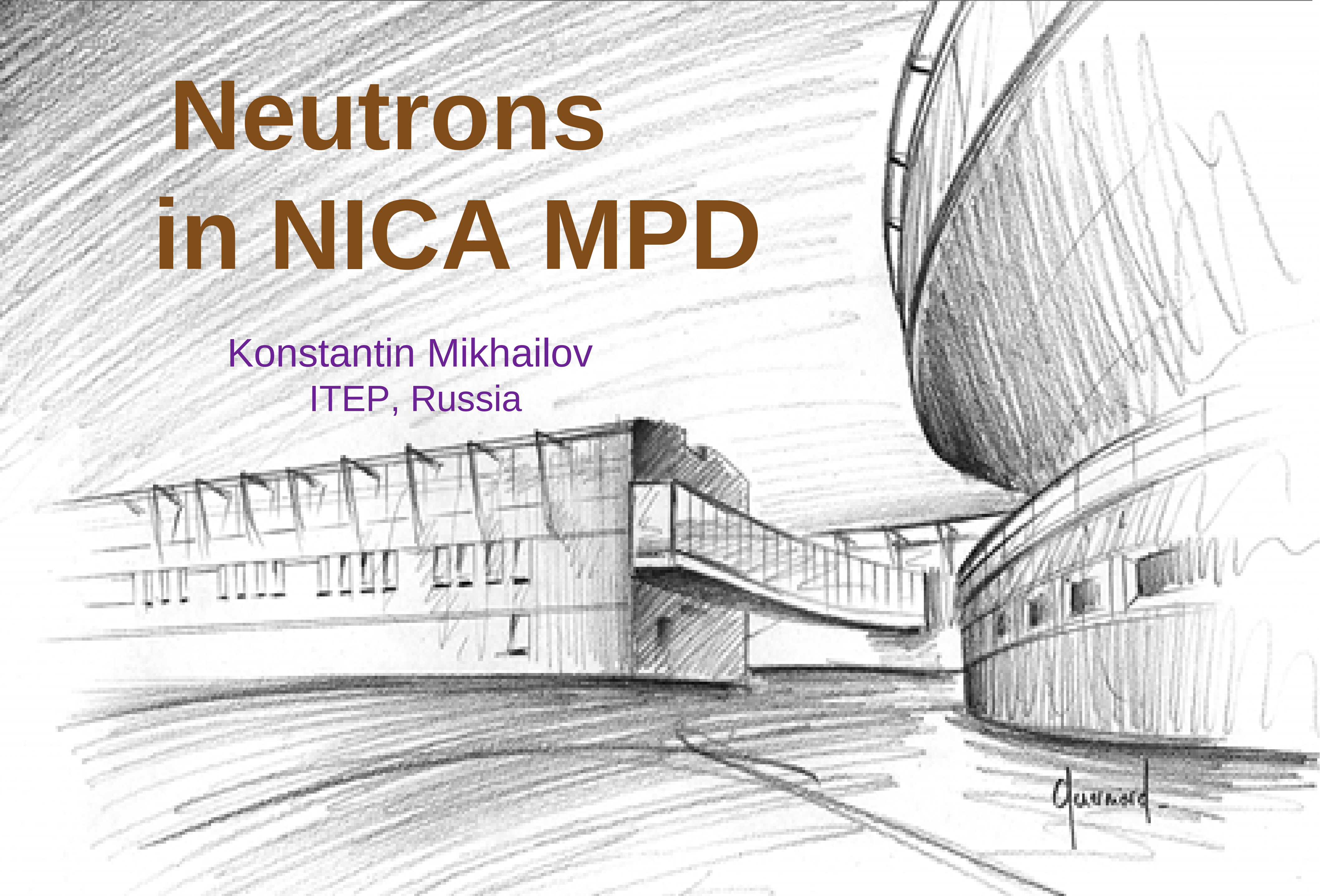
Neutrons in NICA MPD

Konstantin Mikhailov
ITEP, Russia



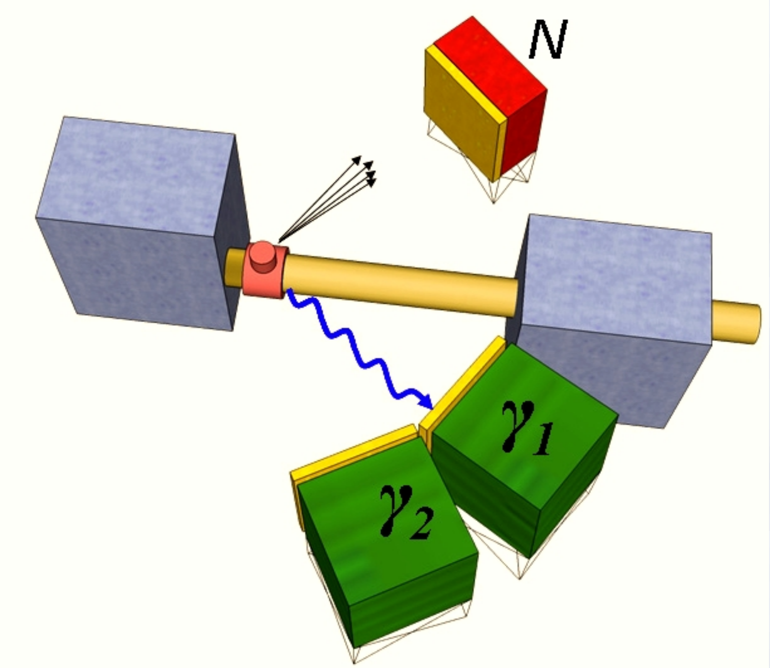
Outline

- Introduction
- Tests of prototype (in ITEP)
- Efficiency of Ndet (Geant3 in MPD ROOT)
- Feasibility of Σ^+ and Σ^- identification (MPD ROOT)
- Conclusion

Introduction

FLINT experiment in ITEP

[Physics of Atomic Nuclei, v.11 (2008) p. 184]



The study Dense Cold Matter

[http://arxiv.org/abs/0911.1658]

with **position sensitive neutron detector** (NDet)

List of participants in Ndet project from ITEP:

O. Denisovskaya, G. Dzyubenko, K. Mikhailov, P. Polozov, M. Prokudin, G. Sharkov, A. Stavinsky, V. Stolin, R. Tolochek, S. Tolstoukhov

Everyone is welcome !

Could we use Ndet also for MPD?

Motivation for NICA

1. Increase a list of measurable baryons with NDET (+):

n	p	$\Lambda \to p\pi^-$	$\Sigma^+ \to n\pi^+$	$\Sigma^- \to n\pi^-$	$\Sigma^0 \to \Lambda\gamma$	$\Xi^- \to \Lambda\pi^-$	$\Xi^0 \to \Lambda\pi^0$	$\Omega \to \Lambda K^-$
+	+	+	+	+		+		+

2. AntiNeutron, antiΣ+, antiΣ^- with Ndet
   (and possible help for other antibaryons)
3. New ratios: n/p, Σ/p, ...
4. 3-dimension phase diagram (add axis Nn-Np)
5. Femtoscopy nn, np, pp, Σp, Σn, ...
   Unknown low energy scattering parameters for ΣN
6. Study of Dense Cold Matter (our proposal for NICA MPD):
   If we have not neutron detector, we will lose a half of information
7. Neutron asymmetries at NICA (new!) [http://arxiv.org/pdf/1006.1331]

Neutron asymmetries at NICA

http://arxiv.org/pdf/1006.1331

Chiral vortaic effect and neutron asymmetries at NICA

Oleg Rogachevsky,[1,2,*] Alexander Sorin,[1,3,†] and Oleg Teryaev[1,3,‡]

[1] *JINR, 141980 Dubna (Moscow region), Russia*

[2] *PNPI RAS, 188300 Gatchina (Leningrad district), Russia*

[3] *Dubna International University, 141980 Dubna (Moscow region), Russia*

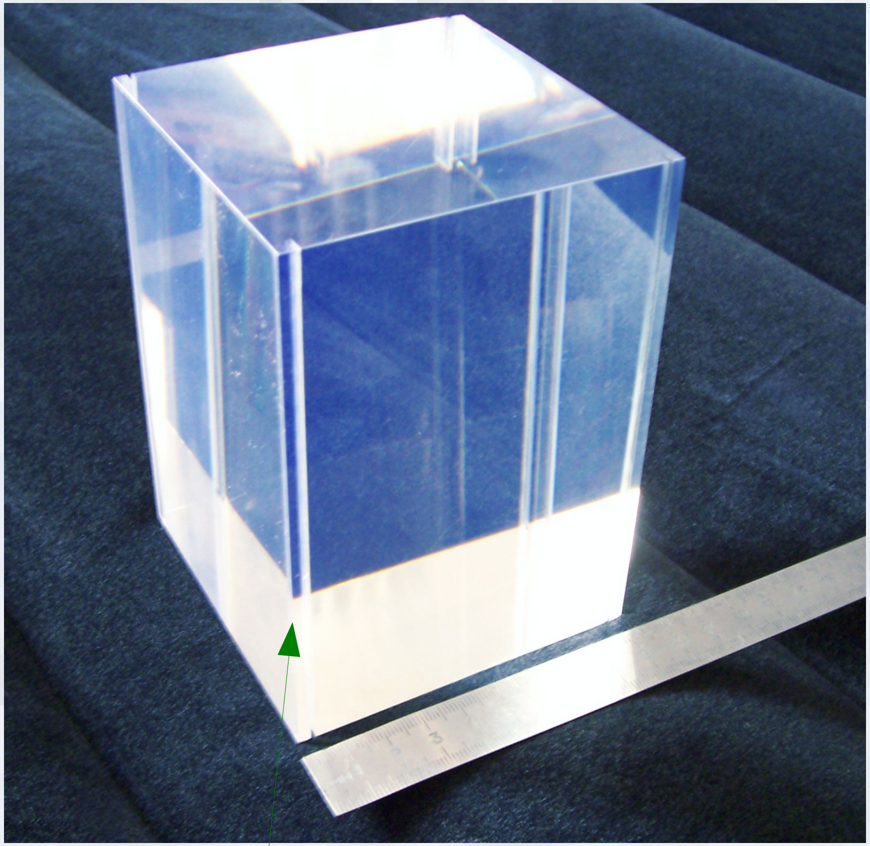
(Dated: June 7, 2010)

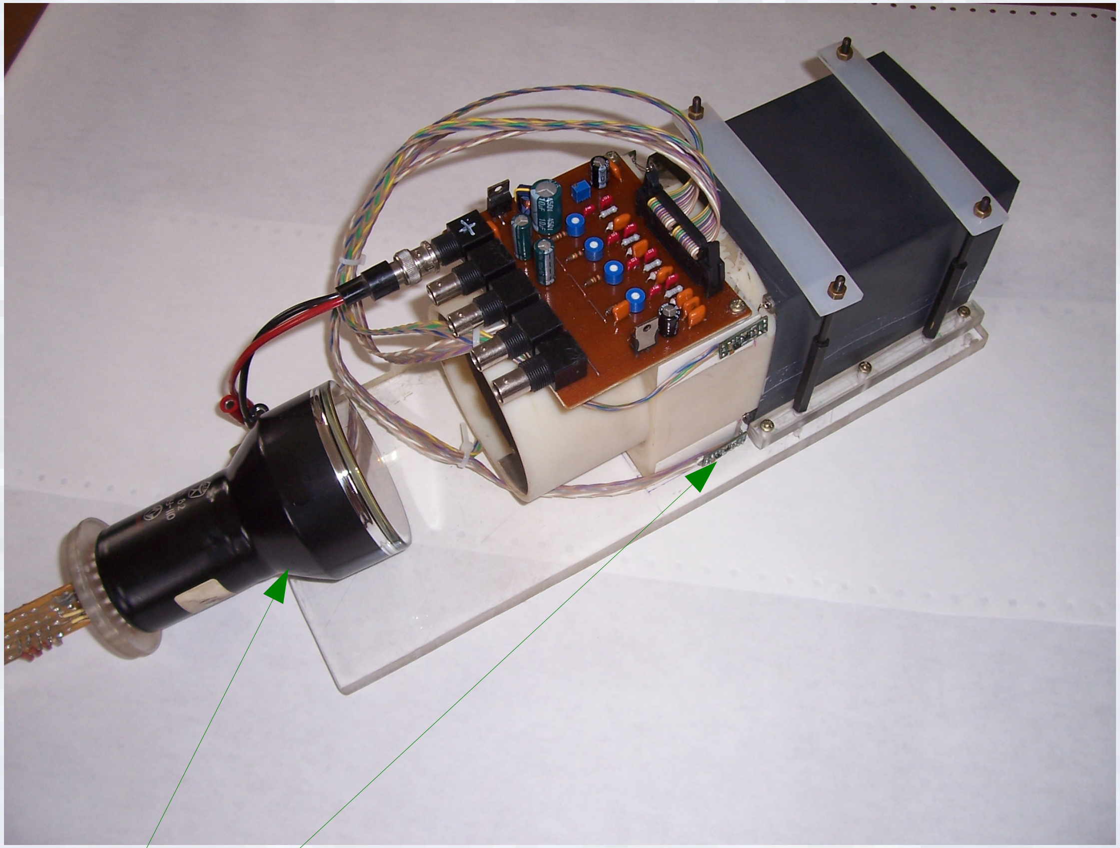
Abstract

We study the possibility of testing experimentally signatures of P-odd effects related with the vorticity of the medium. The Chiral Vortaic Effect is generalized to the case of conserved charges different from the electric one. In the case of baryonic charge and chemical potential such effect should manifest itself in neutron asymmetries at the NICA accelerator complex measured by the MPD detector. The required accuracy may be achieved in a few months of accelerator running. We also discuss polarization of the hyperons and P-odd correlations of particle momenta (handedness) as probes of vorticity.

The prototype of
position sensitive neutron detector...

The prototype of Ndet





Plastic Scintillator 96 * 96 * 128 mm^3

Fiber in the groove : KYRARAY,Y-11,

d =1mm, wavelength shift

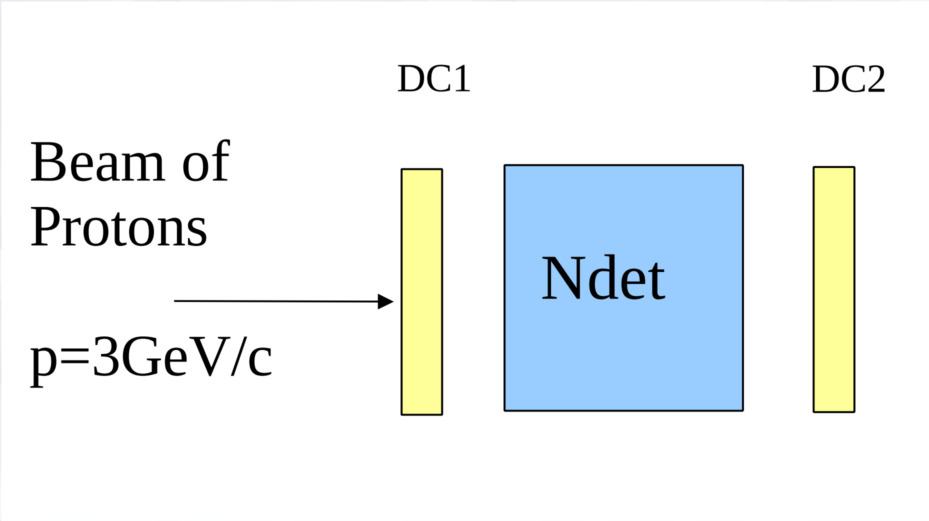
MRS APD & Amplifier -CPTA(Golovin)

PMT for test EMI 9839A

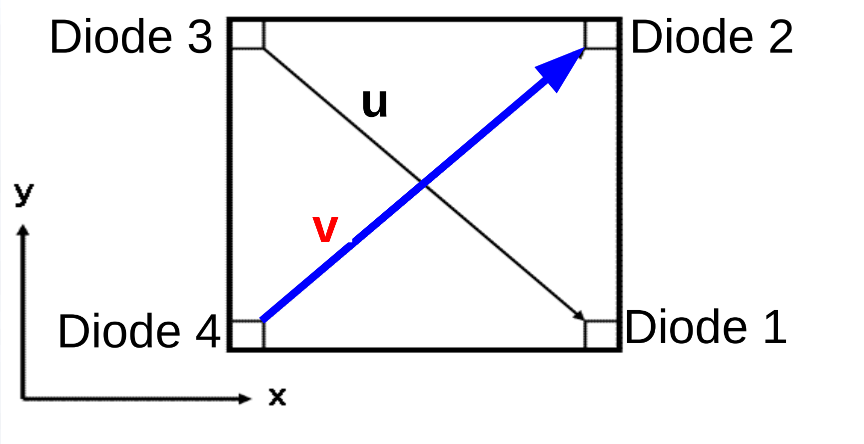
Efficiency ~ 15%

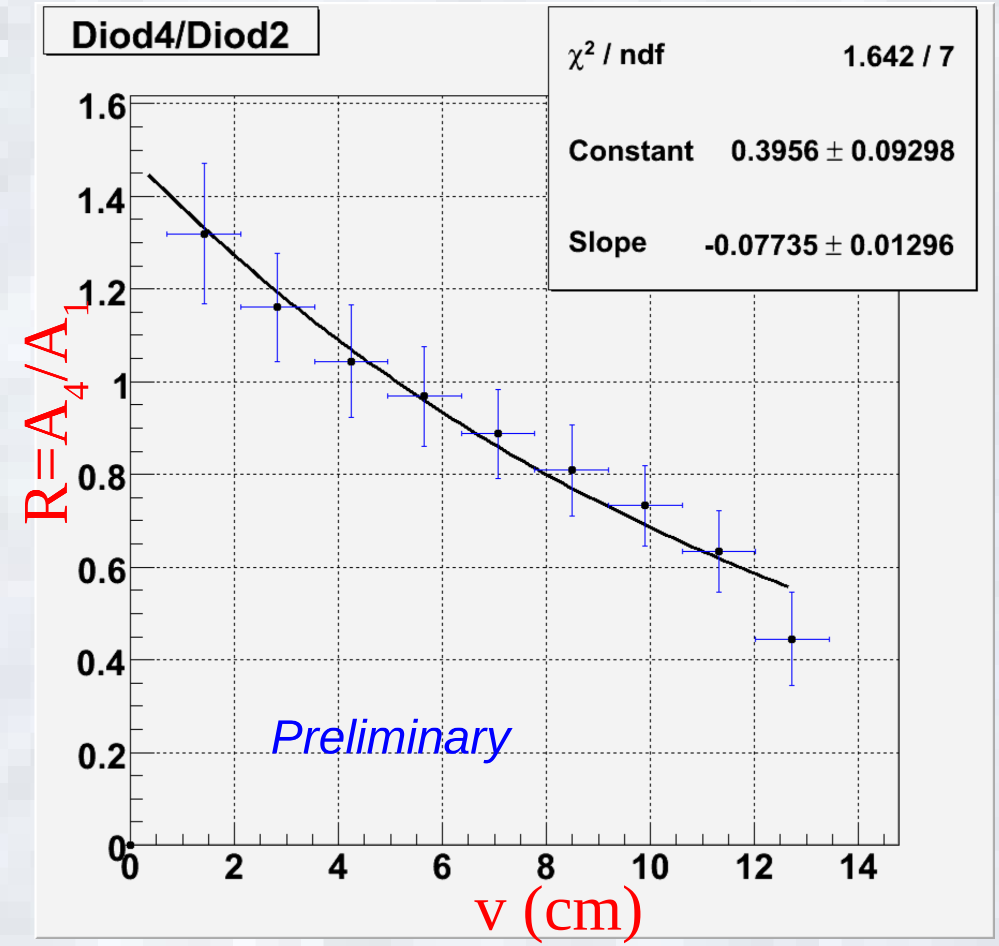
Matrix for FLINT 6x6=36

Beam tests of prototype



Ratio ($R=A_4/A_1$) of amplitude as exp(-R/d)

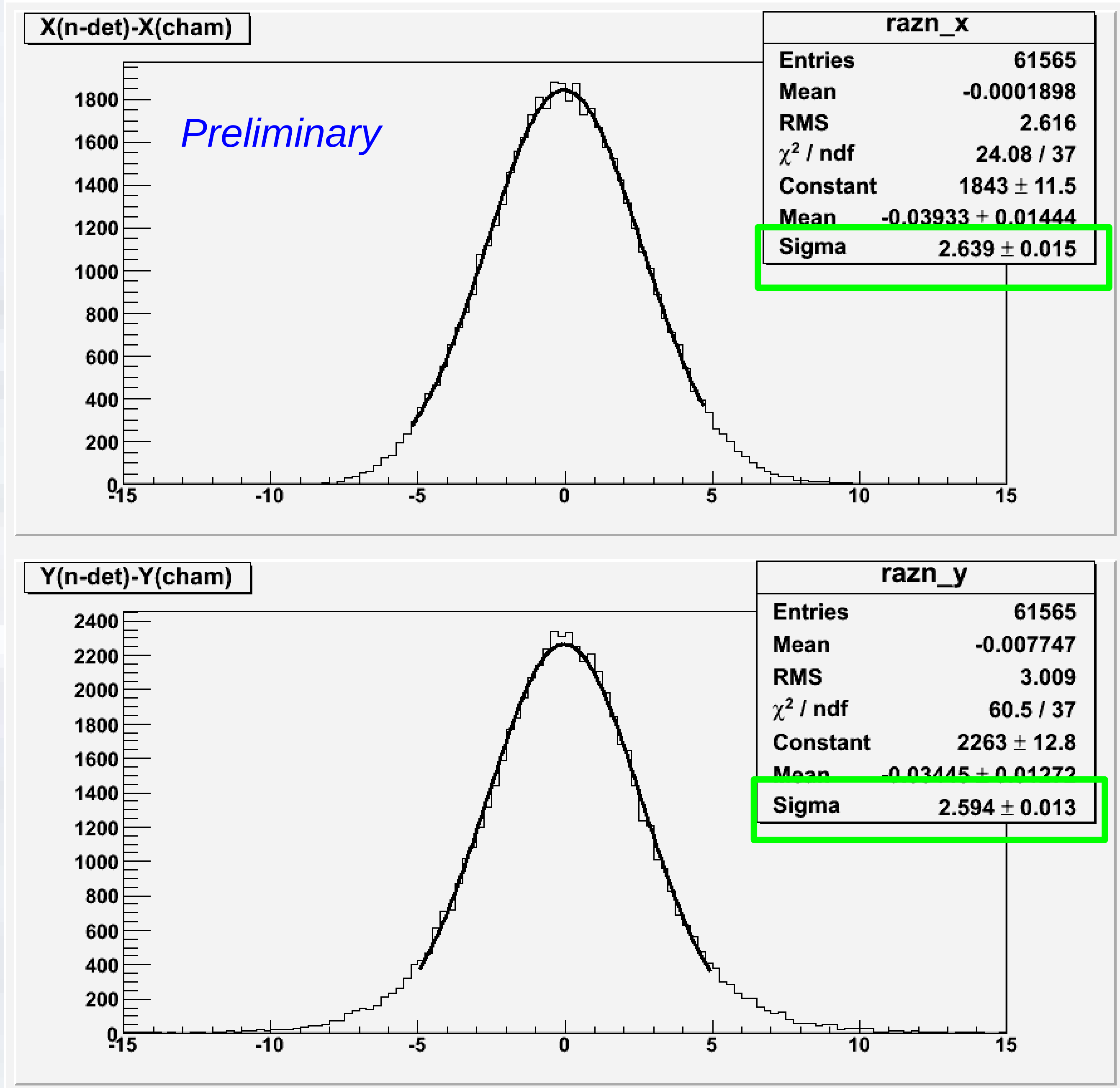




Beam test: Ndet space resolution

Preliminary resolution of neutron detector

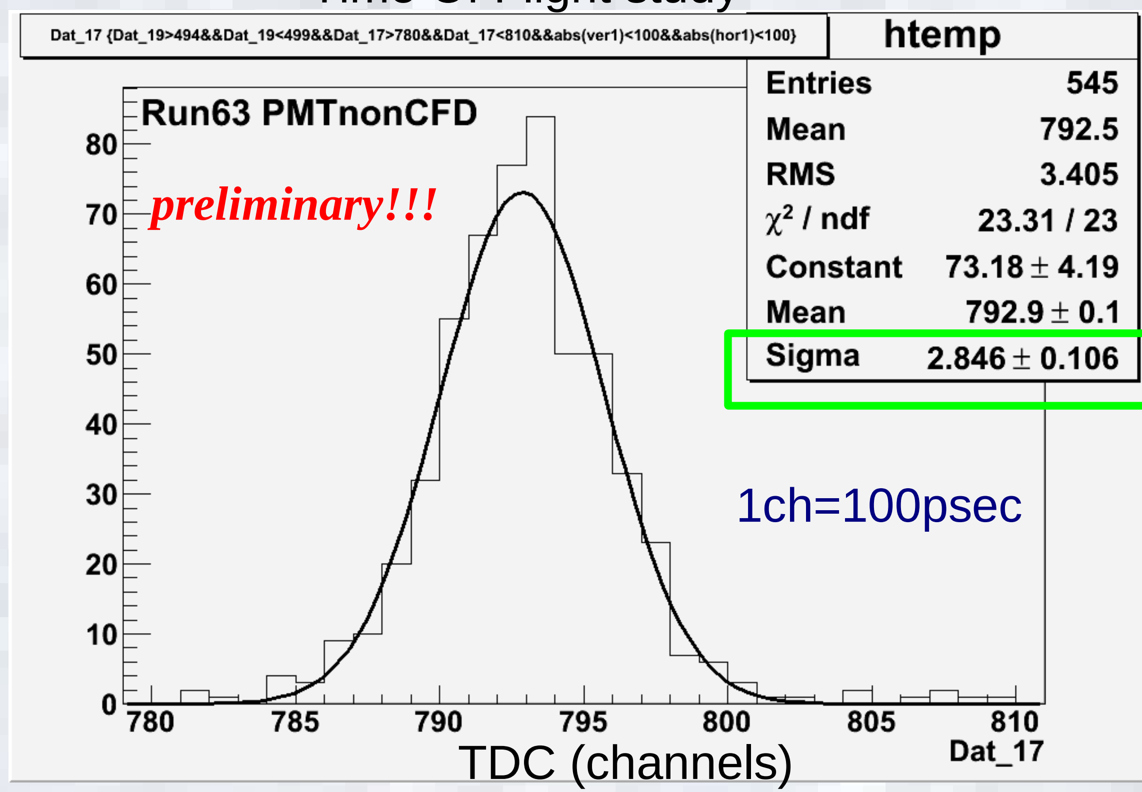
$\sigma_x \approx \sigma_y \approx 2.6$ cm



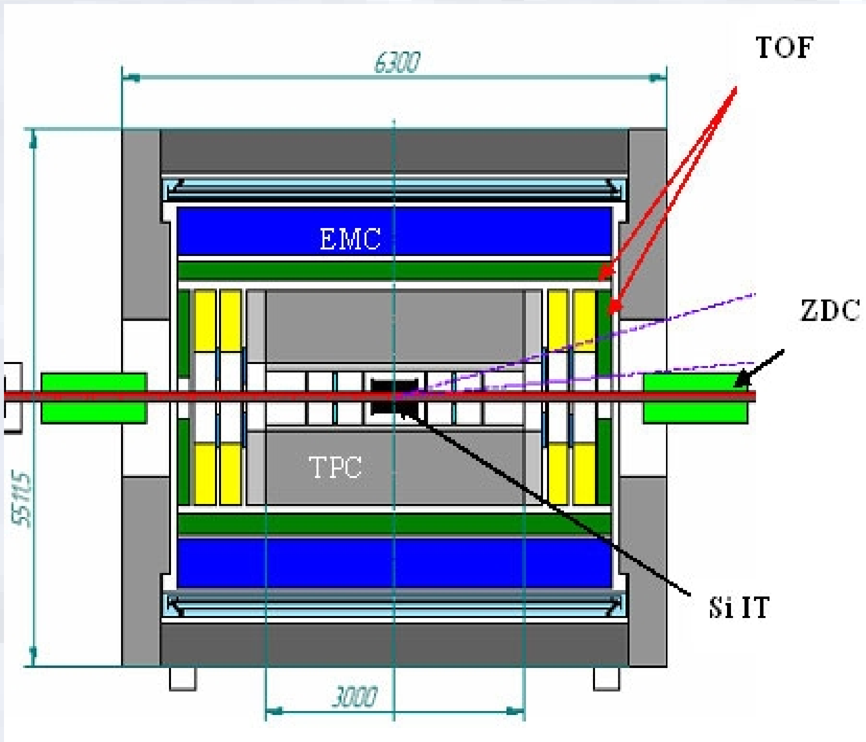
Beam test: Ndet time resolution

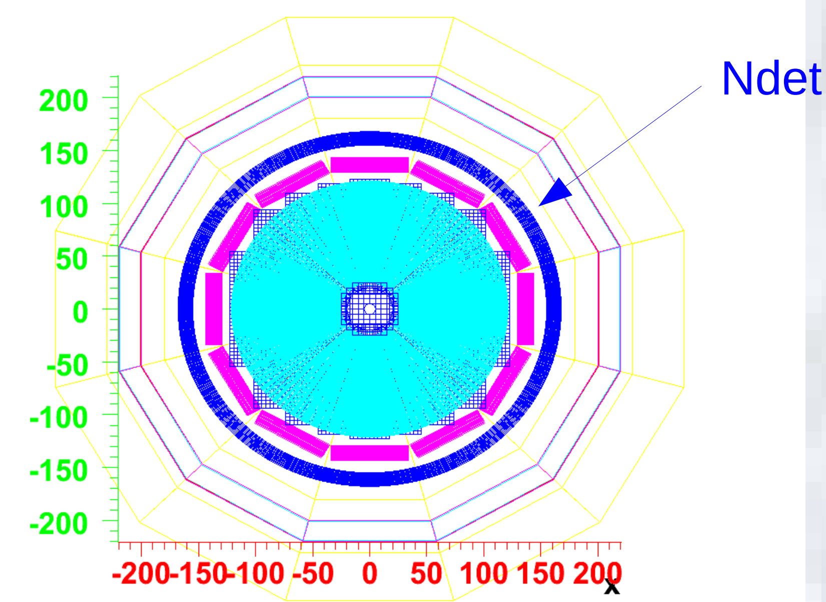
Beam tests of time resolution of Ndet
are in progress.
We had a short first run right on Dec'2009.
Very preliminary:
Time resolution ~ 0.3nsec

Time Of Flight study



Ndet in MPD root





First version of Ndet is in MPDROOT trunk/ndet

(ring of plastic with r=155cm and width 12.8cm, box 9.6x9.6cm Zlength~3m
Matrix ~ 3000 detectors)

Test with MC central events AuAu at sqrt(s)3.8 GeV/c

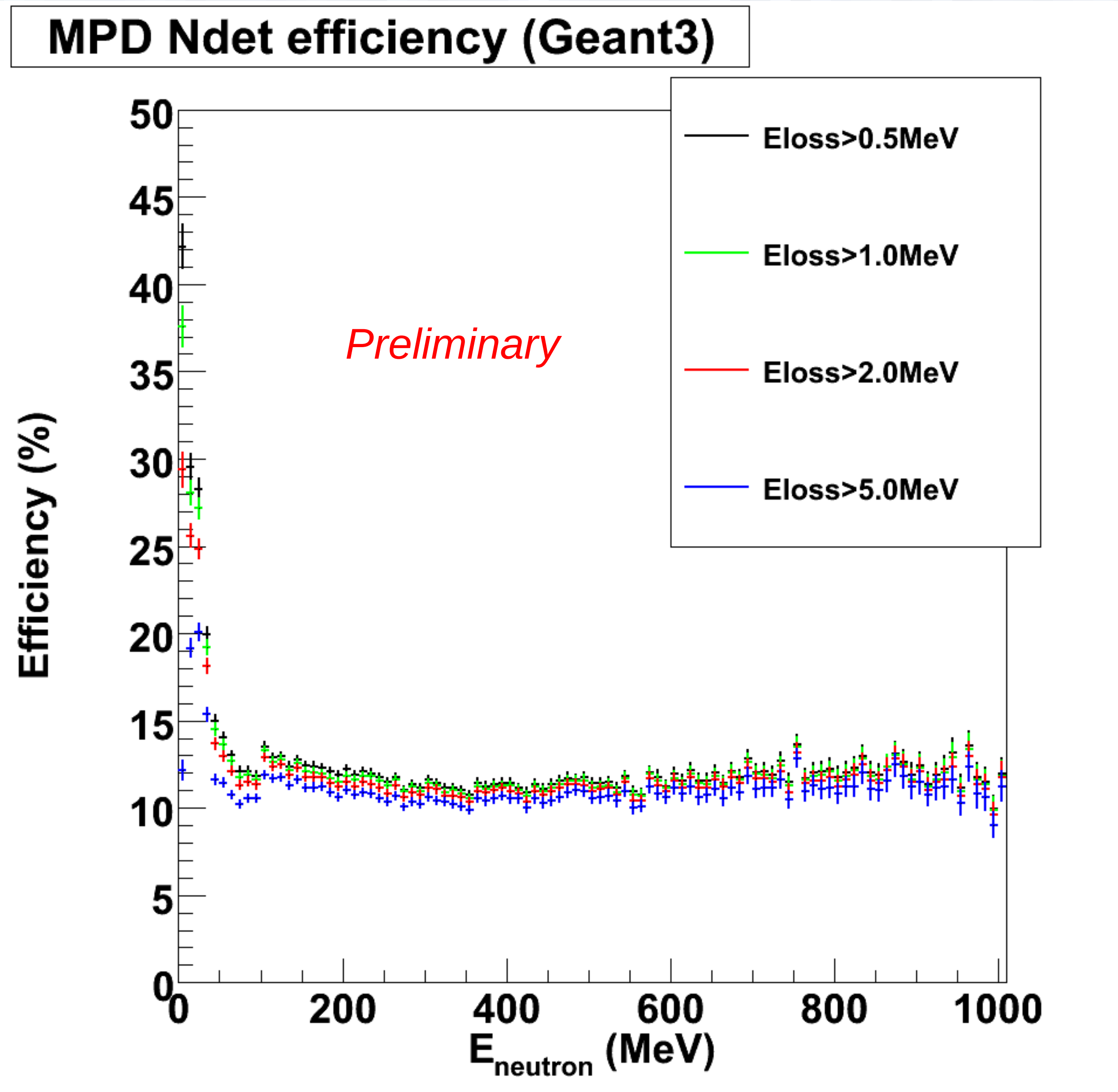
First step to the efficiency

- 10^4 UrQMD AuAu central events sqrt(S)=3.8GeV/nucleon
- MPD root with Geant3
- Preliminary Ndet efficiency with primary neutrons
- Comparison with DeMoN detector efficiency

Ndet efficiency in Geant3

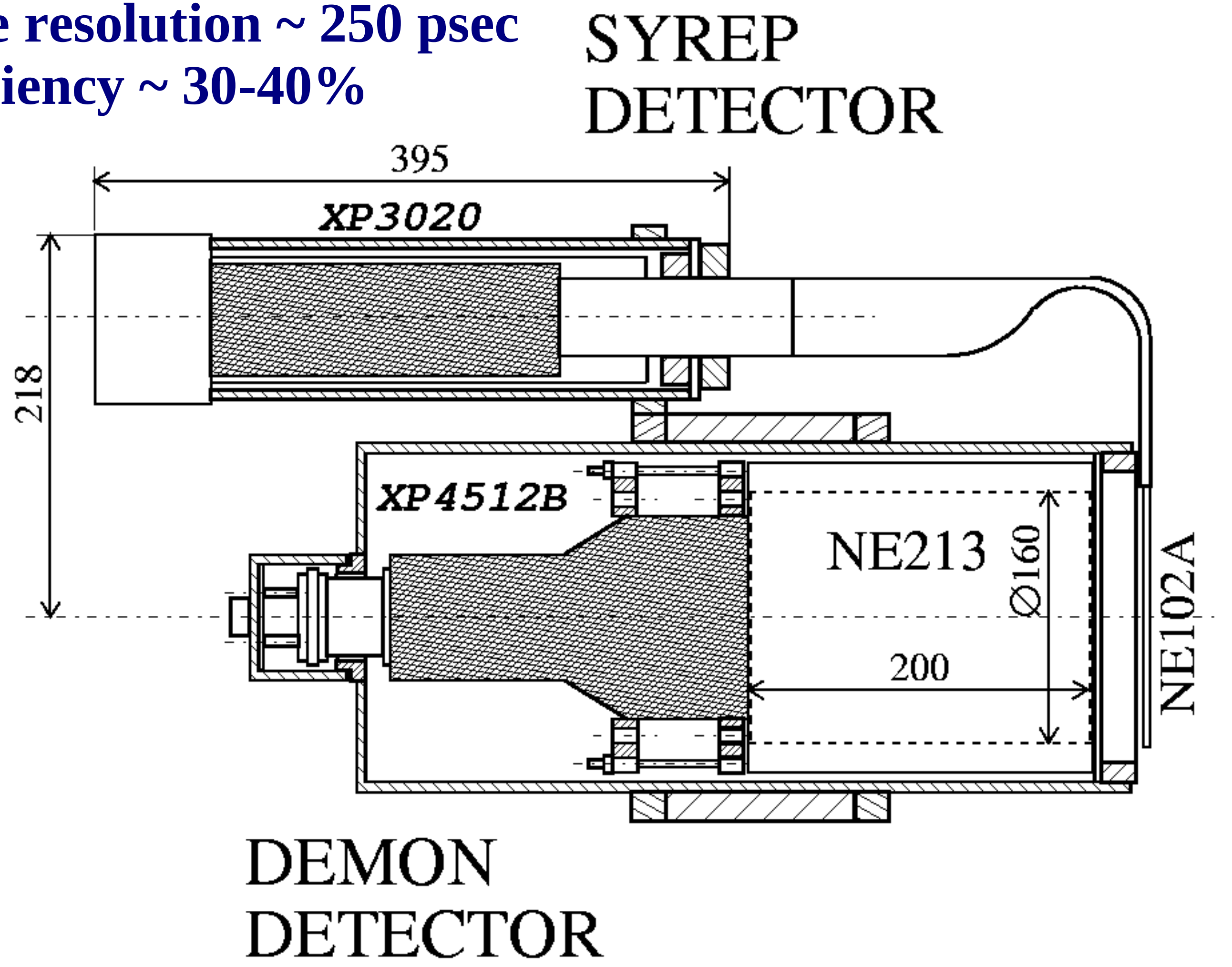
The efficiency of neutron registration is about 13% (length of Ndet is 128mm) at En>100 MeV

If proton momentum > 500 MeV/c we have to know Ndet efficiency starting from En>50MeV

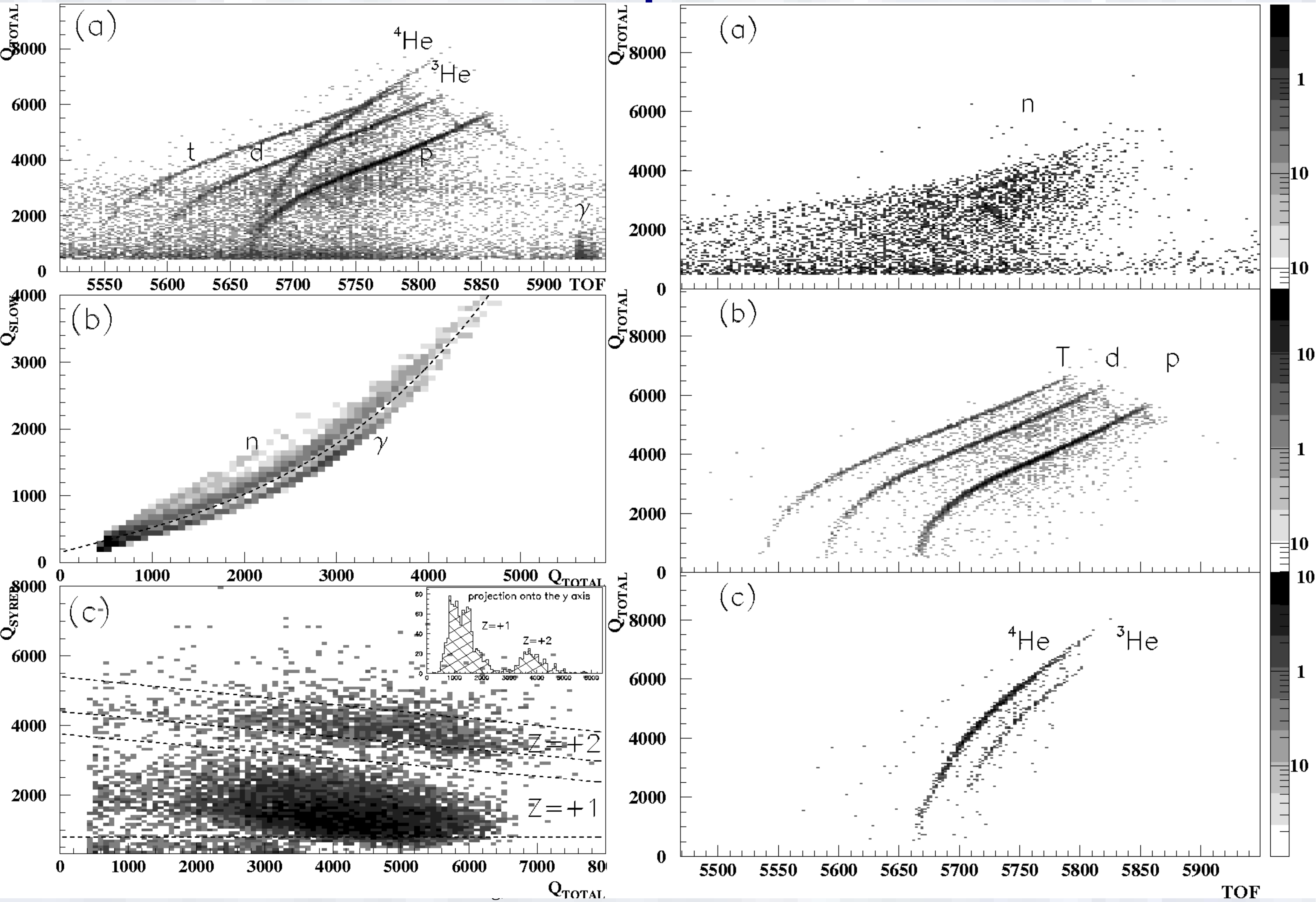


DeMoN detector

Time resolution ~ 250 psec
Efficiency ~ 30-40%



E286 experiment

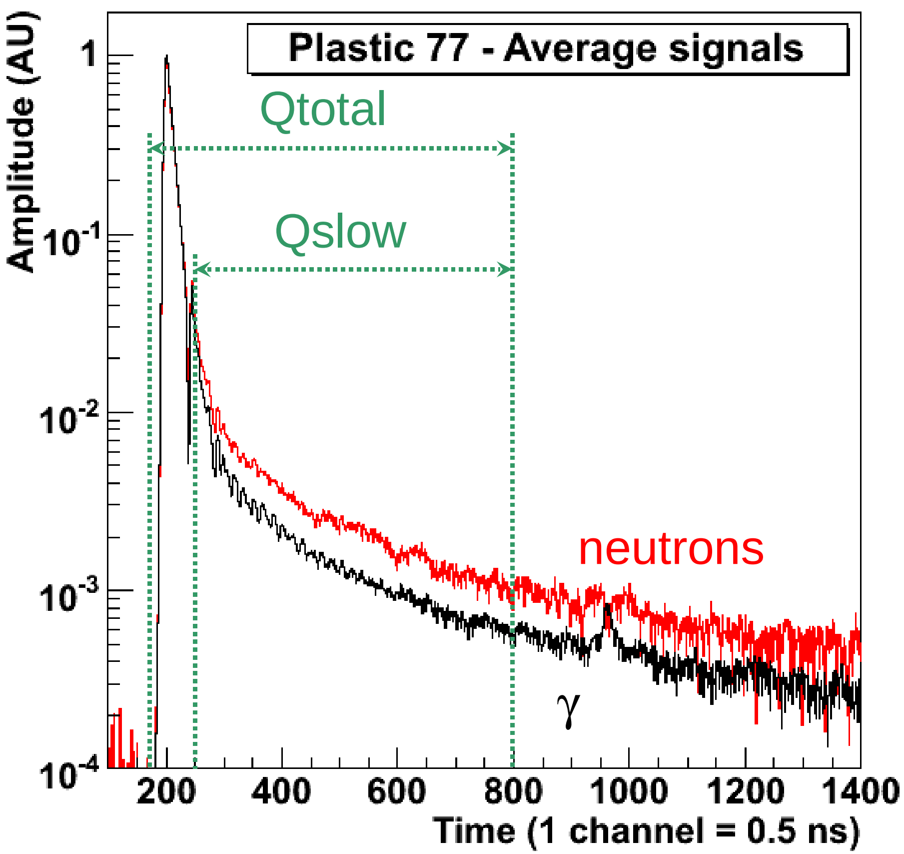


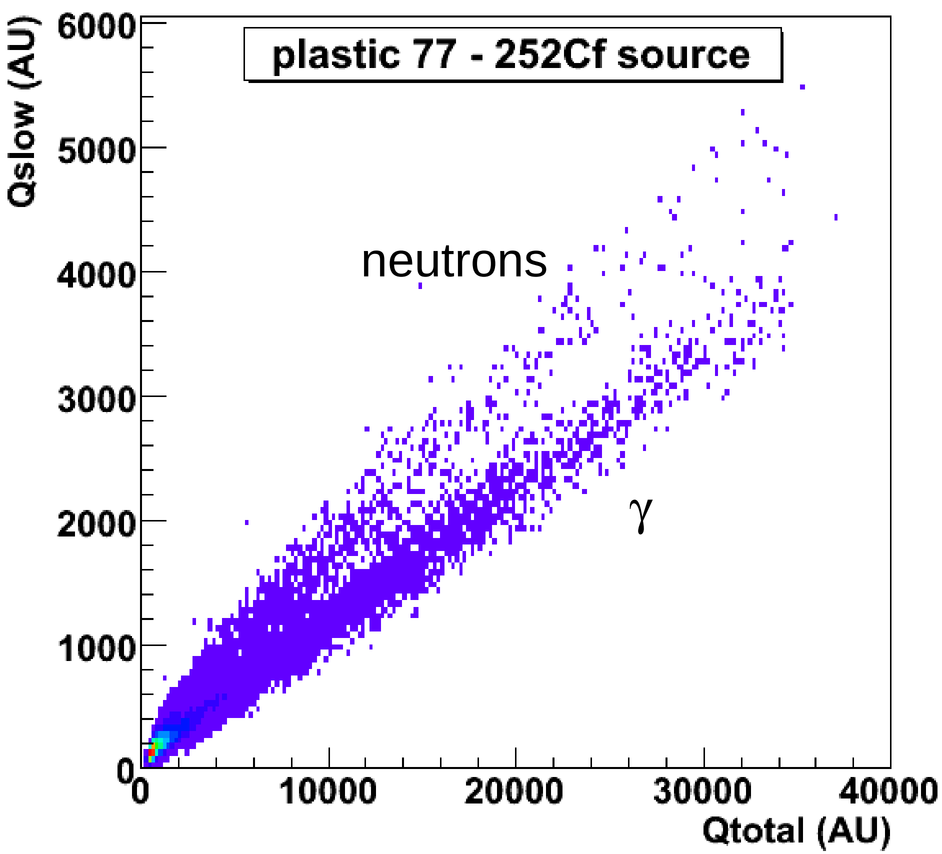
Discriminating plastic

« plastic 77 », Brooks et al, IRE Trans. Nucl. Sci., NS-7, 35 (1960)

No exotic compounds (similarities with NE213)
Light output ~ BC400
Clean synthesis process (CEA Saclay)

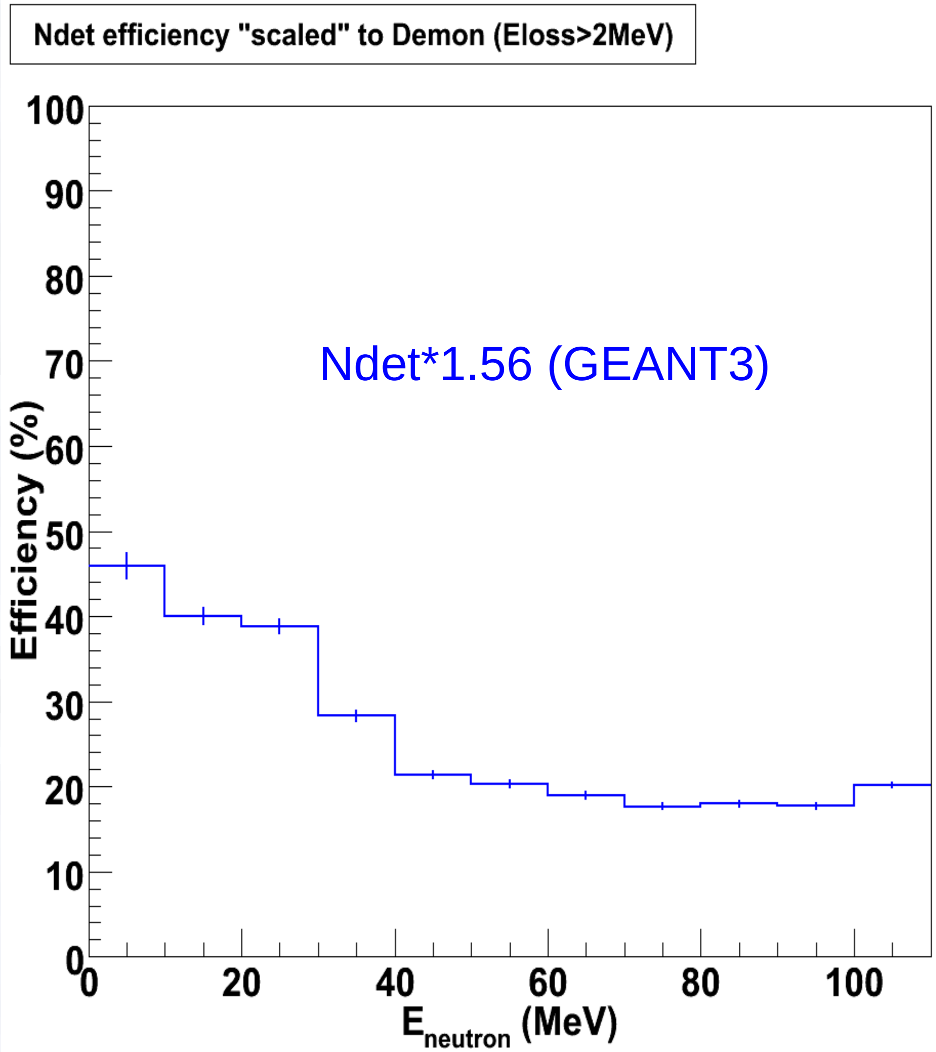
Test at LPC with digital ADC : 2 GHz, 12 bits, 2500 samples (1.25 μs), low rate

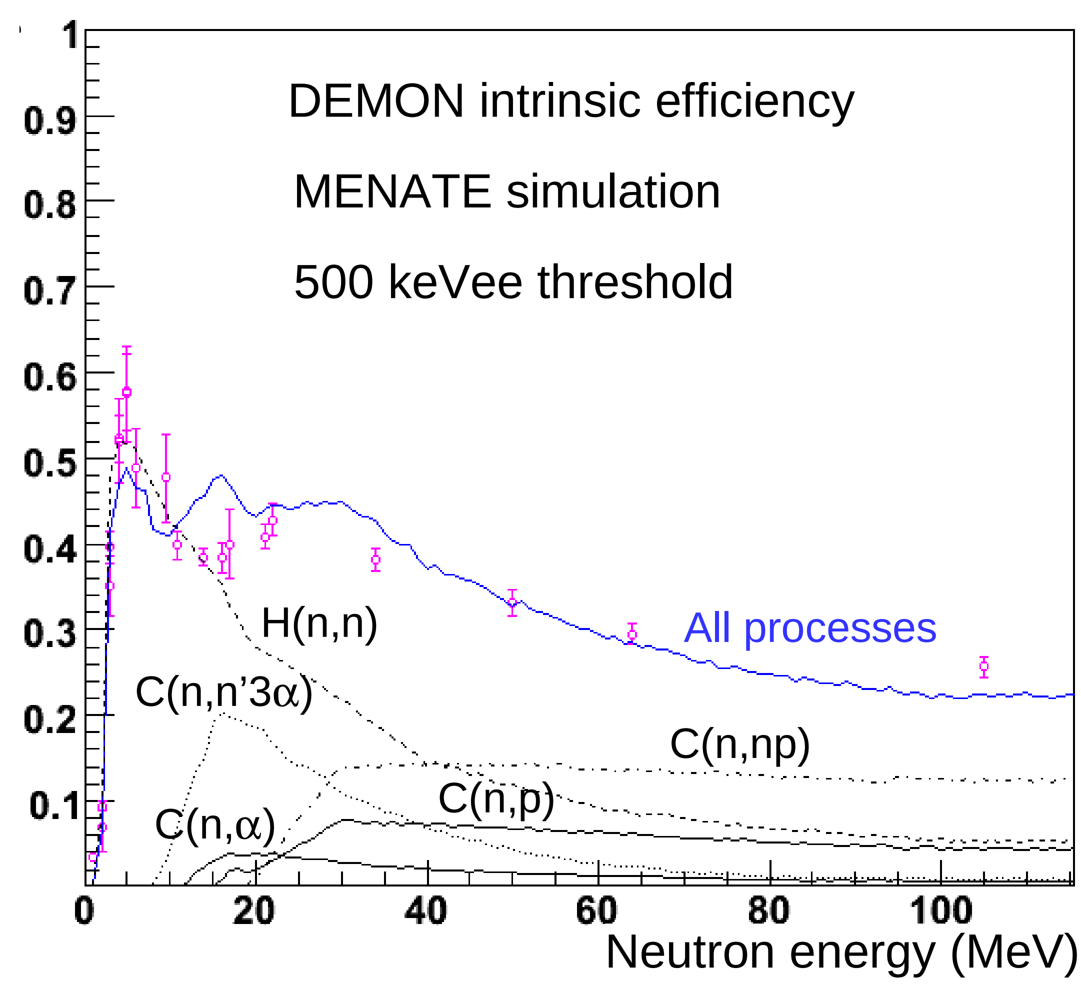




From presentation : « Neutron detector developments at LPC Caen »

Ndet and DeMoN





Present calculation roughly corresponds to DeMoN efficiency

P. Désesquelles et al, NIM A 307, 366 (1991)

Diaphony and Cross-Talk

In a modular detection system the same neutron can interact in several modules.
If neutron is scattered in one module without being registered and later on is detected in another one then the ***diaphony*** take place.

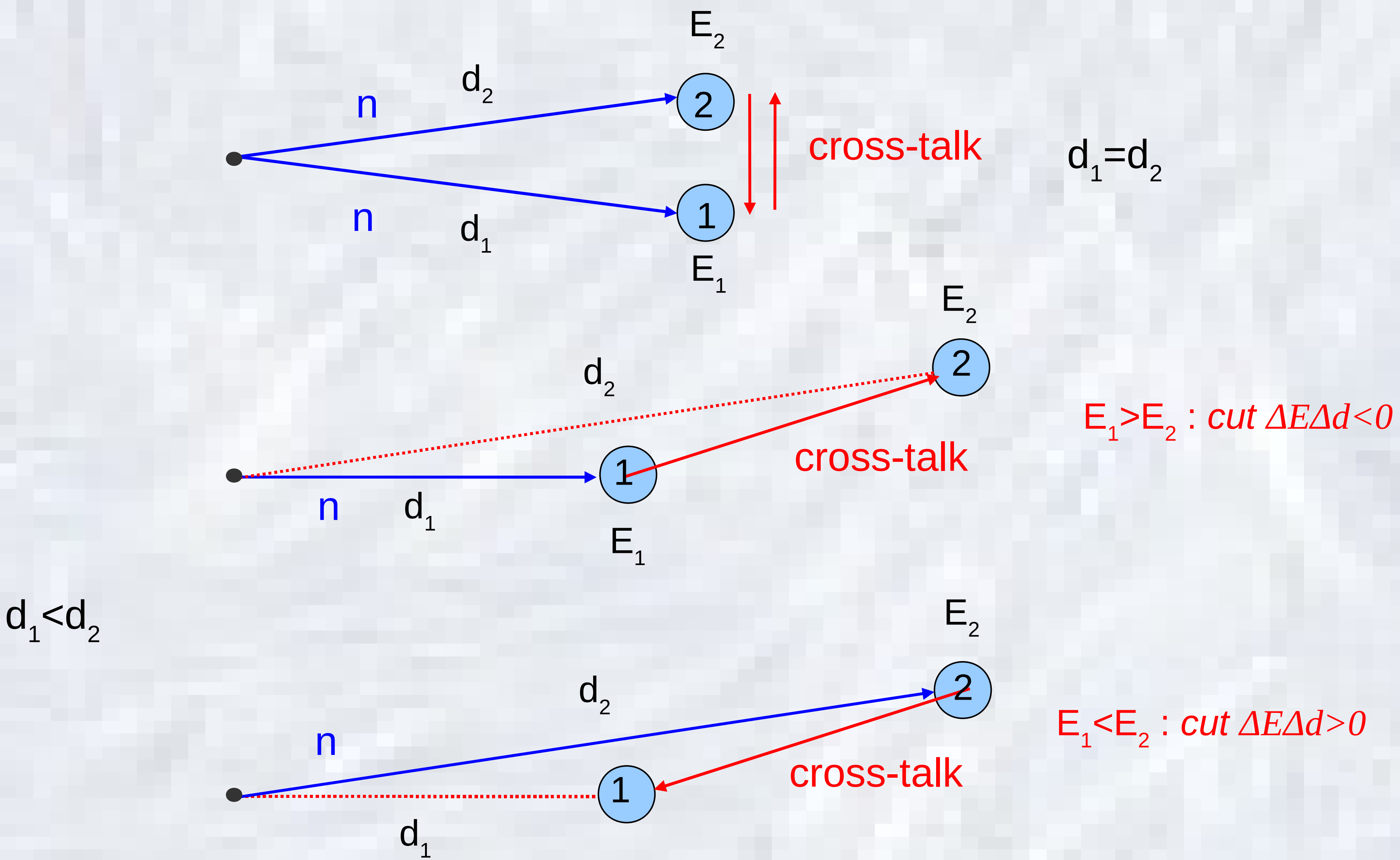
If the same neutron is registered in two or more detectors – the ***cross-talk*** effect occurs.

Diaphony: distortion of the emission angle and the energy

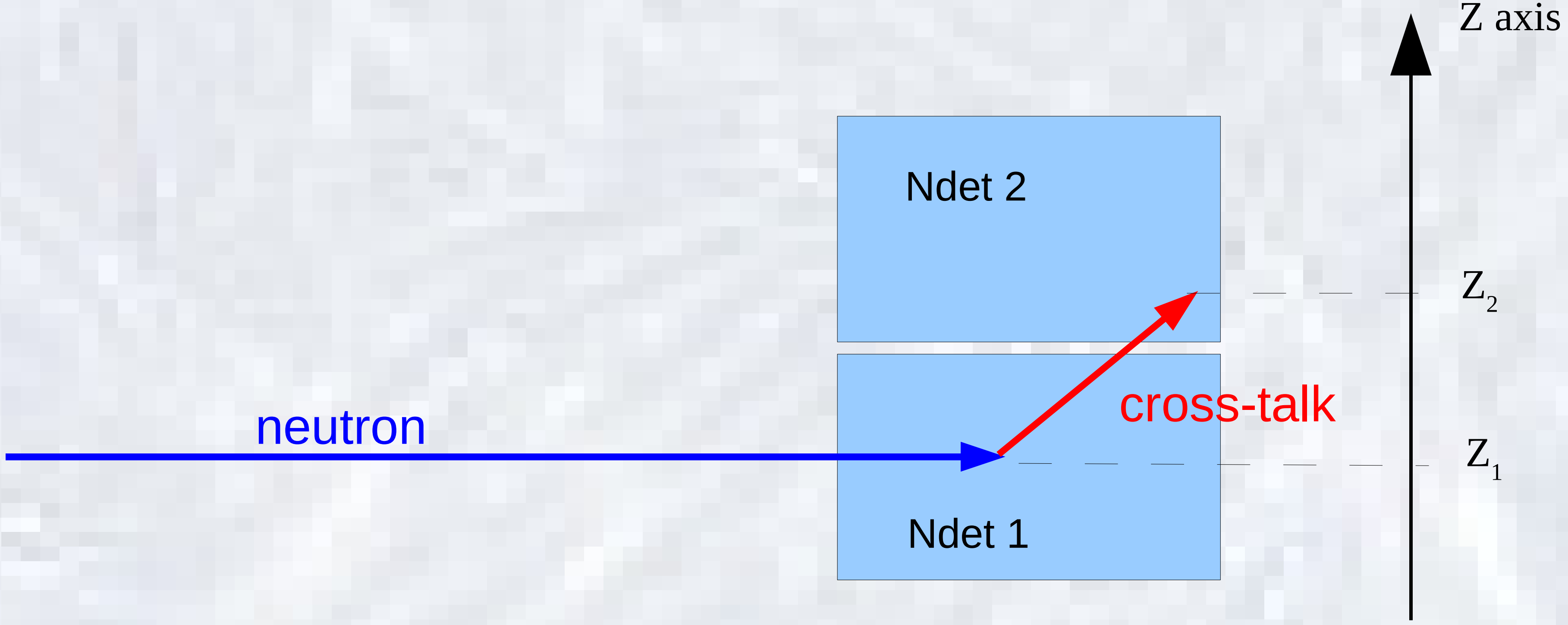
Cross-talk: simulates of two or more neutrons in coincidence leading to a strong spurious correlation. In case of one-particle distribution the cross-talk effects are usually small, but in femtoscopy measurements this effect is quite important and dangerous.

Cut Cross-Talks

J.Pluta et al. NIM A411(1998) 417

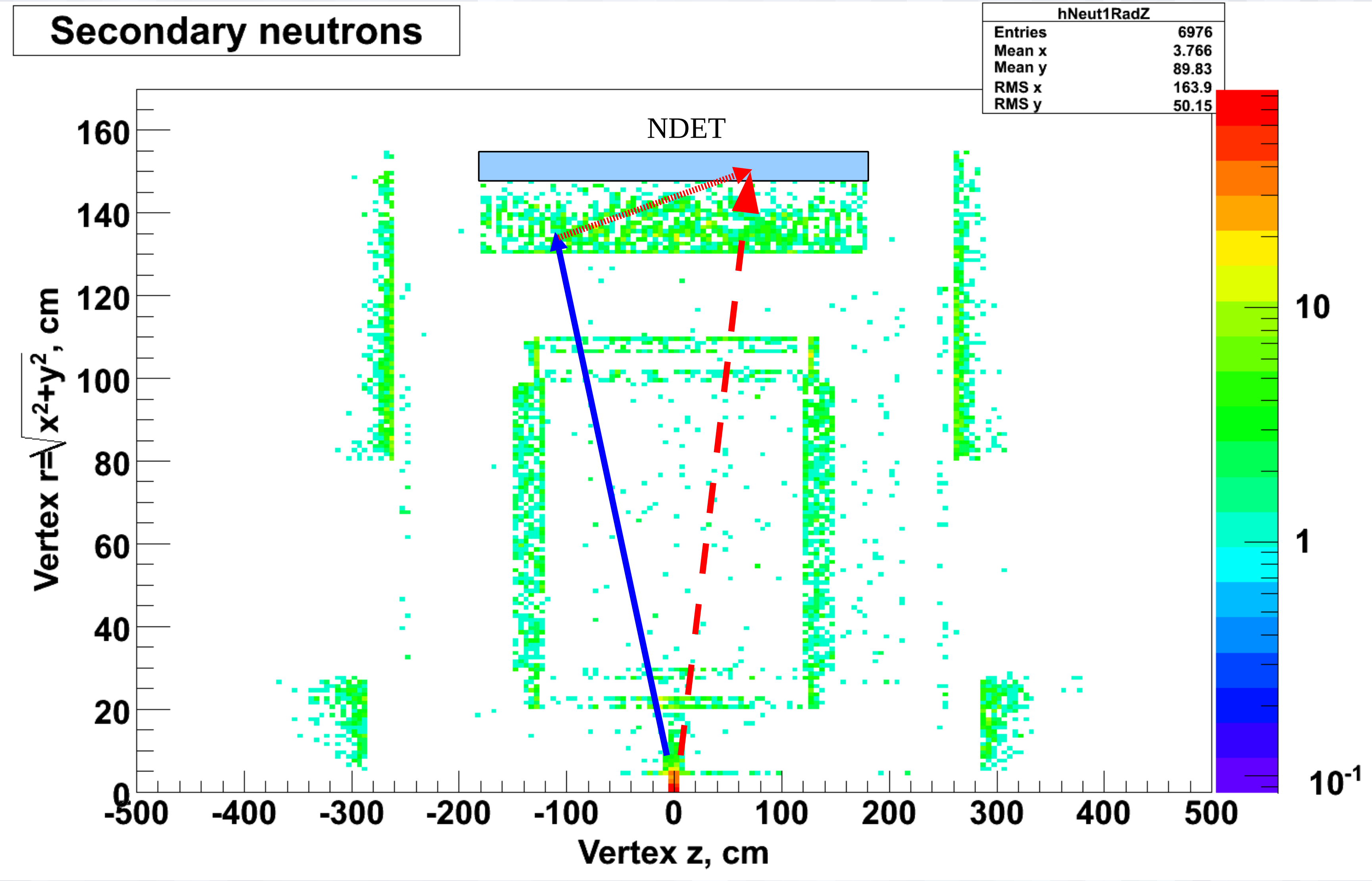


Ndet Cross-Talks



Position sensitive neutron detector could be help to reject cross-talk if we do the cut on coordinate

Fake neutrons in MPD



$\Sigma+$, $\Sigma-$ in MDP

Simulation of Σ

Σ^+ DECAY MODES	Fraction (Γ_i/Γ)	Confidence level	p (MeV/c)
$p\pi^0$	(51.57 ± 0.30) %		189
$n\pi^+$	(48.31 ± 0.30) %		185
$p\gamma$	$(1.23\pm0.05)\times10^{-3}$		225
$n\pi^+\gamma$	[b] $(4.5\pm0.5)\times10^{-4}$		185
$\Lambda e^+\nu_e$	$(2.0\pm0.5)\times10^{-5}$		71

Σ^- DECAY MODES	Fraction (Γ_i/Γ)	p (MeV/c)
$n\pi^-$	(99.848 ± 0.005) %	193
$n\pi^-\gamma$	[b] $(4.6\pm0.6)\times10^{-4}$	193
$ne^-\overline{\nu}_e$	$(1.017\pm0.034)\times10^{-3}$	230
$n\mu^-\overline{\nu}_\mu$	$(4.5\pm0.4)\times10^{-4}$	210
$\Lambda e^-\overline{\nu}_e$	$(5.73\pm0.27)\times10^{-5}$	79

- Simulation in MPD ROOT with Ndet package
- UrQMD AuAu sqrt(S) = 3.8 GeV (10^4 events)
- Smearing due to Ndet tof resolution 0.3 ns
- Smearing due to Ndet space resolution 0.3 cm
- Suppose (for now) 100% neutron efficiency
- Do not use tracking information for pions and do not smear pion momentum

Ndet momentum resolution

Momentum resolution of neutron detector is a combination of time resolution and space resolution

<u>Time resolution</u>

β = L/TOF, where L distance from collision point to Ndet

Suppose TOF smeared by Gaus(TOF,σ_{TOF}) and one can expect $\sigma_{TOF} <$ 0.3ns (to be measured)

Smeared momentum due to time

$P_{smeared} = m\beta_{smeared}/(1-\beta_{smeared}^2)$

<u>Space resolution</u> depends on

Angle $\Phi_{smeared}$ =Gaus(Φ, σ_s/R)

and

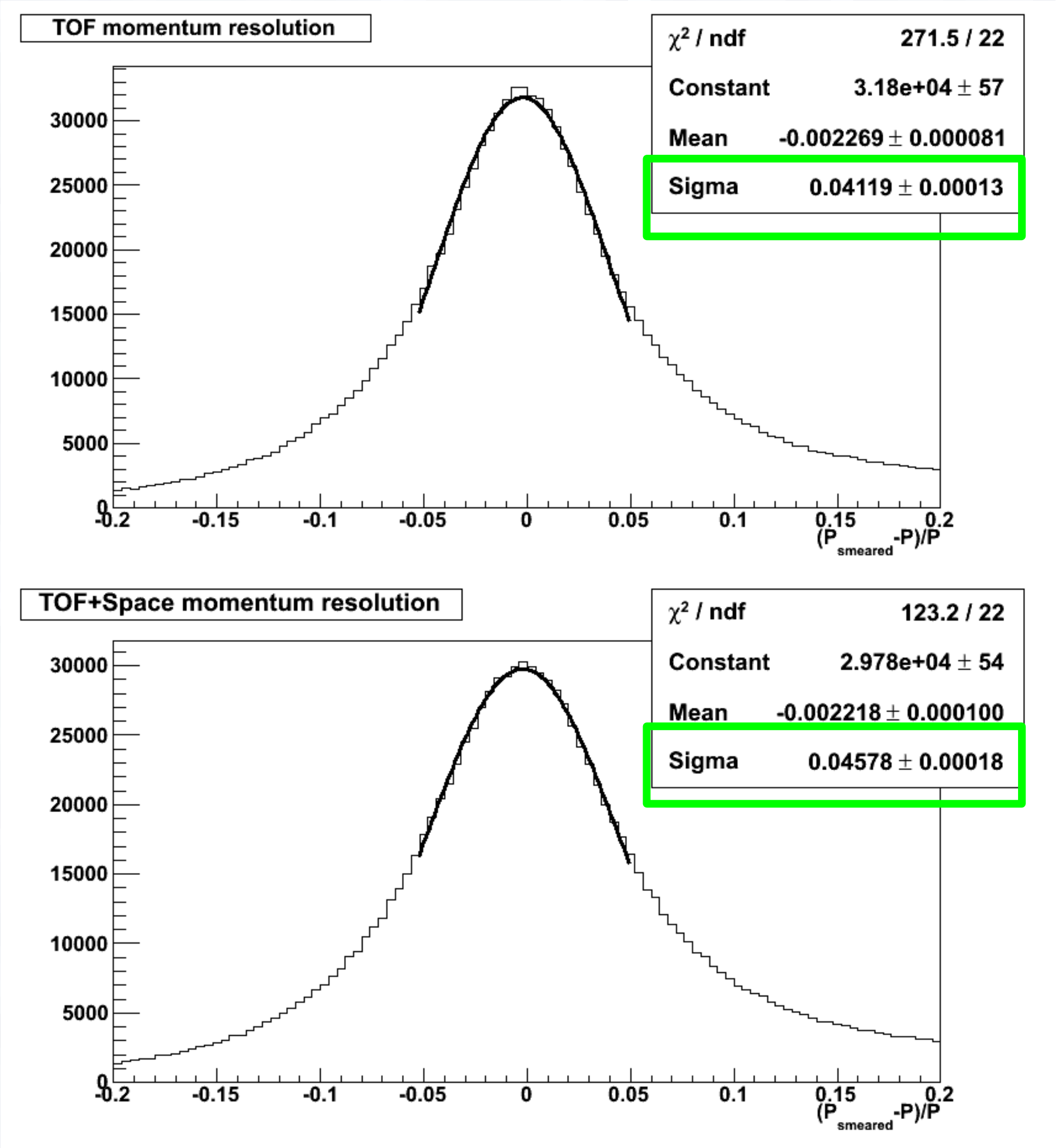
$Z_{smeared}$ = Gaus(Z, σ_s),

where σ_s = 3cm Ndet space resolution

R is radius of Ndet ring (155 cm)

$Y_{smeared} = \cos(\Phi_{smeared})$ R

$X_{smeared} = \sin(\Phi_{smeared})$ R



Sigma selection criteria

- Cut on neutron TOF: 20 ns (cut $\beta<0.3$ and reduce secondary neutrons from MPD detector components)
- Cut on pion vertex (distance from reaction vertex) > 0.1 cm to select decays

  $\Sigma^+ \rightarrow n\pi^+$(48%) $c\tau$ =2.404 cm

  $\Sigma^- \rightarrow n\pi^-$ $c\tau$ =4.434 cm

  Background processes:

  $K^0_S \rightarrow \pi^+\pi^-$ $c\tau$ =2.68 cm

  $\Lambda^0 \rightarrow p\pi^-$ $c\tau$ =7.89cm

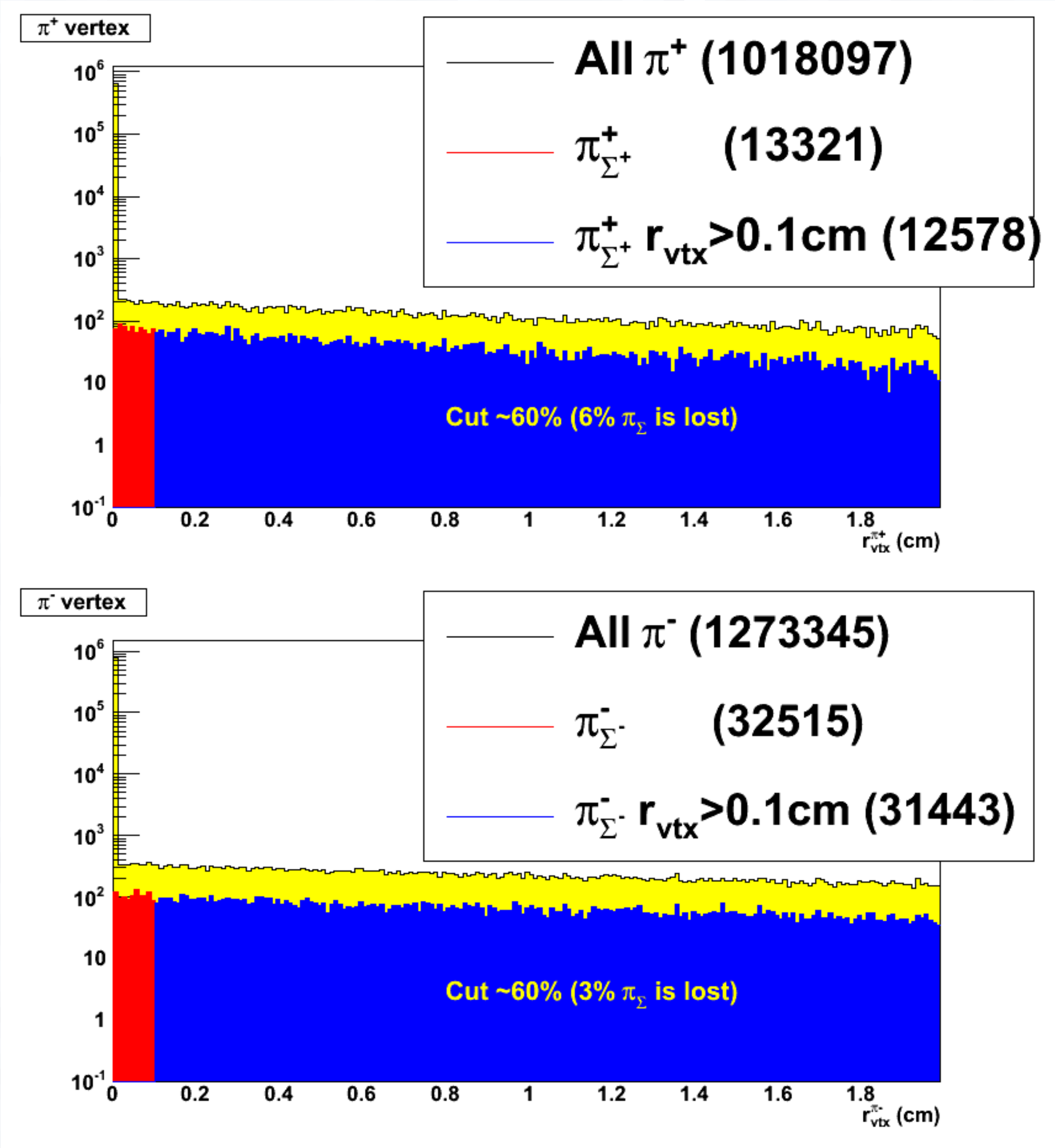
- Cut on vertex of reconstructed Σ, distance from collision point to Σ momentum line less than 0.1cm
- Cut on pion momentum > 0.15 GeV/c (reduce combinatorial BG)

Pion Vertex cut

Most pions come from collision vertex

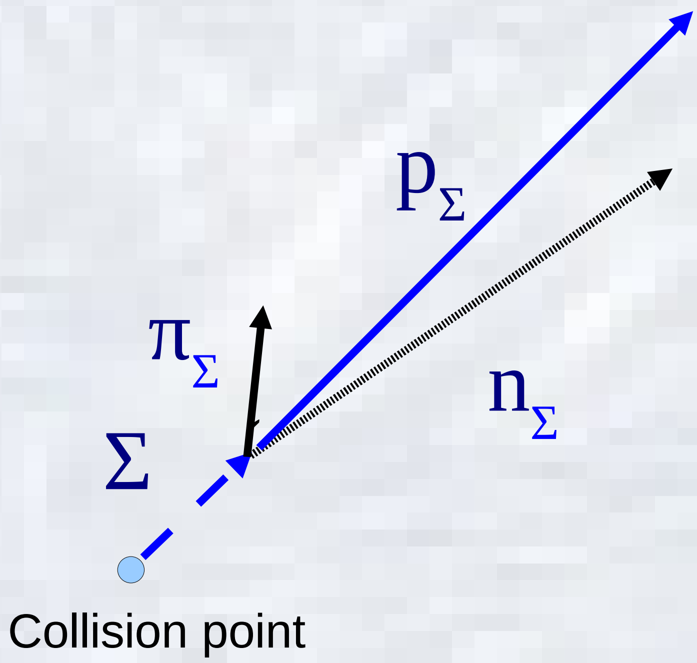
Cut on pion vertex > 0.1 cm

We cut about 60% of all pions and lost a few percents of pions from Sigma decay!

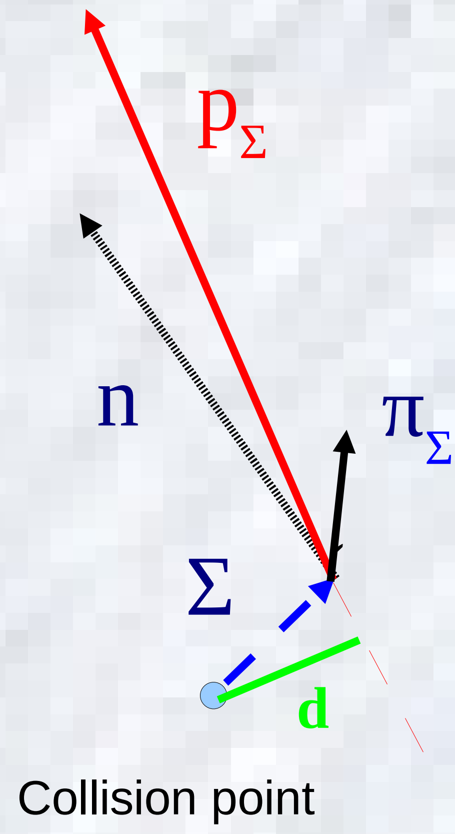


Vertex cut for Sigma

Real Σ comes from collision point (cp)

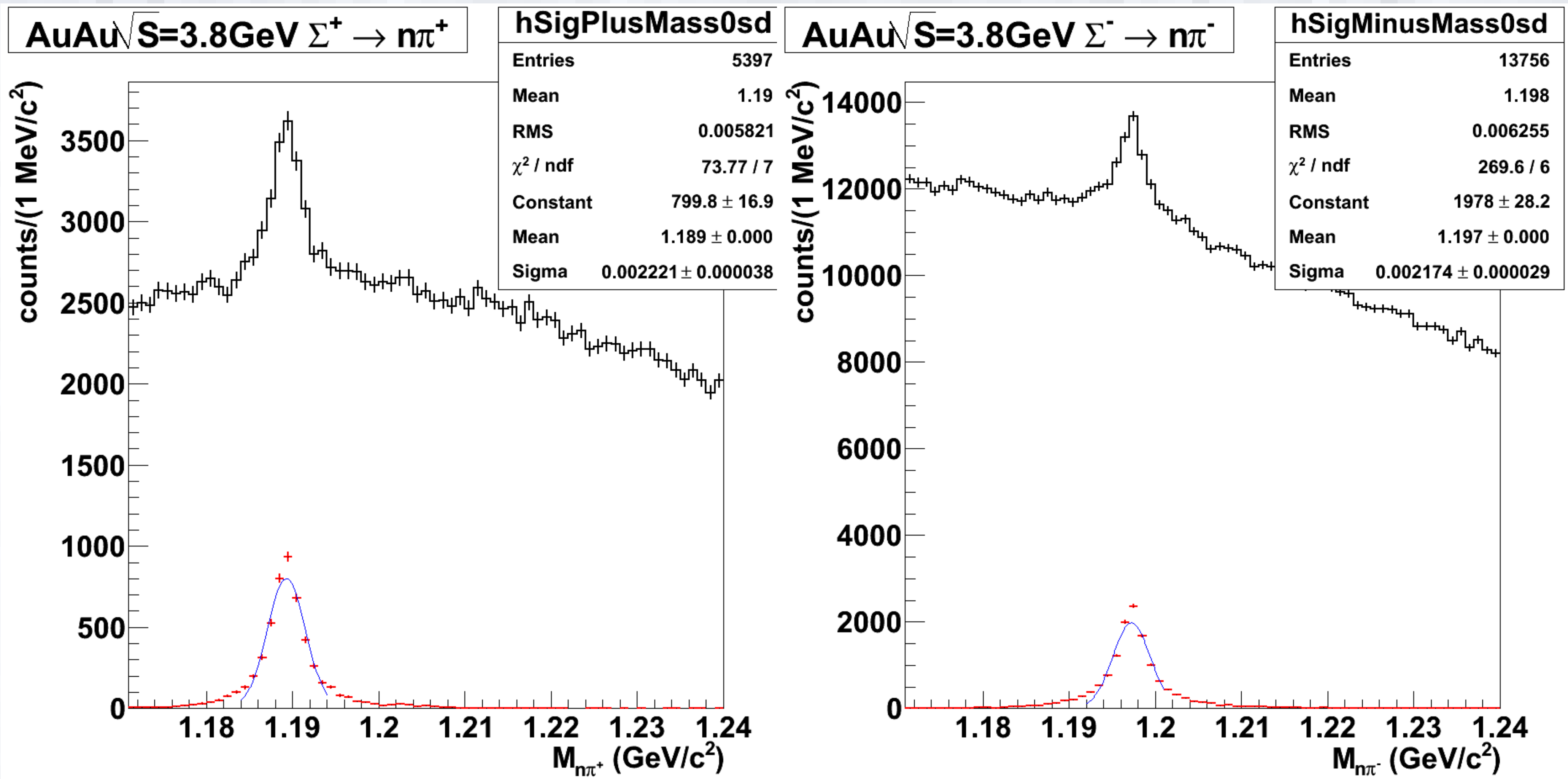


Fake Σ does NOT come from collision point (cp)
Cut on distance of closest approach (**d**)



Feasibility of Σ detection

10^4 AuAu central events at $\sqrt{S_{NN}}$=3.8 GeV



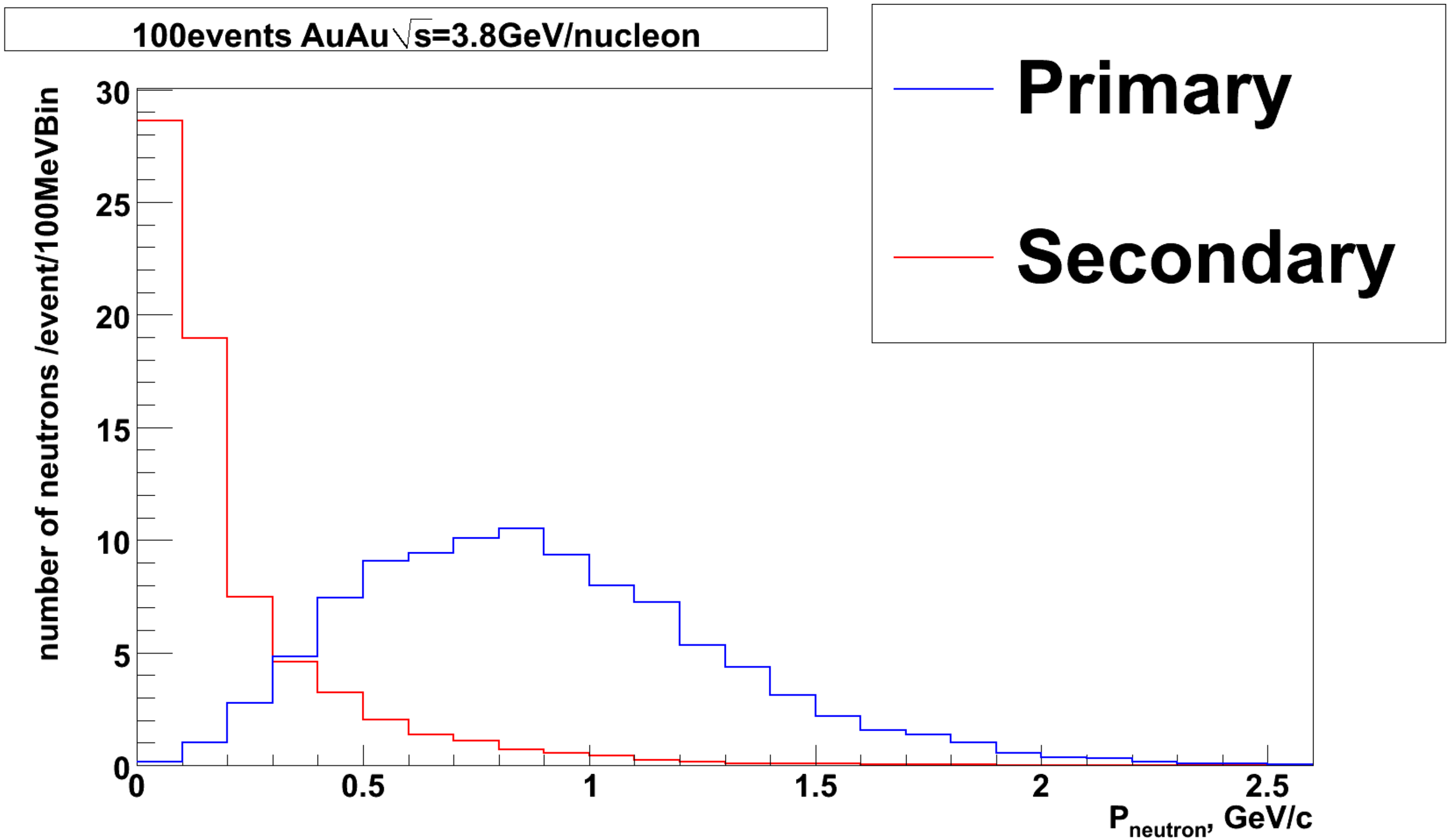
$|\eta|<1$, $\Sigma \rightarrow n\pi$ <En> ~ 250 MeV (730MeV/c β~0.6) <Pπ> ~ 230 MeV/c <P_Σ> ~ 800 MeV/c

Conclusions

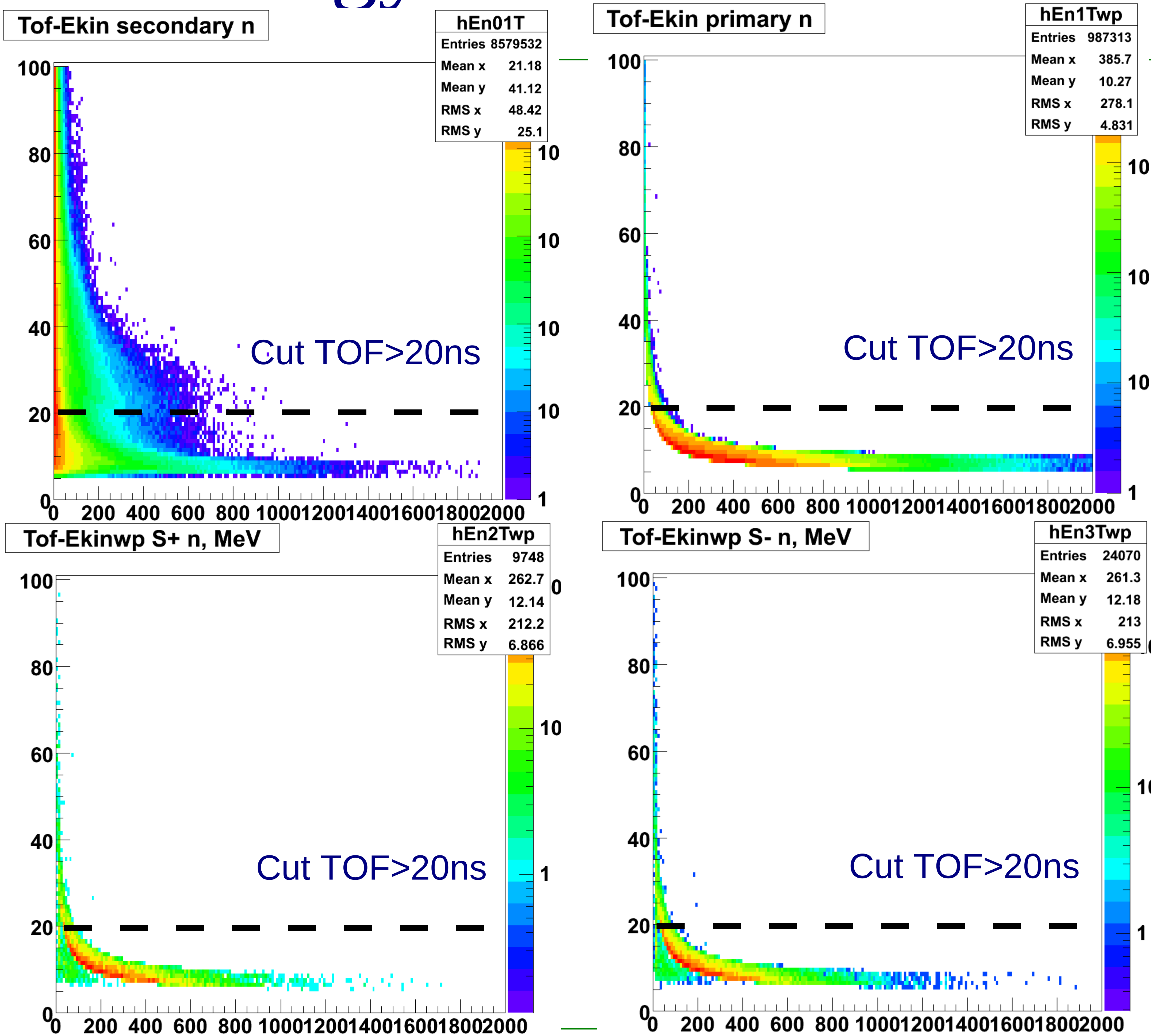
1. First beam tests of Ndet was done in ITEP
2. Space resolution is about 2.5 cm
3. Time resolution is better than 300ps
3. Ndet is in MPD ROOT (option of MPD)
4. Preliminary estimation of Ndet efficiency with GEANT3 is about 15%
5. Feasibility of Σ+ and Σ- detection in MPD with neutron detector is shown

Extra

Primary and secondary momentum



Energy-TOF neutrons



$|\eta|<1$, $\Sigma \to n\pi$

<En> ~ 250 MeV (730MeV/c β~0.6)

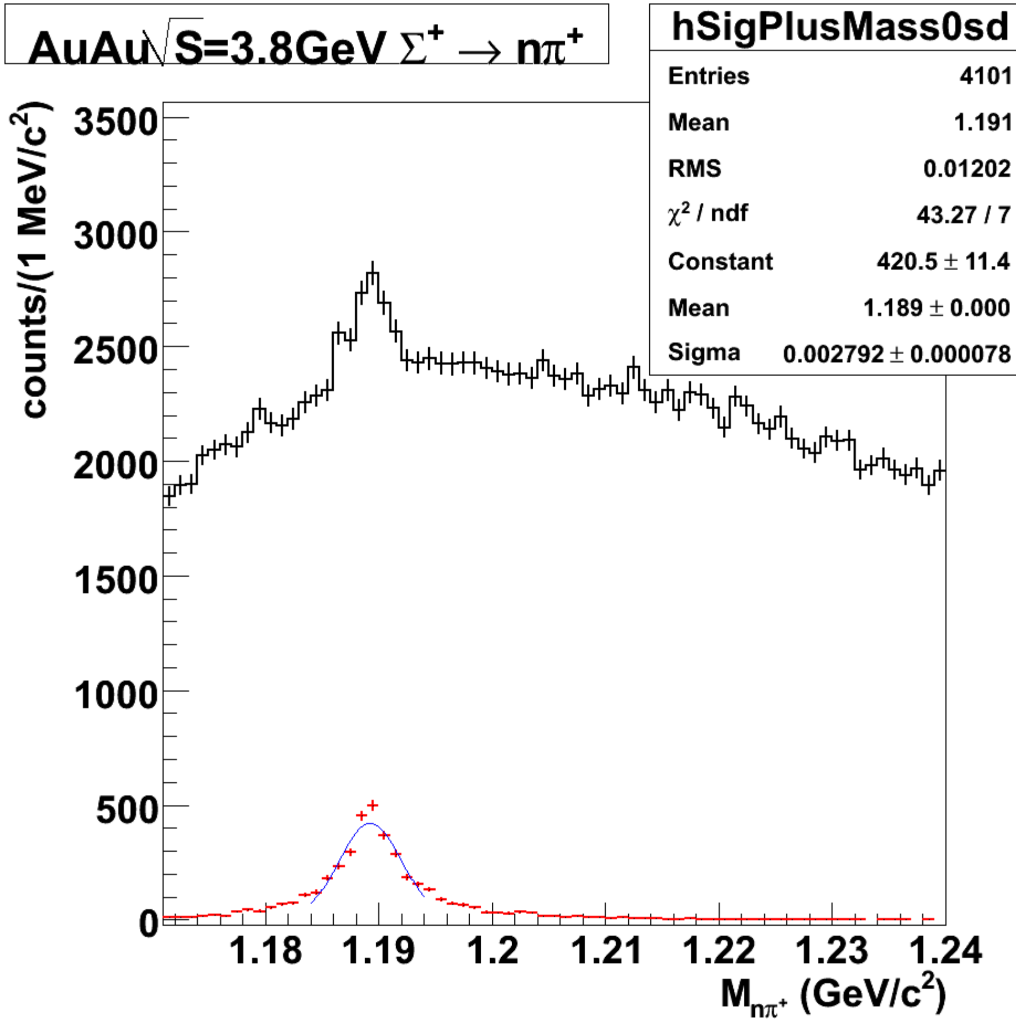
<Pπ> ~ 230 MeV/c

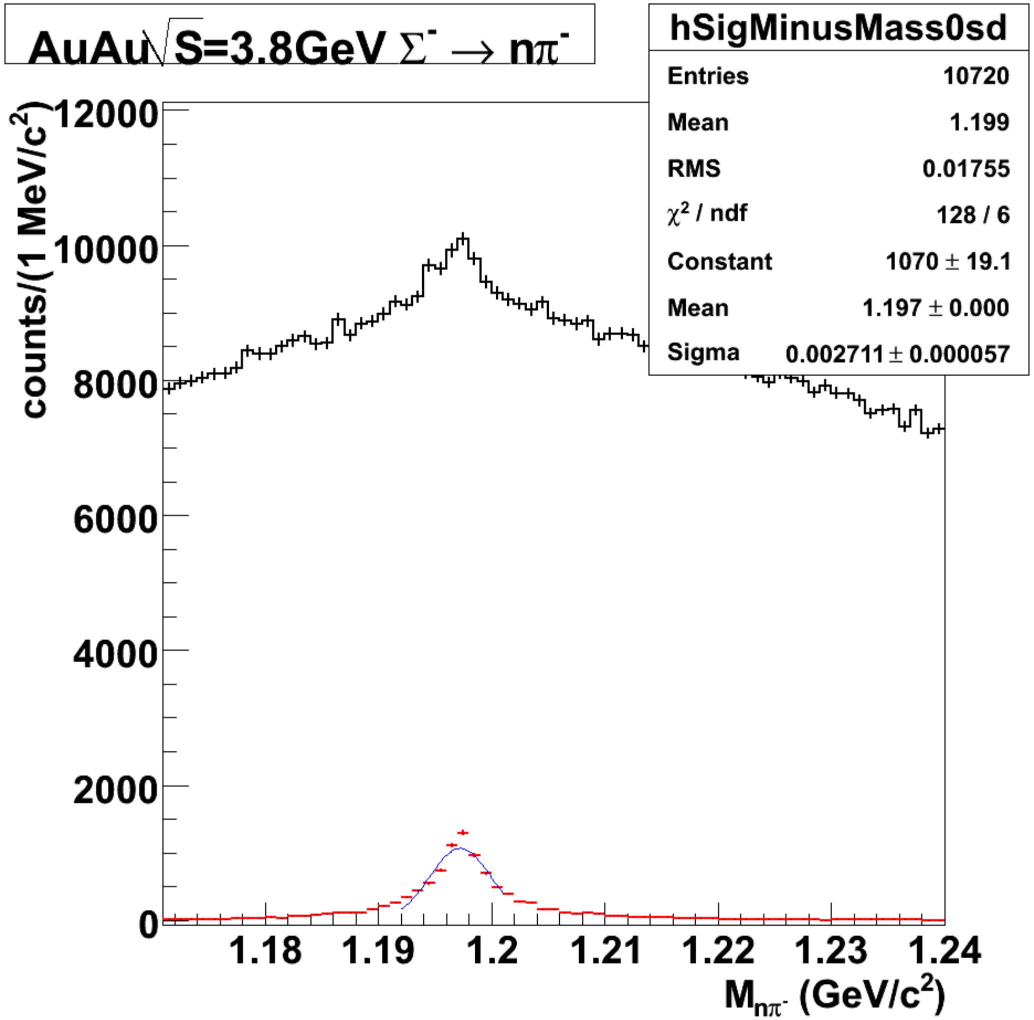
<P_{Σ}> ~ 800 MeV/c

Σ detection (800 psec)

10^4 AuAu central events at sqrt(S_{NN})=3.8 GeV

Time of flight resolution 800 psec



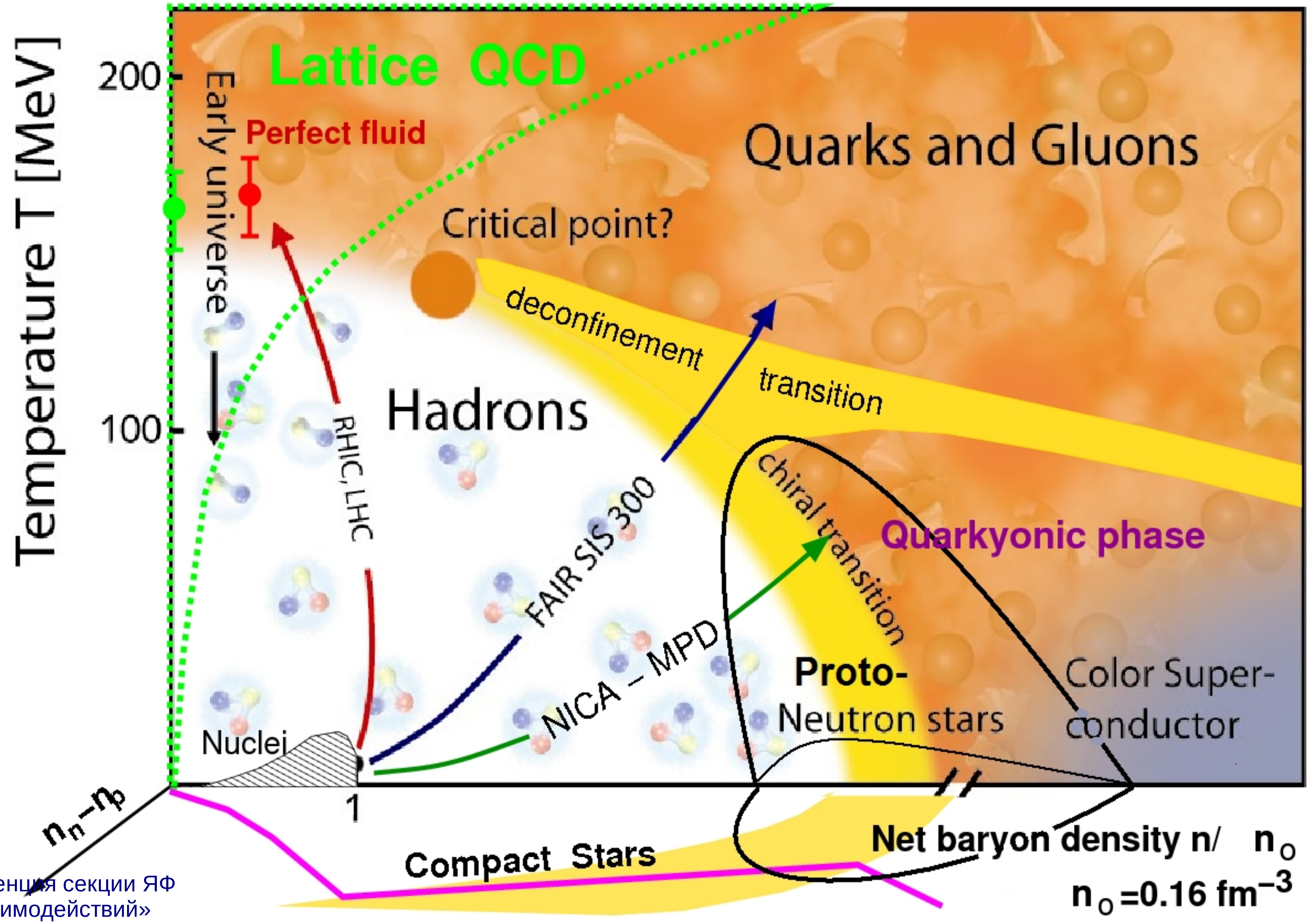


$|\eta|<1$, $\Sigma \rightarrow n\pi$ <En> ~ 250 MeV (730MeV/c β~0.6) <Pπ> ~ 230 MeV/c <P_Σ> ~ 800 MeV/c

Средняя множественность для центральных Au+Au событий (прицельный параметр b < 3 фм) вычисленная по URQMD

Part.	4 GeV		7 GeV		11 GeV	
	4π	$\lvert\eta\rvert < 1$, $p > 100$ MeV/c	4π	$\lvert\eta\rvert < 1$, $p > 100$ MeV/c	4π	$\lvert\eta\rvert < 1$, $p > 100$ MeV/c
charged	430	250	870	430	1300	550
p	170	91	160	63	160	49
n	200	110	180	68	170	53
π^+	110	65	310	160	470	230
π^-	120	78	340	170	520	240
π^0	120	72	340	180	510	240
K^+	12	7.6	38	19	57	24
K^-	1.3	0.82	12	6.2	26	12
K^0	12	7.7	38	19	57	26
Λ	10	6.2	26	12	31	12
Σ^+	3.4	2.1	8.0	3.7	9.2	3.6
Σ^-	4.0	2.4	8.8	4.0	10	3.8
Σ^0	3.2	1.9	7.9	3.6	9.4	3.8
Ξ^-	0.16	0.11	0.87	0.42	1.7	0.66
Ξ^0	0.13	0.077	0.86	0.42	1.3	0.62
Ω^-	0.003	0.002	0.022	0.011	0.038	0.015

3d phase diagram



ИТЭФ, г. Москва, научная сессия-конференция секции ЯФ
ОФН РАН «Физика фундаментальных взаимодействий»
А.Н.Сисакян (ОИЯИ) NICA - российский проект тяжелоионного коллайдера

Эксперимент E286

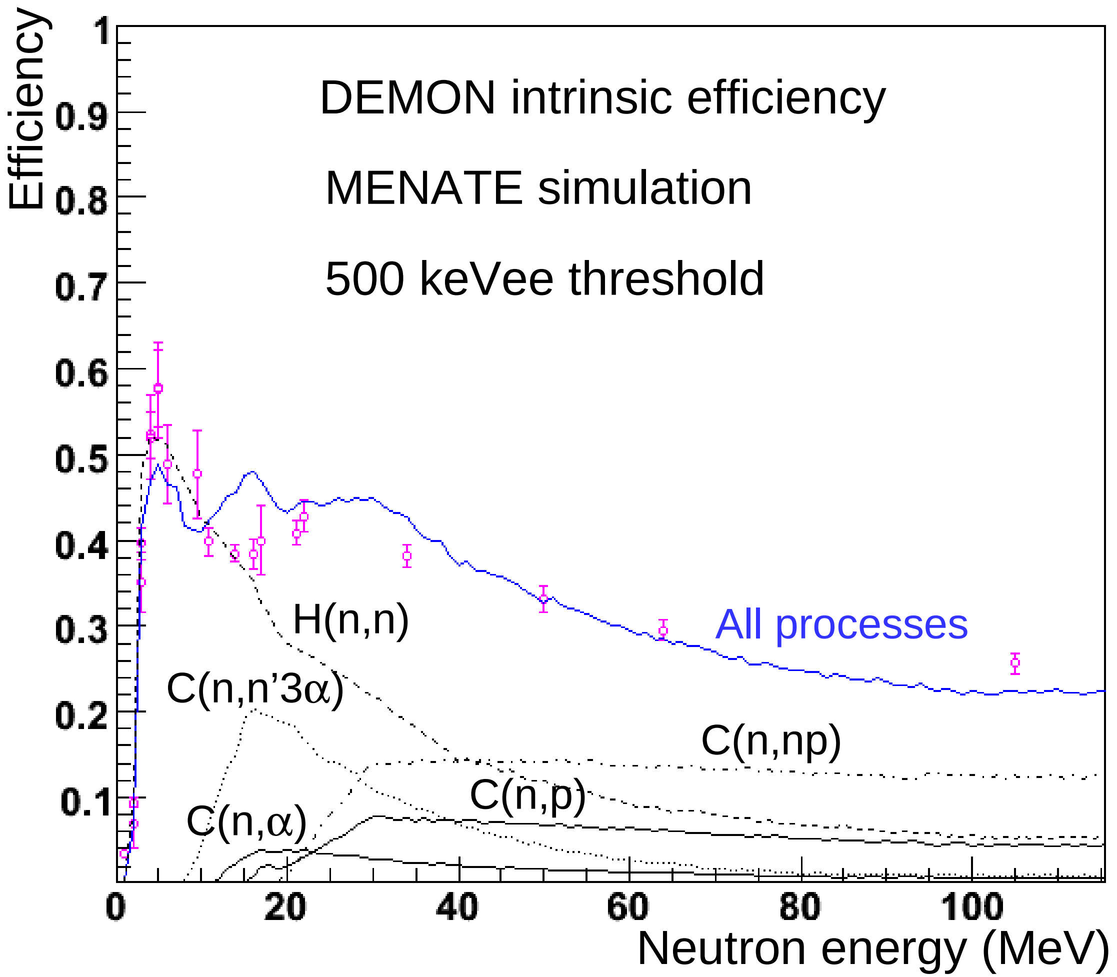
^{40}Ar (77 МэВ/нуклон) + $^{58}Ni \rightarrow n, p, d, T, {}^{3}He, {}^{4}He + X$

"Data on light-fragment correlations in $^{40}Ar+^{58}Ni$ at 77MeV/nucleon"
Eur. Phys. J. A18 (2003) p.645-651. Коллаборация E286.

K.Mikhailov[1], A. Stavinskiy[1], J.C.Angelique[2], B.Benoit[3], E. de Goes Brennand[3], G.Bizard[2], J.Colin[2], G.Costa[4], P.Desesquelles[5], O.Dorvaux[4], D.Durand[2], B.Erazmus[6], Yu.Grishuk[1], F.Hanappe[3], A.Kieliszek[7], S.Kuleshov[1], C.Lebrun[6], R.Lednicky[8], G.Leksin[1], P.Leszczynski[7], M.Marques[2], Th.Materna[3], K.Miller[7], G.Papatheofanous[3], T.Pawlak[7], J.Pluta[7], M.Przewlocki[7], A.Staranowicz[7], L.Stuttge[4], B.Tamain[2], A.Vlasov[1], L.Vorobyev[1], K.Wosinska[7]

[1]Institute of Theoretical and Experimental Physics
[2]Laboratoire de Physique Corpusculaire,IN2P3,CNRS/ISMRA
[3]Universite Libre de Bruxelles,Belgium
[4]IRES,IN2P3-CNRS/Universite Louis Pasteur,France
[5]ISN,IN2P3/CNRS, et Univ.J.Fourier,France
[6]SUBATECH,UMR Univ.,EMN,IN2P3/CNRS, France
[7]Faculty of Physics,Warsaw University of Technology, Poland
[8]Institute of Physics ASCR, Czech Republic

DEMON efficiency with Menate



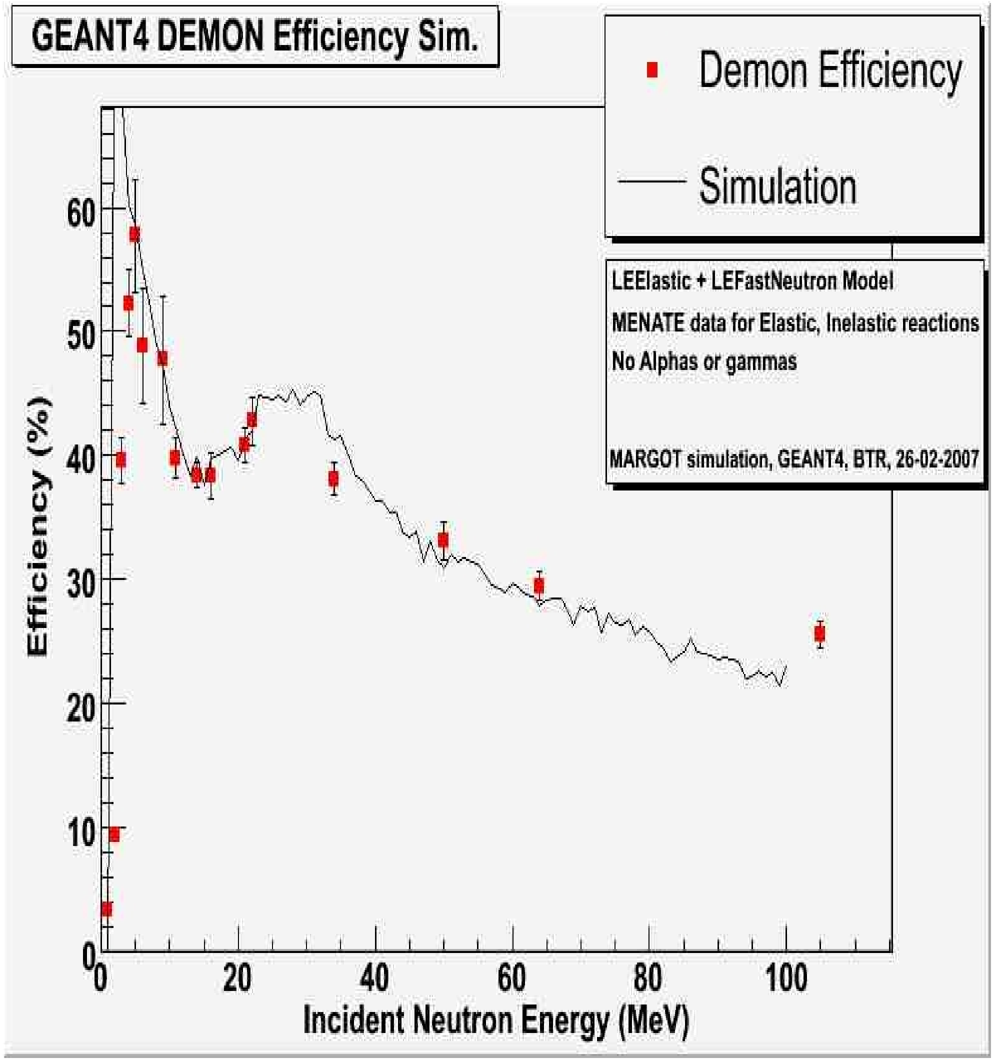
Reactions :
- H(n,n)
- 12C(n,n)
- 12C(n,n'γ)
- 12C(n,2n)
- 12C(n,α)
- 12C(n,n'3α)
- 12C(n,p)
- 12C(n,np)

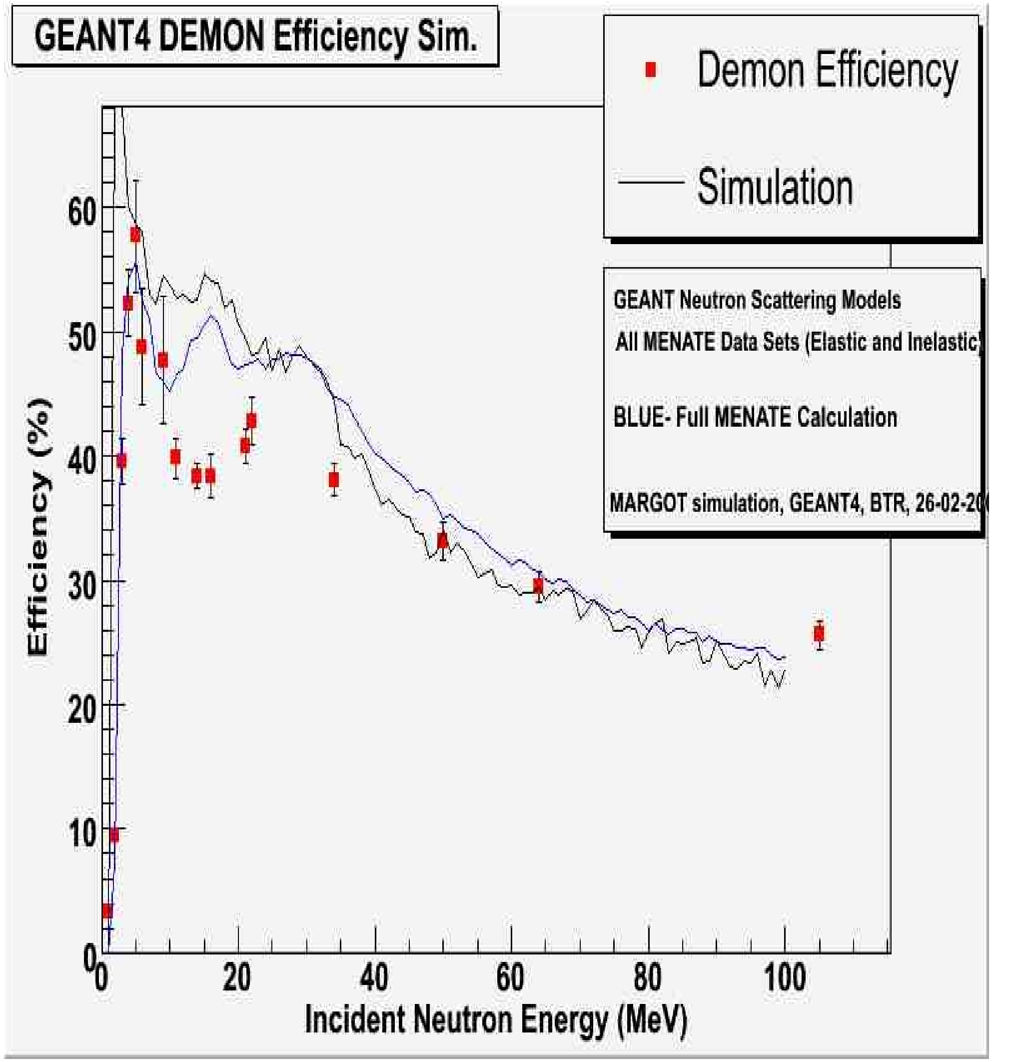
Simple
Reasonably accurate
Only cylindrical detectors with NE213 scintillator

P. Désesquelles et al, NIM A 307, 366 (1991)

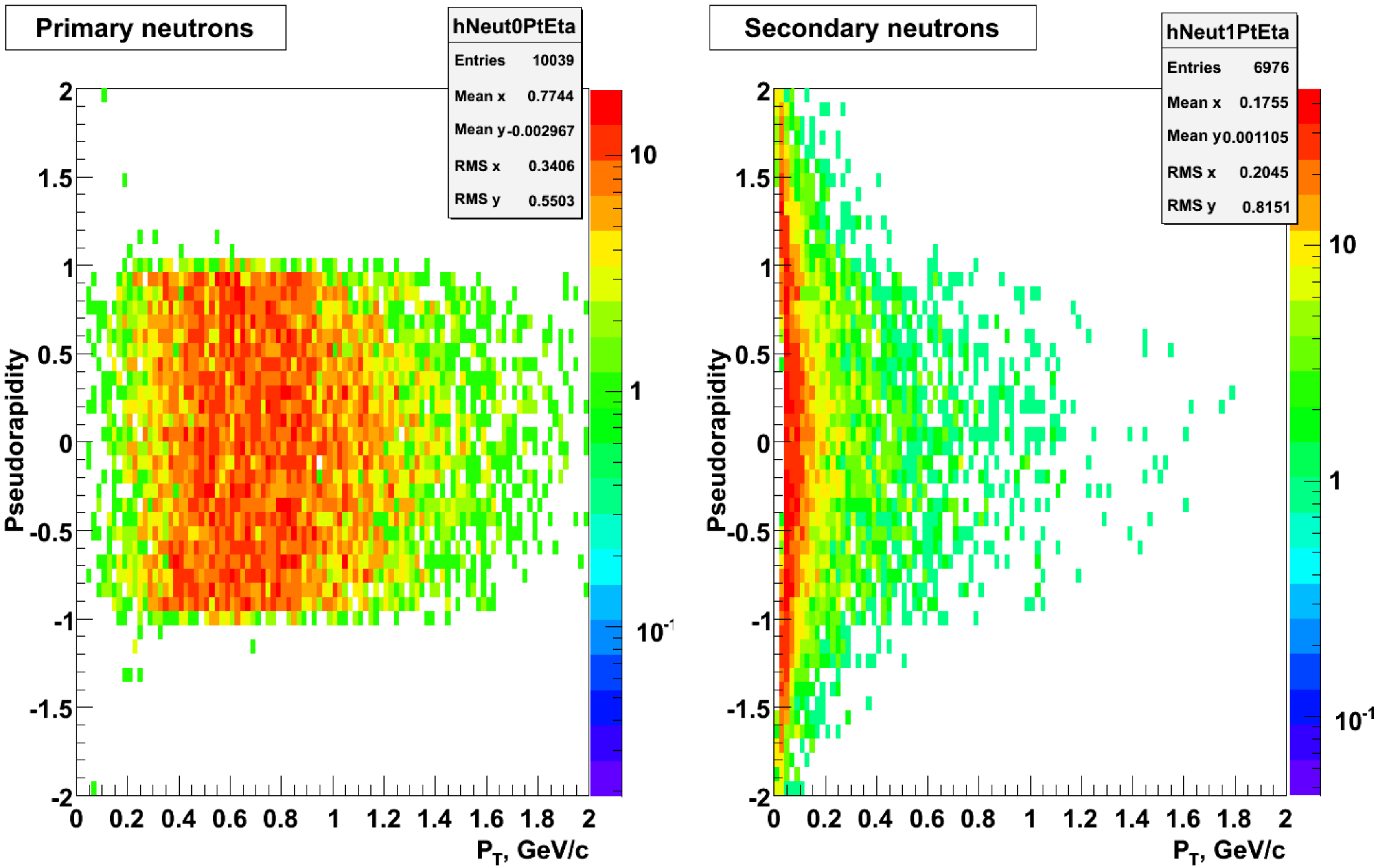
From presentation : « Neutron detector developments at LPC Caen »

Results of LEFastNeutron model

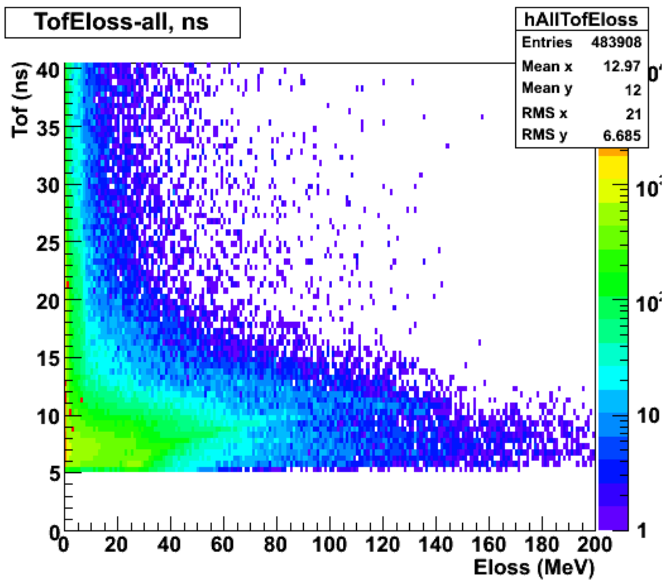


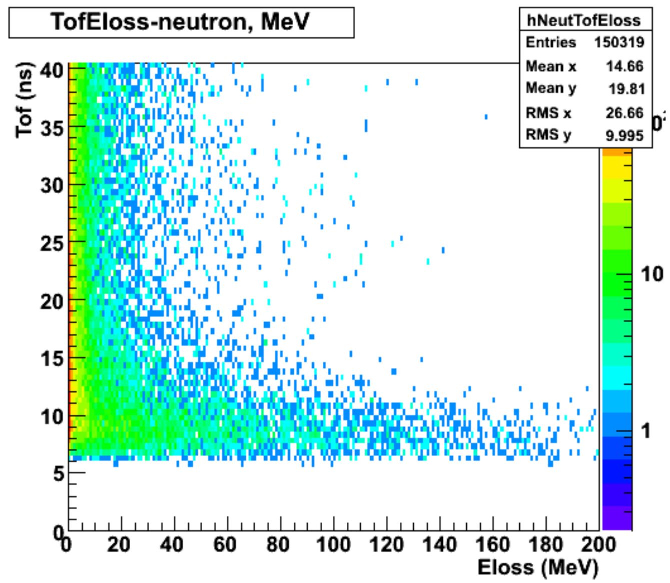


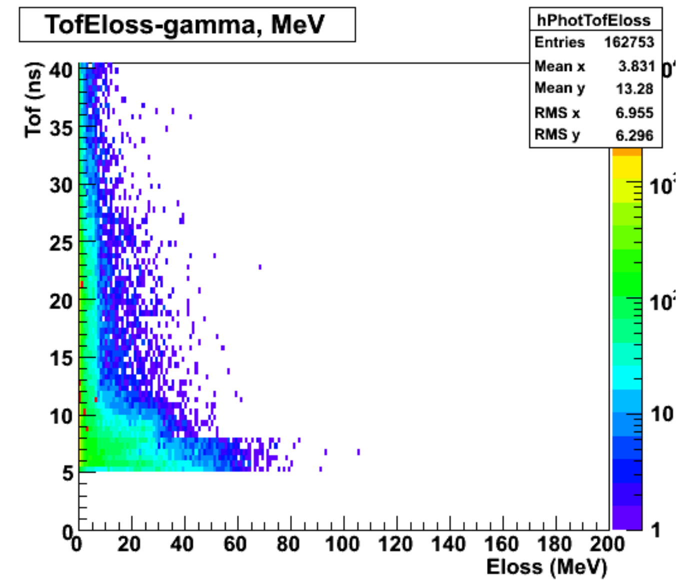
Neutron detector: eta-Pt

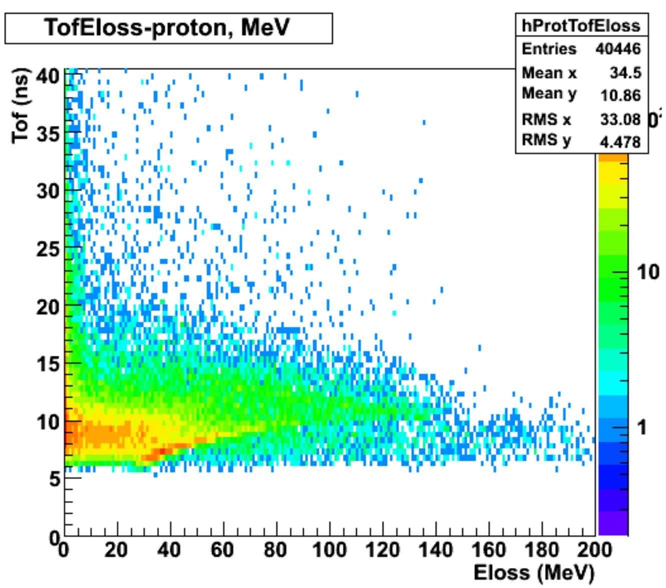


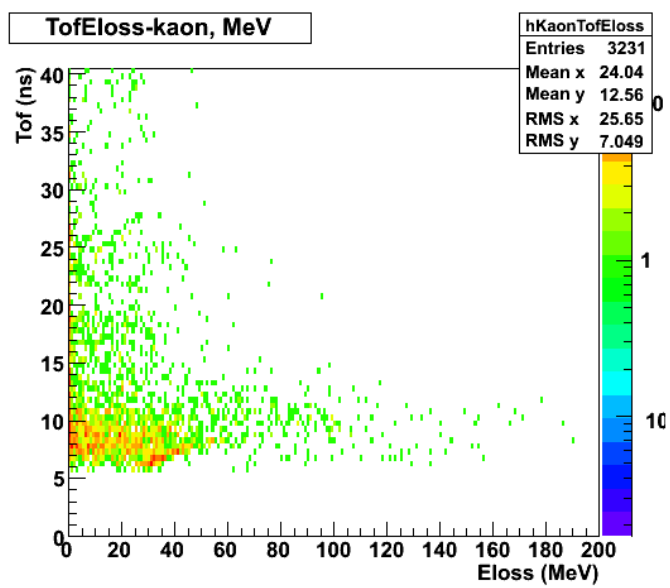
TOF-Eloss(prim&seco part.)

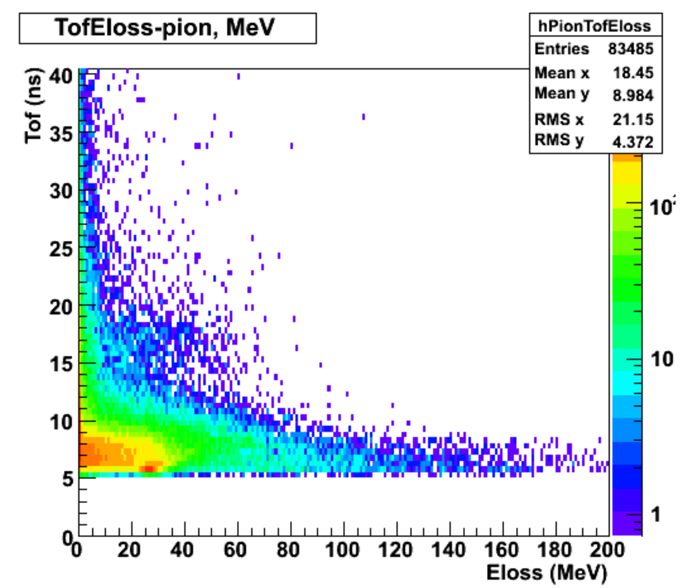




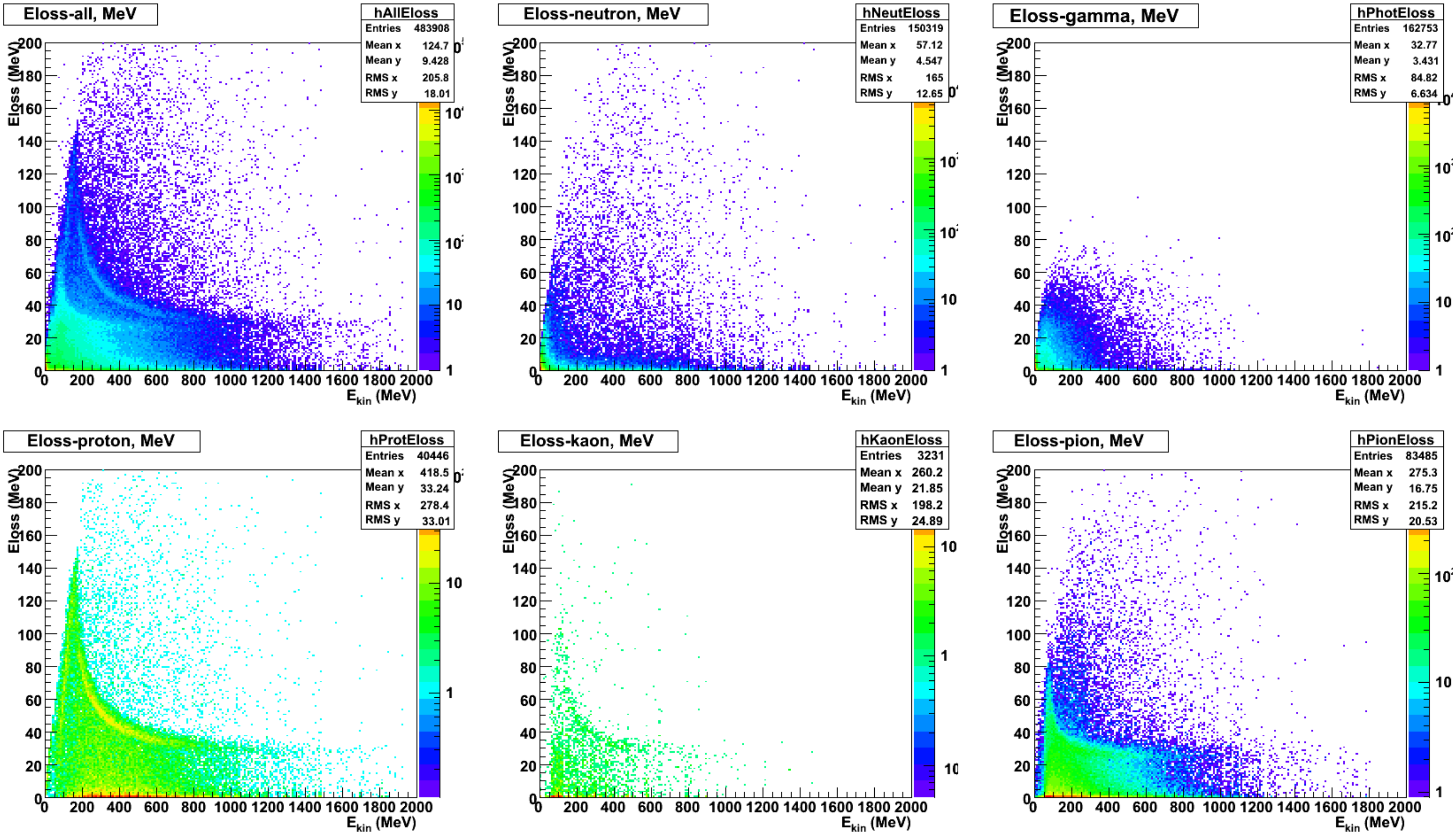








Energy Loss(prim&seco part.)



TOF(prim&seco part.)