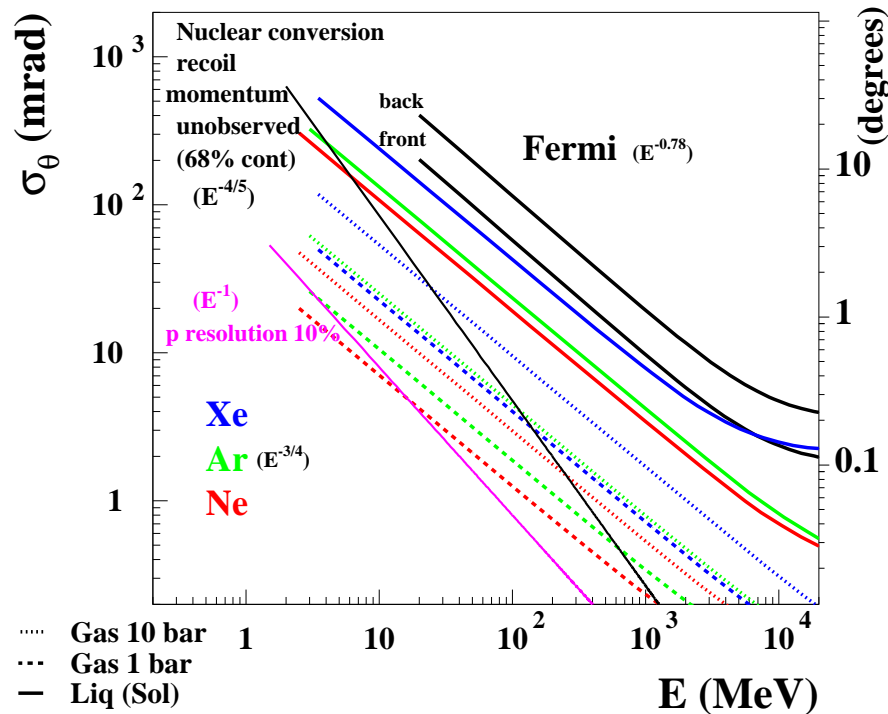
HARPO

- Goal : Characterize potential and performance of a thin active target (TPC) as a γ -Ray (a) telescope (b) polarimeter.
- Collaboration :
 - LLR, Ecole Polytechnique & CNRS/IN2P3
 - 4 staff physicists, Σ FTE ≈ 1
 - 1 post-doc, oct 2013
 - 1 Ph. D, oct 2012
 - 3 engineers (meca, elec, info, Σ FTE ≈ 1)
 - Irfu/CEA Saclay :
 - SEDI : A. Delbart *et al.*,
 - SPP : P. Colas
 - SAp : D. Götz

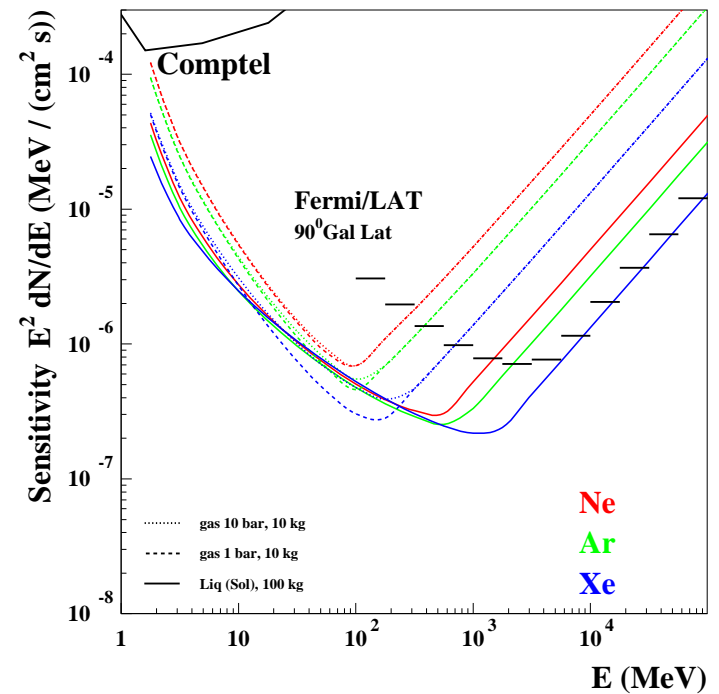
HARPO : Recent Results : 1

- Study of TPC potential for (non polarized) γ -Ray astronomy

γ angular resolution



pointlike source sensibility



D.B., Gamma2012

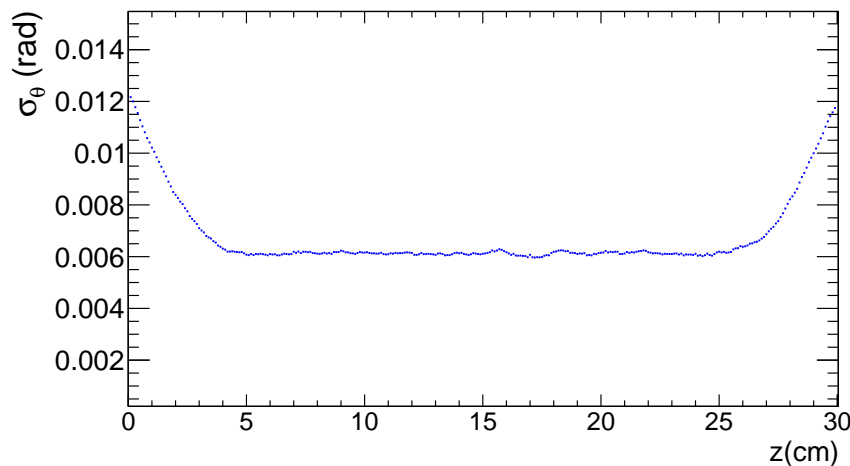
and

NIM A 701 (2013) 225-230

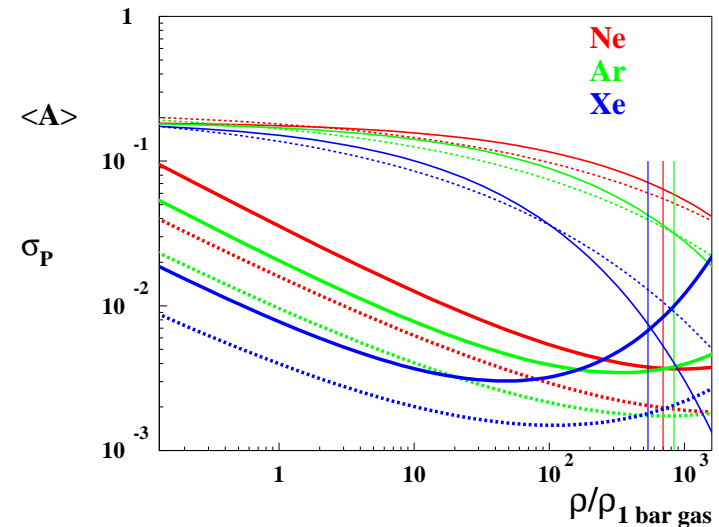
HARPO : Recent Results : 2

- Study of TPC potential for γ -Ray polarimetry
- First full (5D), exact (down to threshold), polarized, event generator
- Detailed study, parametrization, of asymmetry dilution due to multiple scattering, with optimal tracking (e.g. Kalman filter)
- Discovery that multiple scattering is manageable for a gaseous TPC

“Optimal” fit validation
with Kalman filter



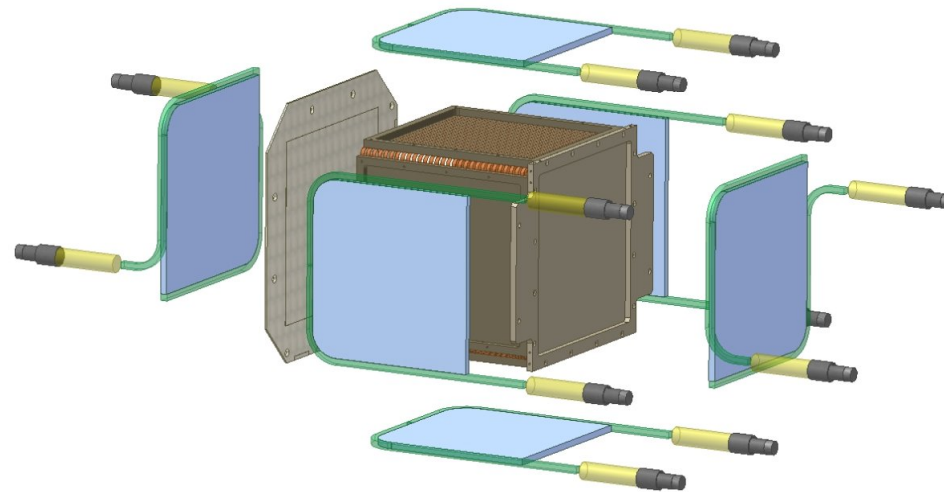
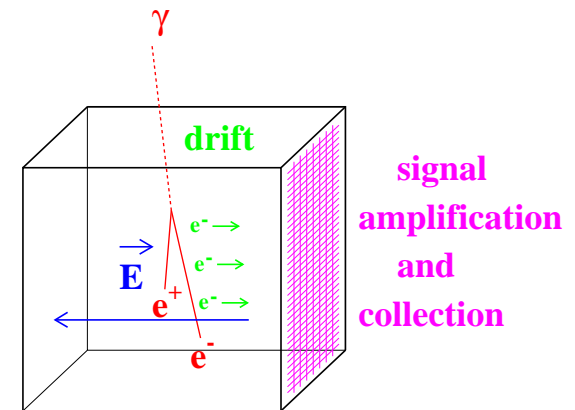
effective asymmetry
and P precision



- P precision on the Crab 1.4 % ($\eta = \epsilon = 1$, and 1 year, 1 m^3 , $\sigma = l = 1 \text{ mm}$.
D.B., Atelier MeV (APC, 2013) and NIM A 729 (2013) 765

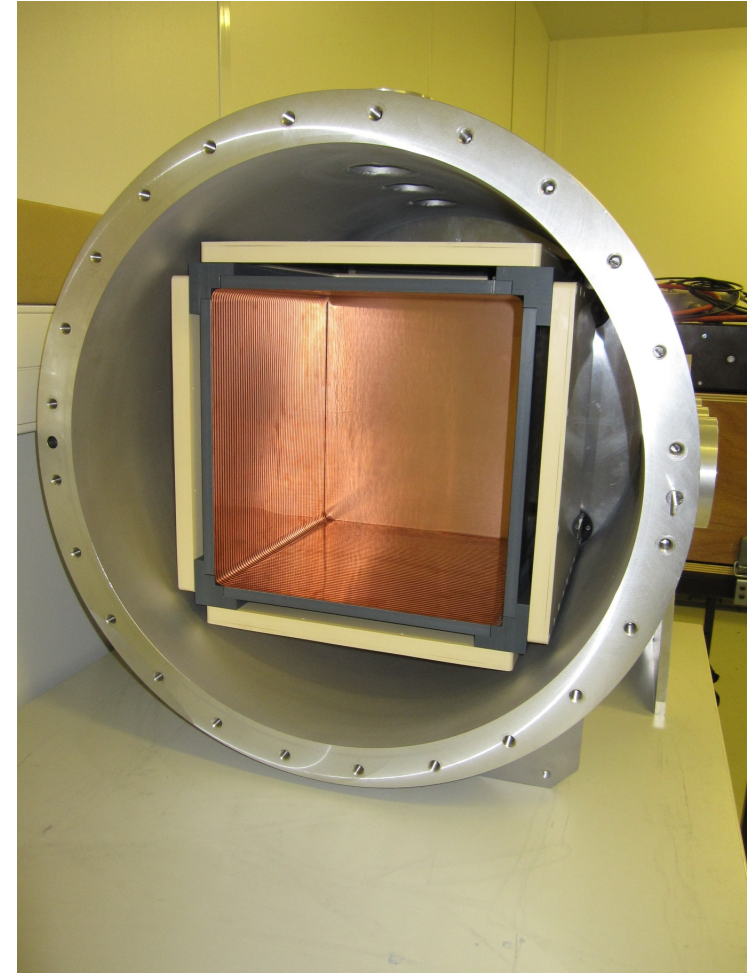
The detector

- Demonstrator built on partial budgets (P-&U 2010, IN2P3 2011)
- $(30\text{cm})^3$ cubic TPC
- Pressure $P \leq 5\text{bar}$
- "T2K gas" Ar95 : IsoButane :2 CF4 :3



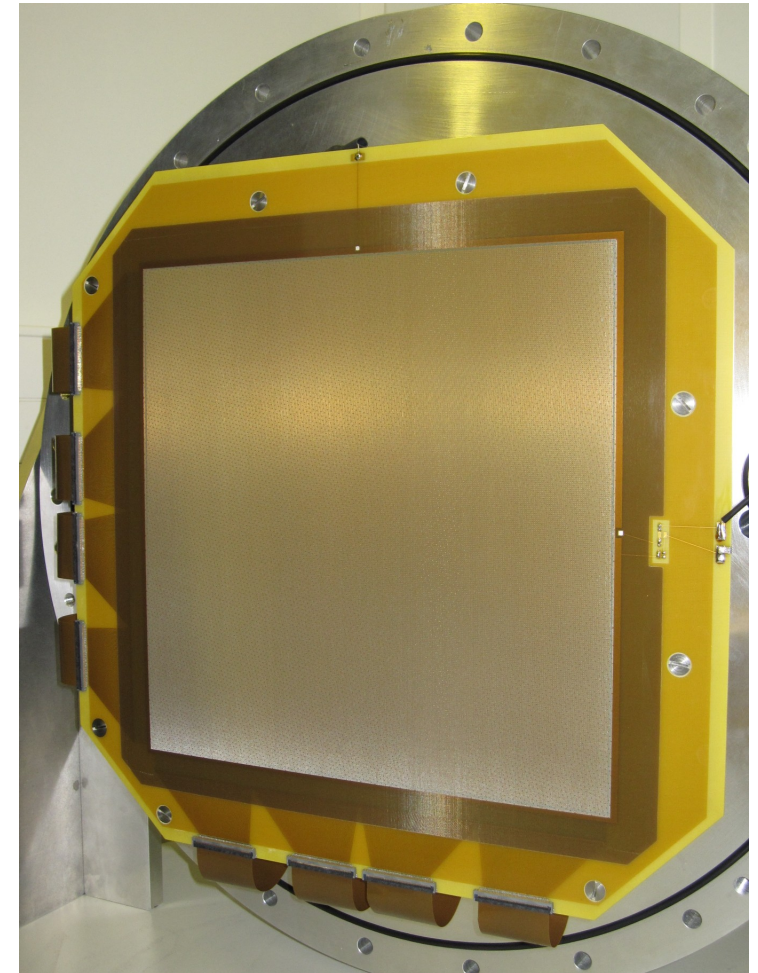
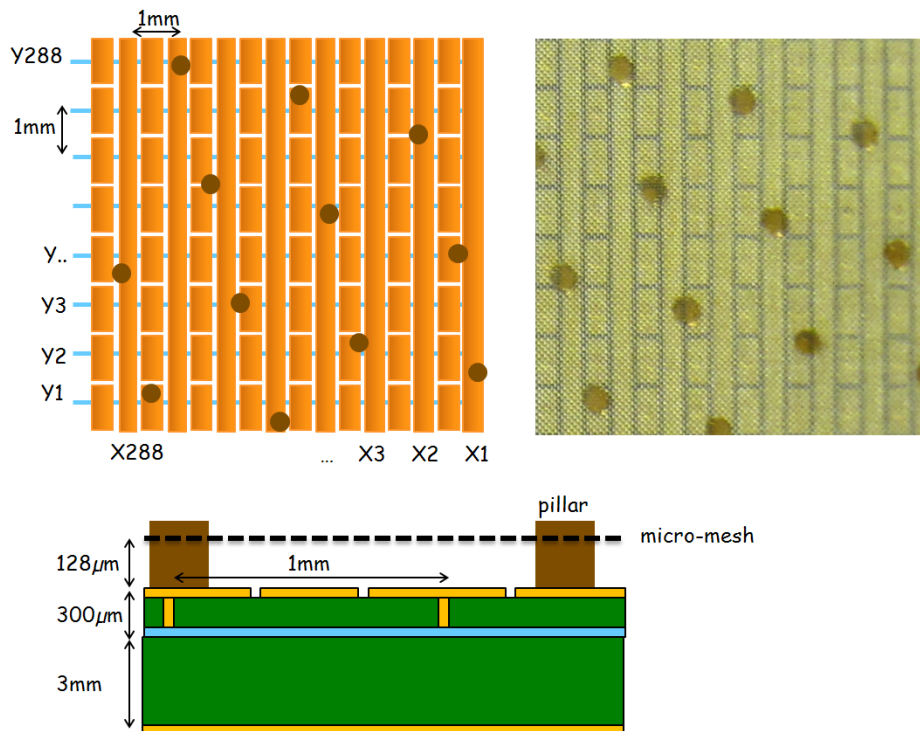
The Field cage

- Sides : PVC plates thinned to 1 mm on beam passage.
- 100 μm Kapton foil with 60, 35 μm -thick 3 mm-wide Cu strips, pitch 5 mm.
- Resistance divider : pairs of resistances of 10 M Ω , paired to an homogeneity of $\approx 3. \times 10^{-4}$.
- Cathode : PCB 1.6 mm, 35 μm Cu
- Cathode downstream for datataking



Anode, amplification

- Amplification by “bulk” micro-mesh micromegas, gap $128\mu\text{m}$ [NIM A 608 \(2009\) 259](#)
- Signal collection by strips on PCB, pitch $\approx 1\text{mm}$



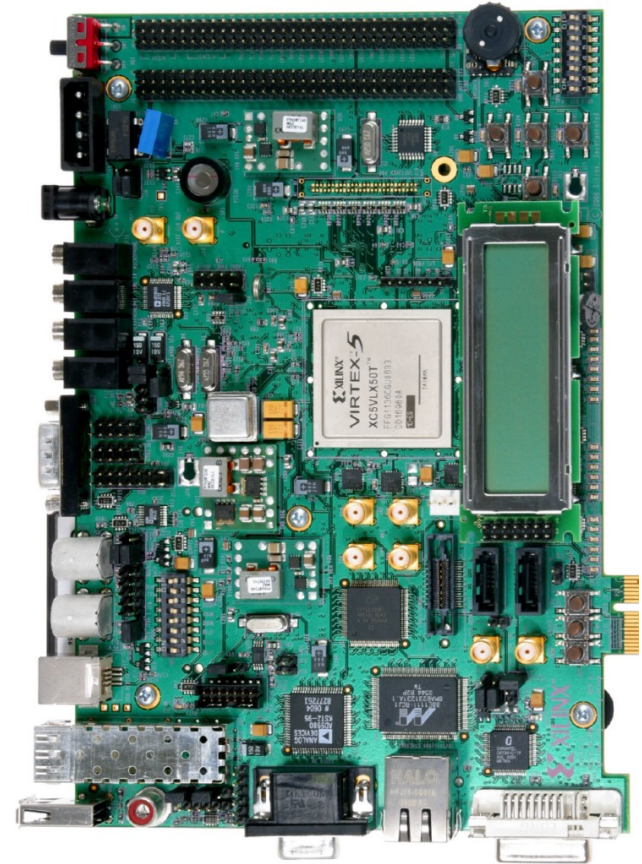
Digitization

- Sampling / acquisition performed by AFTER chip ; 12 bits, shaping min 100 ns [IEEE Trans. Nucl. Sci. 55 \(2008\) 1744](#).
- $F = 100\text{MHz}/n$, $n > 2$. 50 MHz.
- Data taking at chip level 500 evts/s.
- 72 channels/chip, 4 chip/FEC card, 288 channels/FEC.
- 2 FEC in total (x , y).
- Instrumented area 288 * 288 mm



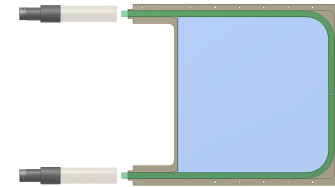
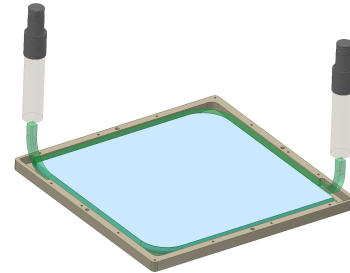
Interface Card

- We don't use T2K's FEM + DCC system
- Use FPGA ML507 Evaluation Platform "kits" from Xilinx
- Ethernet connection to PC.



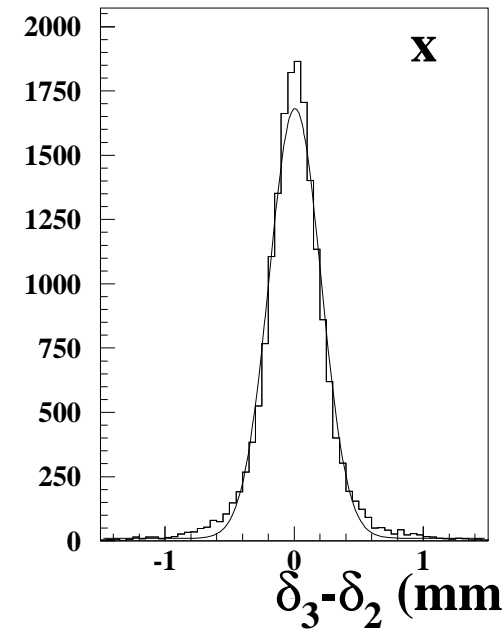
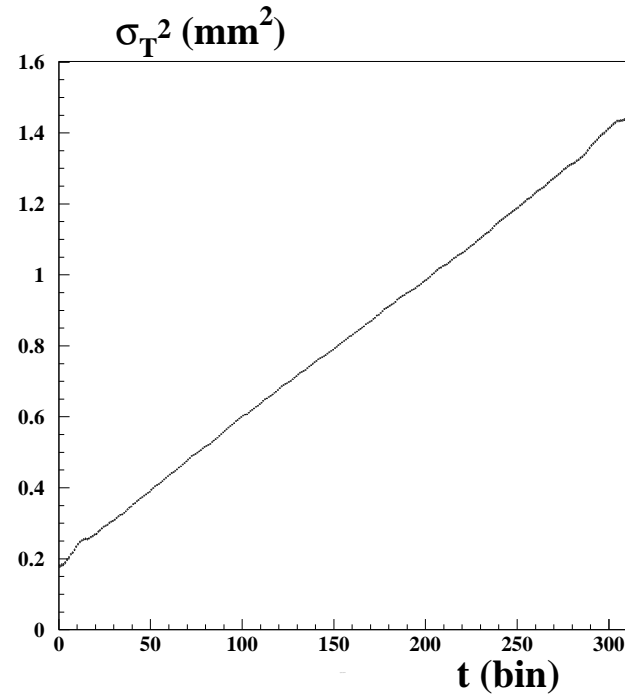
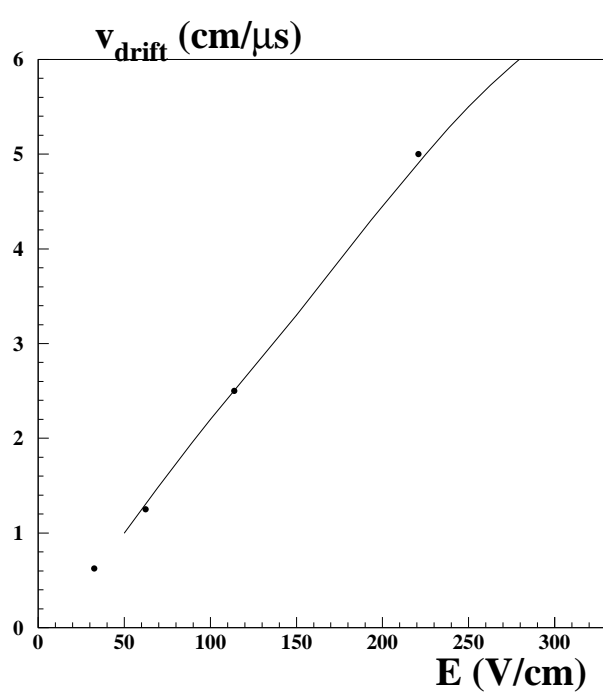
Trigger

- 6 scintillator plates surrounding TPC
- “Blue” scintillator EJ-208 (Eljen Technology), $30 \times 30 \times 1$ cm.
- “Green - yellow” WLS bars EJ-280, 1×1 cm
- Doped PVT, $n = 1.58$.
- Light exits vessel through windows
- Detected by ETL 9125 FLB17 PMT
Former BaBar DIRC PMT : Were used $20 \text{ mV} @ 1 \gamma e^-$, $g = 1.7 \times 10^7$
- At the moment the trigger signal is simple up-down NIM-logic coincidence



2012 Demonstrator Characterisation

- Tracker characterized (preliminary trigger system) with cosmic rays, $P=2$ bar



Pisa2012 and NIM A 718 (2013) 395

Gain

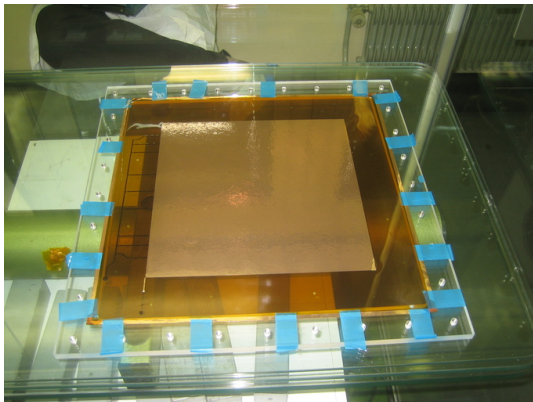
- micromegas incident when $P_2 \rightarrow 5$ bar
(HT 500 \rightarrow 700 V)
 - repaired since
 - spare produced
 - diagnosed to too narrow HT operation range
 \Rightarrow
decision of complement with 2 GEM
(Gas Electron Multiplier)



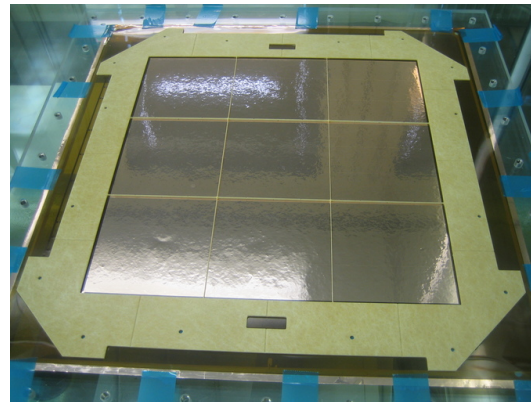
GEM development

- GEM designed (LLR), produced (CERN), glued on frames (RD51/CERN) : 2013
- “standard” configuration (50 μm kapton ..)

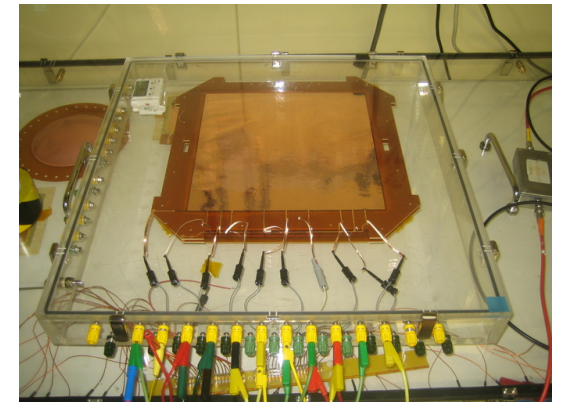
gluing
preparation



glued
on frame

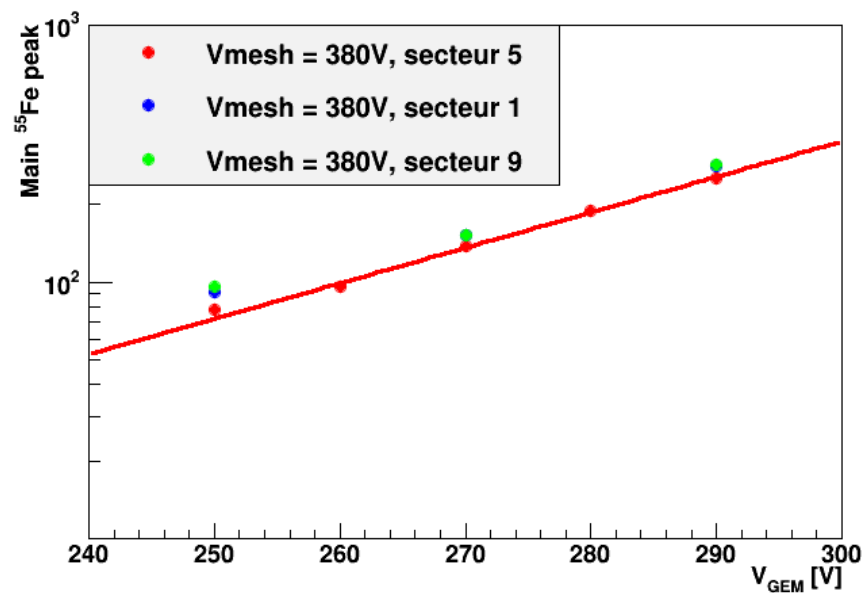
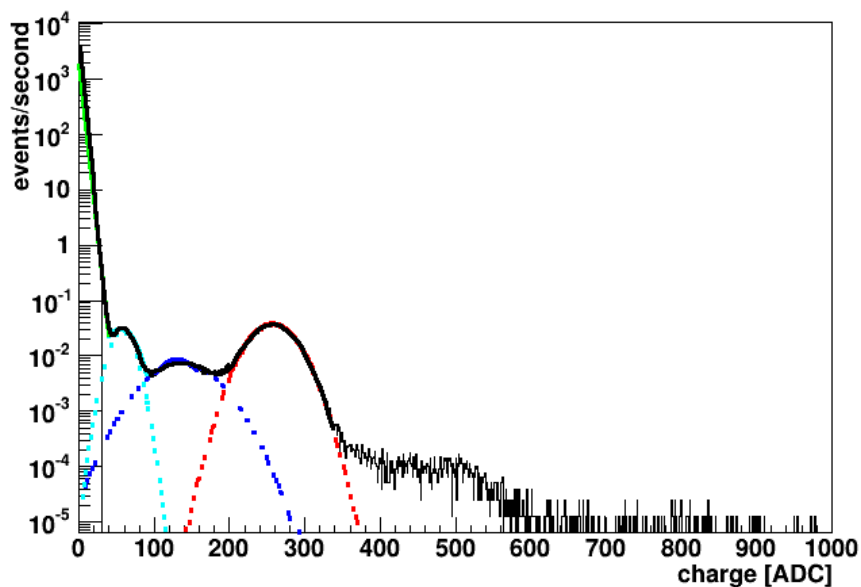
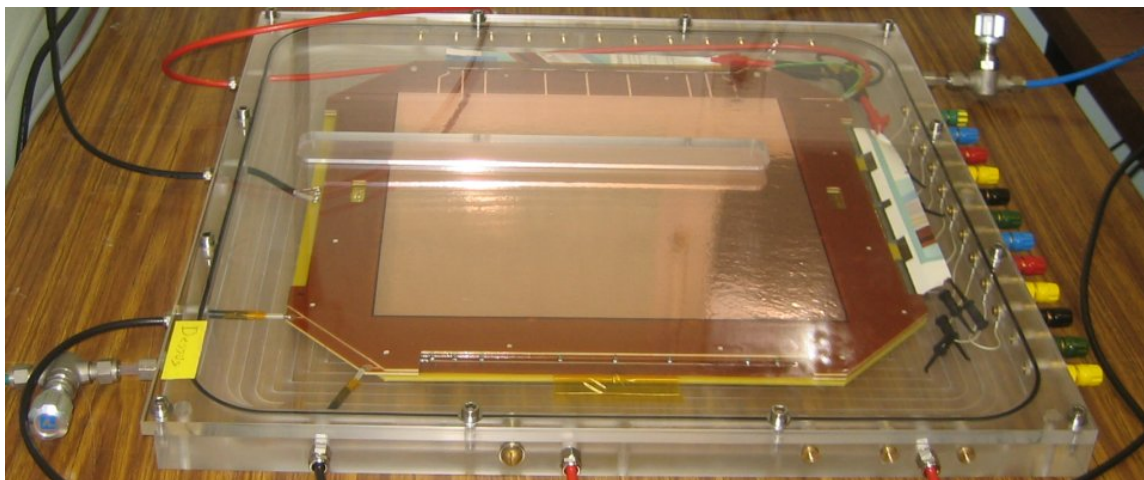


electrical
tests



- 3 pieces (2 + 1 spare) produced.
- Integration into the detector in preparation
- Detector to be (re) characterized with cosmic rays

$\mu M+GEM$: ^{55}Fe source tests



- Ar :95 Iso :05, 1 bar
- Oct 2013 : Tests of $\mu M+GEM$ system

analysis in progress.

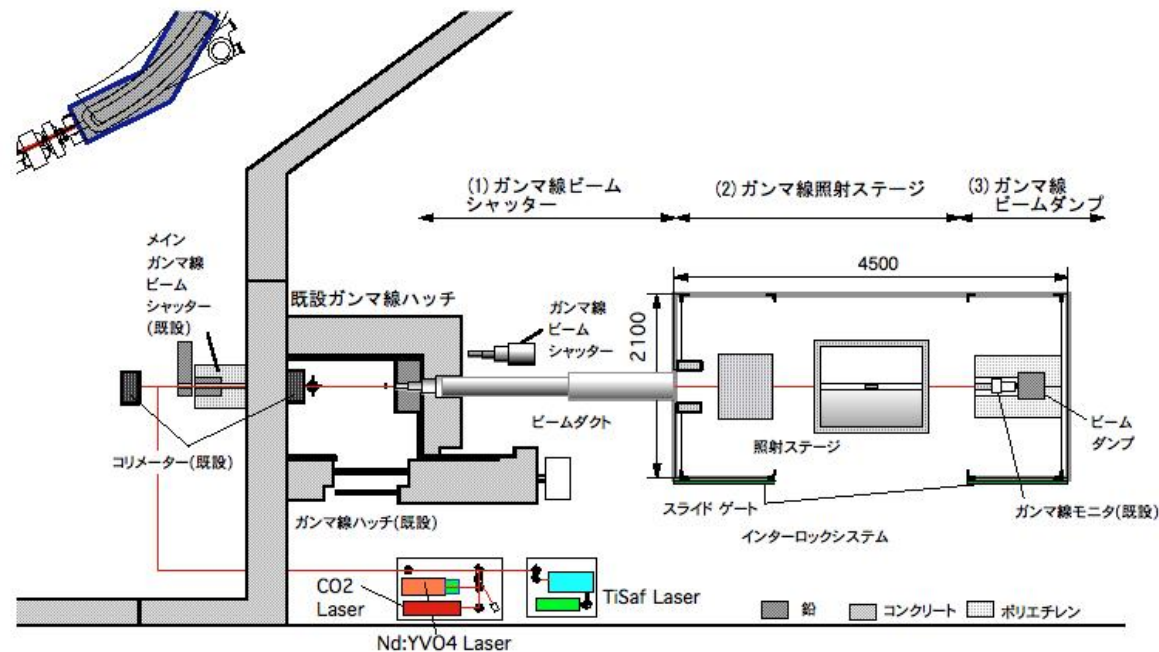
Trigger development

- Present cosmic-ray trigger is simple NIM-module $Up \cap Down$
 - γ beam : need veto Up , and an \cup of the 5 downstream scintillators. (6 scintillators, 12 PMT in total)
 - Were lent a PMM2 card (IPN Orsay), Parisroc chip (16 channels)
 - Presently learning how to use it.
-
- Consider \cap micromegas signal to reject γ conversion in the downstream scintillator or cathode
 - Consider vetoing the first 200 ns (1 cm) of the micromegas signal to reject γ conversion in the PCB after the vetoed Up scintillator
 - ORTEC 142PC preamplifier appropriate for mesh signal amplification (Detector capacitance is huge 8 nF)



Beam line – Experimental zone

- Data taking in SPring8/NewSUBARU, Japan planned 2014.
- $\approx 100\%$ linearly polarized γ beam, by on-axis collision of optical/UV laser pulse on GeV e^- .
- 2 - 76 MeV energy range available.



- Gamma-ray Collaboration Hutch of KOnan University (GACKO) Experimental zone finalized (2012) and validated (2013)

Funding & Manpower

- CNES : presentation at “astro” committee (sept 2011)
⇒ funding of Shaobo WANG thesis [oct 2012 - sept 2015] (CNES/CNRS)
 - Finalized C++ version of non-paraxial Kalman filter tracking
 - Presently developing [event reconstruction](#)
- Labex P2IO :
 - Funding R&D [2012 - 2014], LLR-Irfu
 - Post-doc [oct 2013 - sept 2015] Philippe Gros : will write [Geant4 event simulation](#) of the γ beam experiment.
- ANR 2013 : LLR-Irfu [2014 - mid 2017]
 - Includes
 - finalization of characterization on polarized γ beam
 - design of a technological demonstrator (clean techno, small gap high pressure, self triggerable chip GET ..)
- SPring8 accelerator system presently undergoing upgrade.
Data taking in JFY2014 (> Apr. 1 2014)