ГРУППА МЕЗОЯДЕРНЫХ РЕАКЦИЙ

Итоги **2004** года

Precision Measurement of Muon Capture on the Proton

"μCap experiment"

$$\mu^- + p \rightarrow \nu_\mu + n$$

www.npl.uiuc.edu/exp/mucapture/

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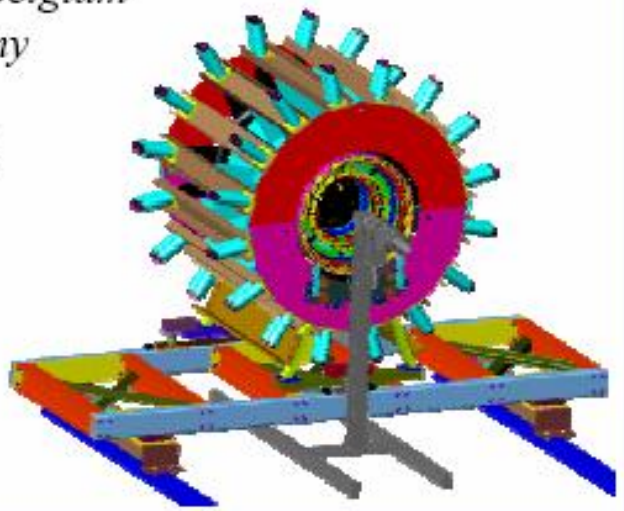
University of California, Berkeley, UCB and LBNL, USA
University of Illinois, Urbana-Champaign, USA
Universite Catholique de Louvain, Belgium
TU Munich,Garching, Germany
Boston University, USA
University of Kentucky, USA

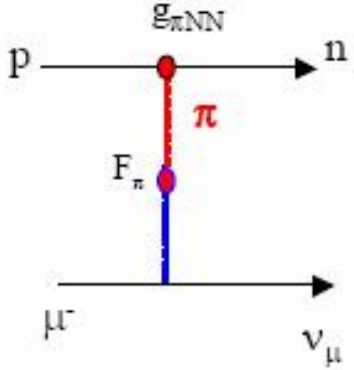


pseudoscalar form factor g_P

PCAC:

$$g_P(q^2) = \frac{2 m_\mu M}{m_\pi^2 - q^2} g_A(0)$$

g_P=8.7



heavy baryon chiral perturbation theory:

$$g_P(q^2) = \frac{2 m_\mu g_{\pi NN} F_\pi}{m_\pi^2 - q^2} - \frac{1}{3} g_A(0) m_\mu M \, r_A^2$$

$g_P = (8.74 \pm 0.23) - (0.48 \pm 0.02) = 8.26 \pm 0.23$

Λ calculations $O(p^3)$ show good convergence: 100 % 25 % 3 %
delta effect small LO NLO NNLO

$g_{\pi NN}$
13.31(34)
13.0(1)
13.05(8)

author	year	g_P	Λ_S	Λ_T	comment
Primakoff	1959		664(20)	11.9(7)	smaller g_A
Opat	1964		634	13.3	smaller g_A
Bernard et al	1994	8.44(23)			
Fearing et al	1997	8.21(9)			
Govaerts et al	2000	8.475(76)	688.4(38)	12.01(12)	
Bernard et al	2000/1		687.4 (711*)	12.9	NNLO, small scale
Ando et al	2001		695 (722*)	11.9	NNLO

*NLO result

Experimental information on g_P

Ordinary Muon Capture $\mu^- + p \rightarrow \nu_\mu + n$

BR~10^{-3}, 8 experiments 1962-82, BC, neutron, electron detection
"in principle" most direct g_p measurement

Radiative Muon Capture $\mu^- + p \rightarrow \nu_\mu + n + \gamma$

BR~10^{-8}, TRIUMF (1998), E_γ>60 MeV, 297 ± 26 events
closer to pion pole → *3x sensitivity of OMC*
theory more involved (min substitution, ChPT)

- Muon capture in nuclei

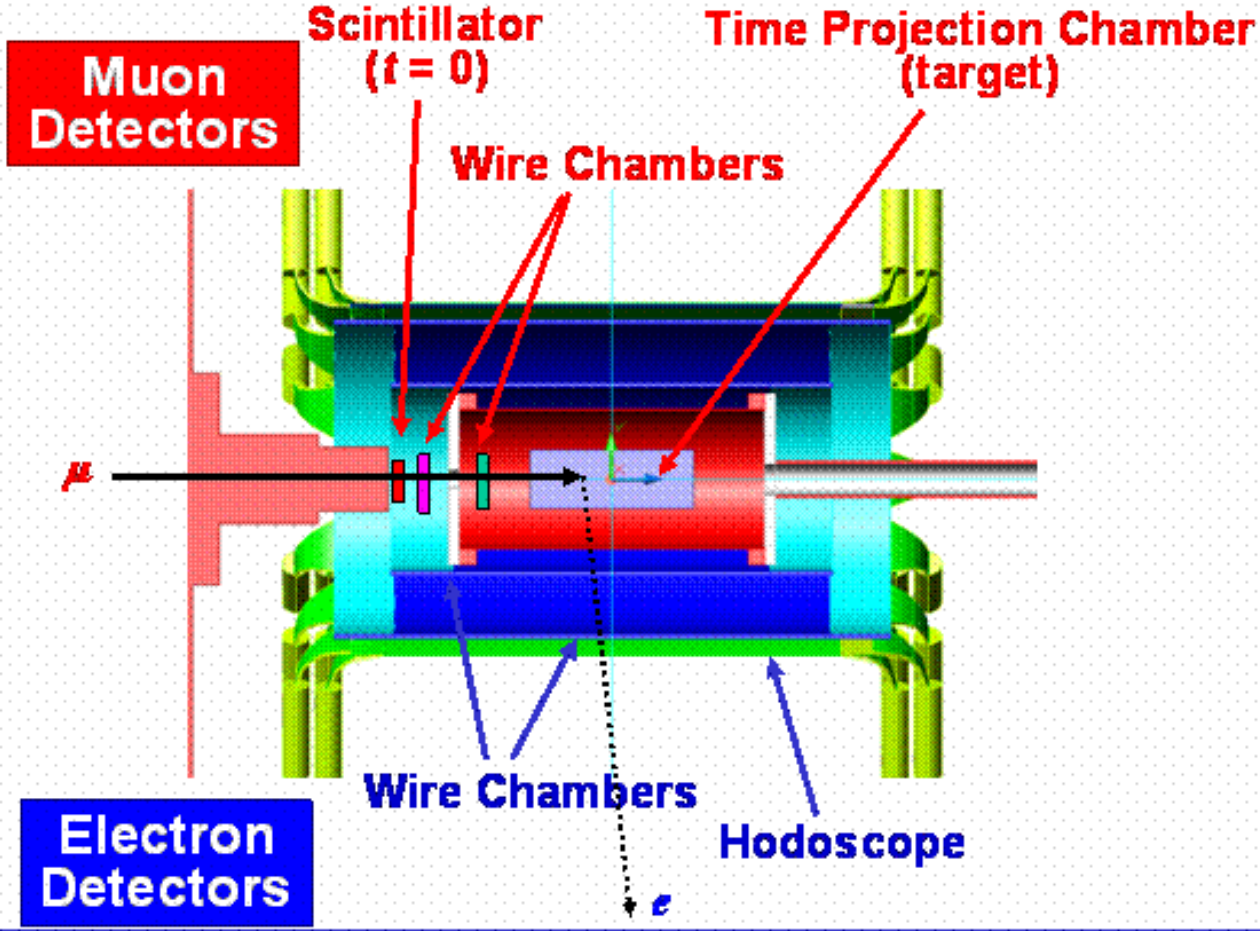
  $\mu + {}^3He \rightarrow \nu + {}^3H$ Λ_{st}=1496 ±4 s^{-1} PSI (1998)
  $g_p = g_p^{th}$ (1.08 ±0.19) error dominated by 3-N theory
  correlation measurements

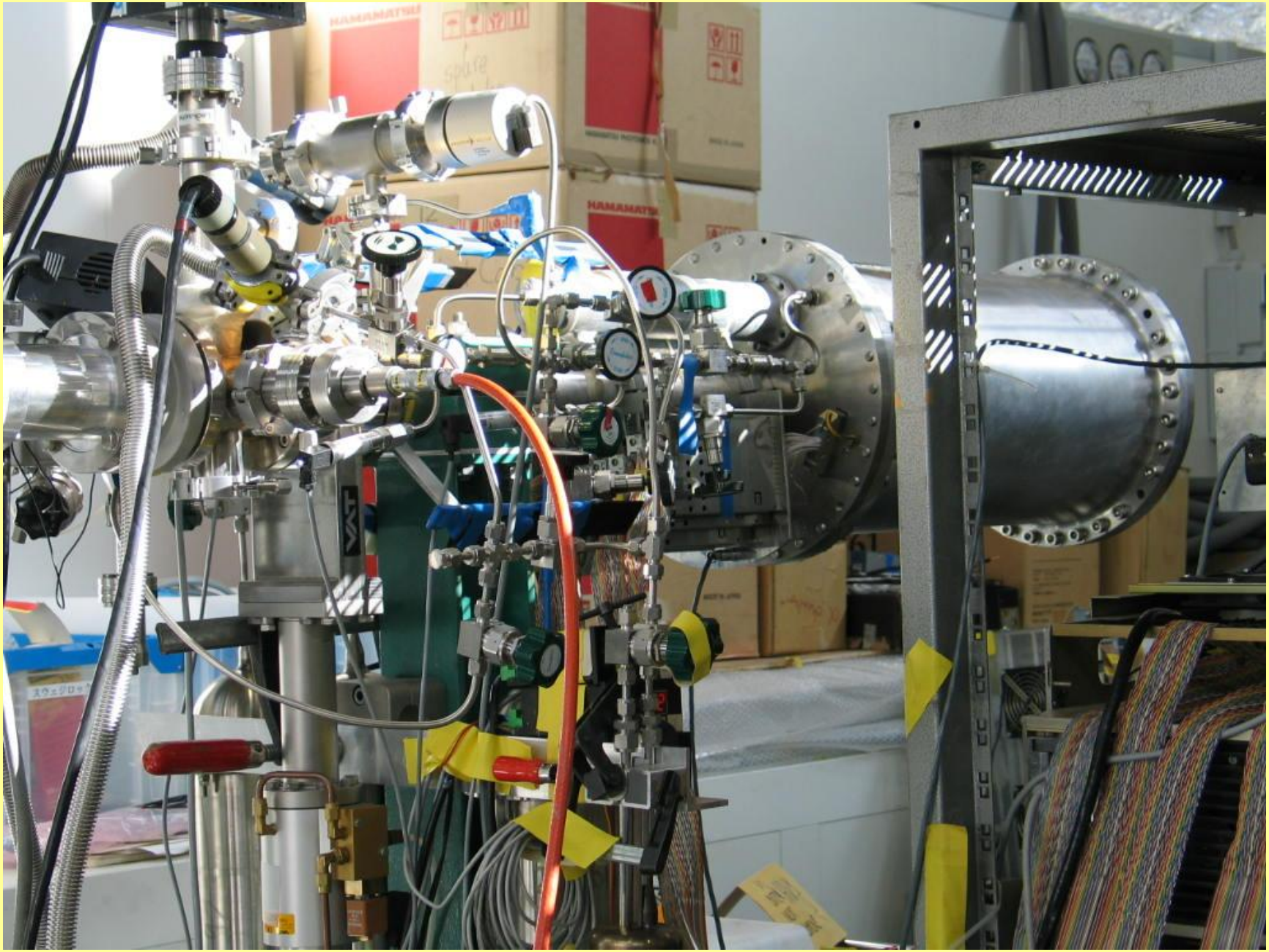
- Neutrino scattering

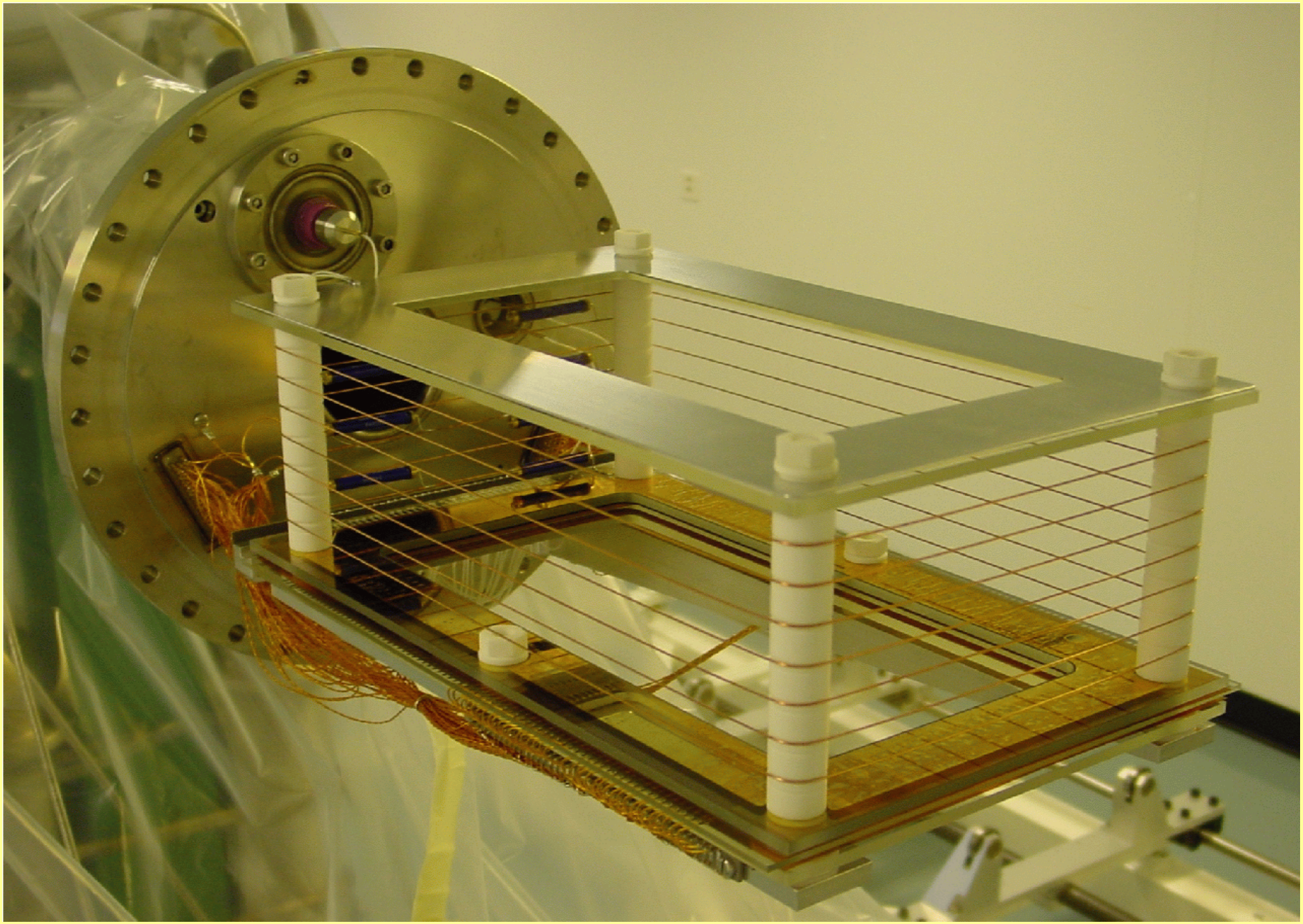
- π electro production at threshold

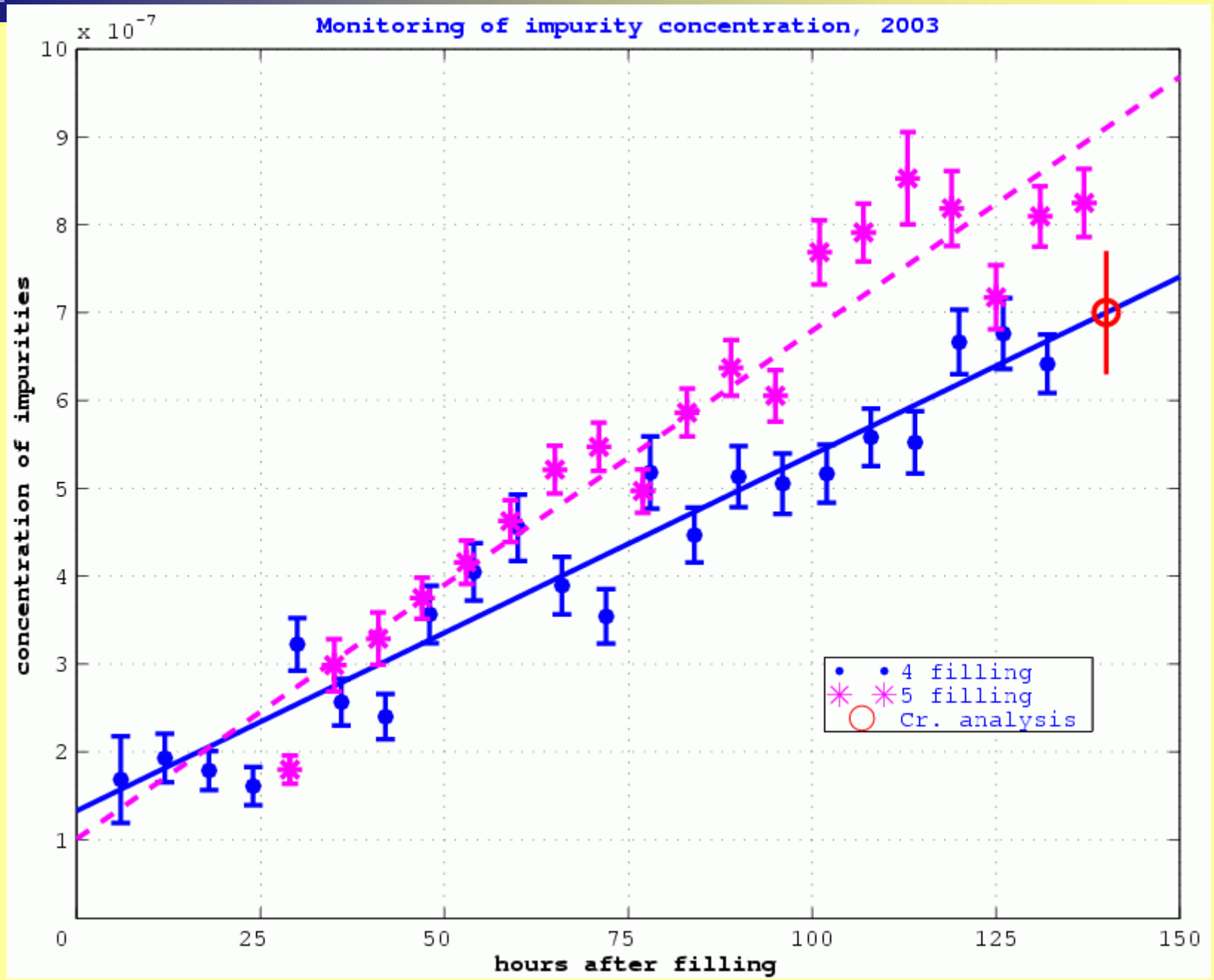
μCap Experimental Setup

Key ideas: active target of ultra-pure H_2 gas 10 bar for muons, separate large tracking detector for electrons.




HAMAMATSU




Monitoring of impurity concentration, 2003
x 10^-7
concentration of impurities
hours after filling
4 filling
5 filling
Cr. analysis
0
25
50
75
100
125
150
1
2
3
4
5
6
7
8
9
10

Задачи 2004 года

1. Провести сборку «чистой» вакуумной системы откачки (январь - февраль)
2. Завершить изготовление корпуса и начать сборку TPC – детектора в «чистой» комнате (январь - май)
3. Осуществить запуск системы циркуляционной очистки водорода (январь - май)
4. Наработать необходимое количество протия для тестовых испытаний (~ 1м^3) (январь - февраль)
5. Запустить установку в полном объеме на пучке PSI. Добиться не менее 20 кГц остановок мюонов в объеме TPC – детектора (август - октябрь)


Группа Шапкина
Протий-газ
Хим. очистка и
анализ примесей
Отдел Крившича
MWPC's, TPC
mCap
ПИЯФ
ГМР
Лаборатория
Чернова
Система
рециркуляции
Лаборатория
Алексеева
(ОНИ)
Протиевая вода
ФТИ им. Иоффе
Анализ
примесей D2

experimental challenges

$$\mu^- p\,(\uparrow\downarrow) \rightarrow \nu_\mu + n$$

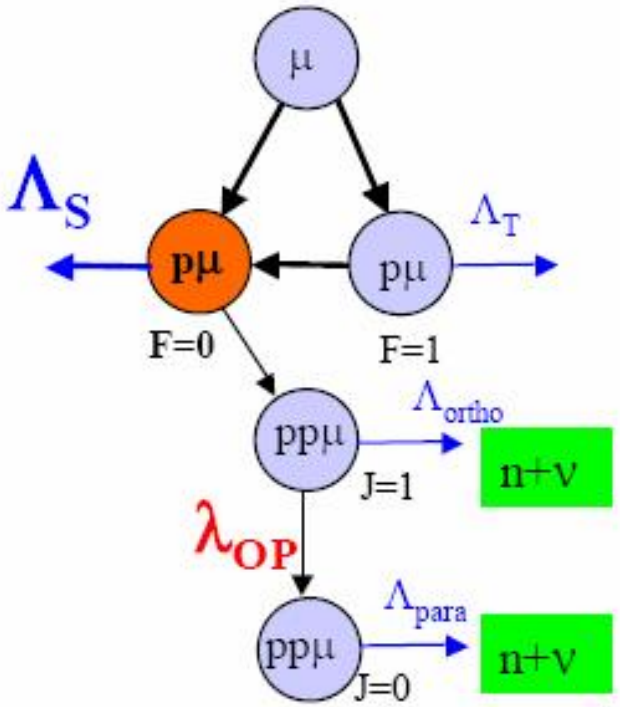
$$\mu^- \rightarrow e + \bar{\nu}_e + \nu_\mu$$

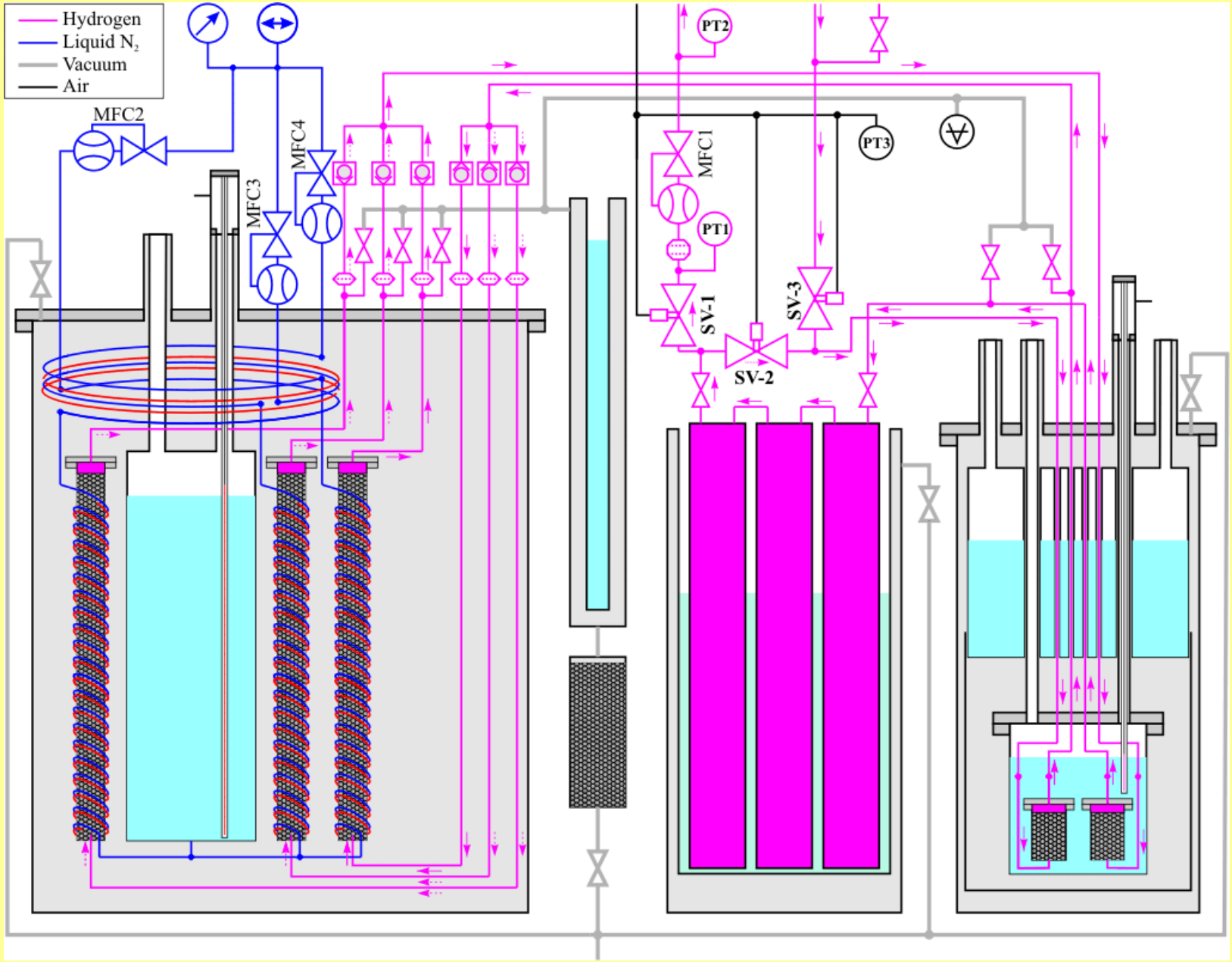
(Rich) physics effects

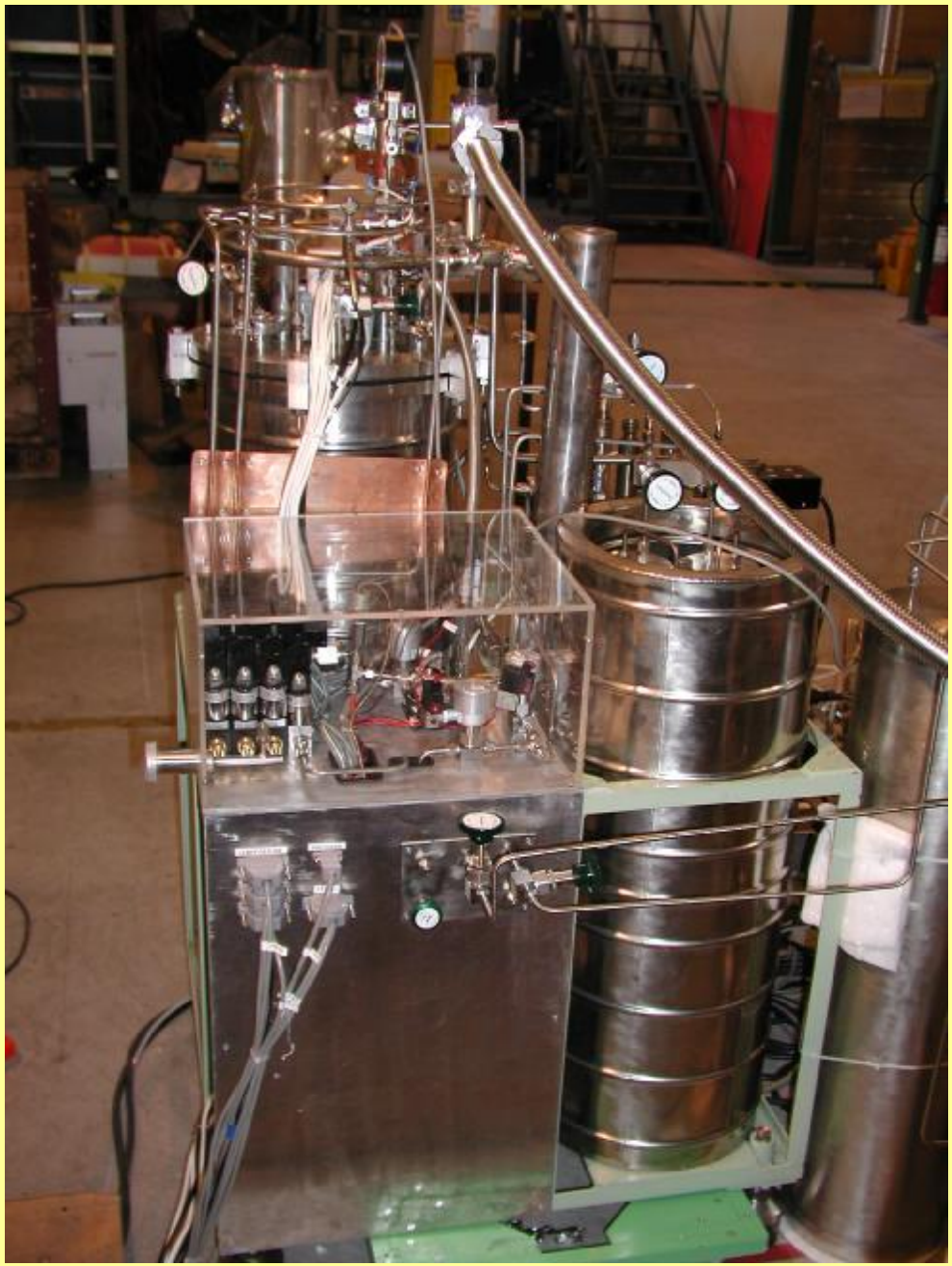
- **Interpretation:**
  where does capture occur ?

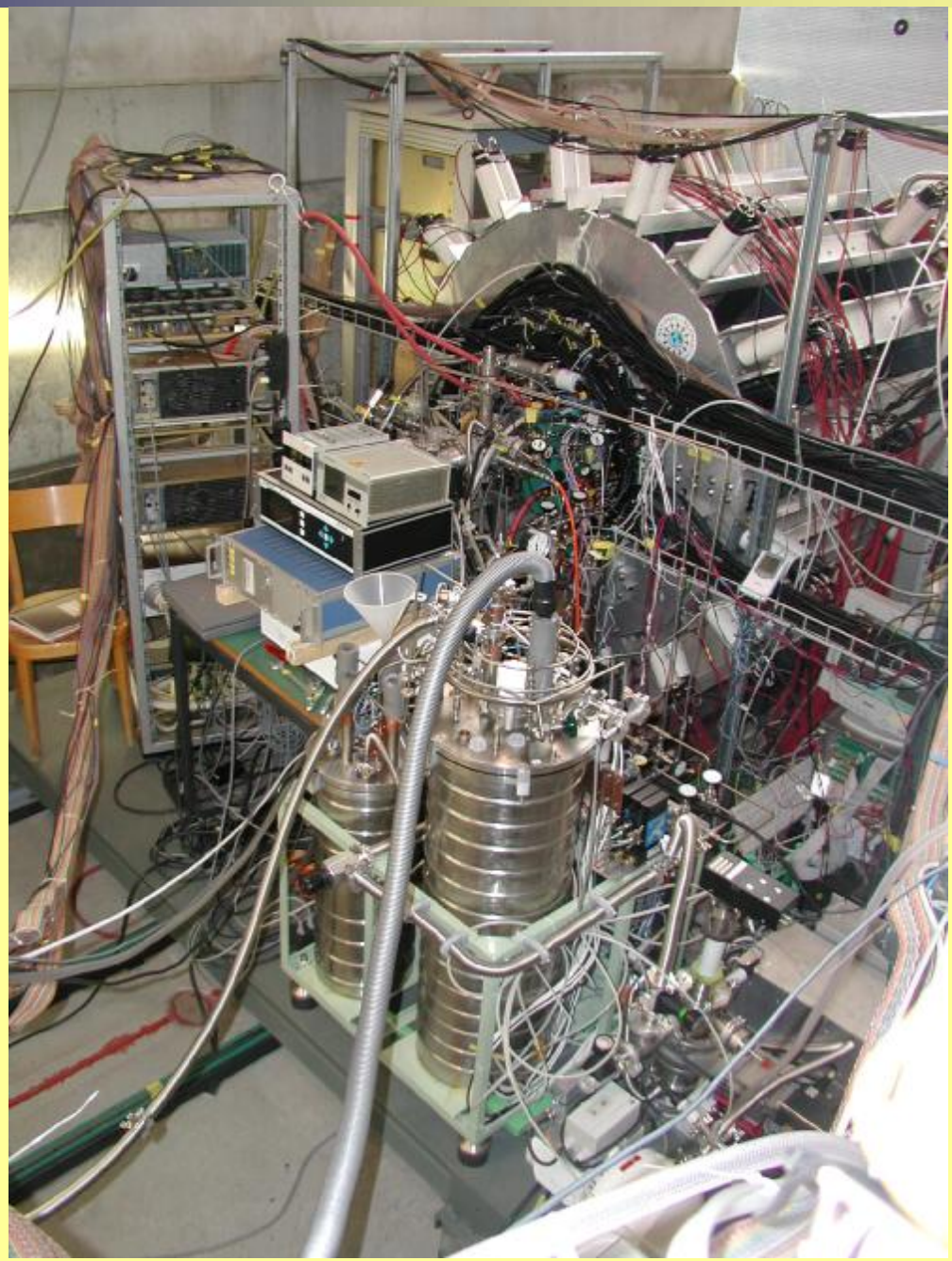
  Critical because of strong spin dependence of V-A interaction

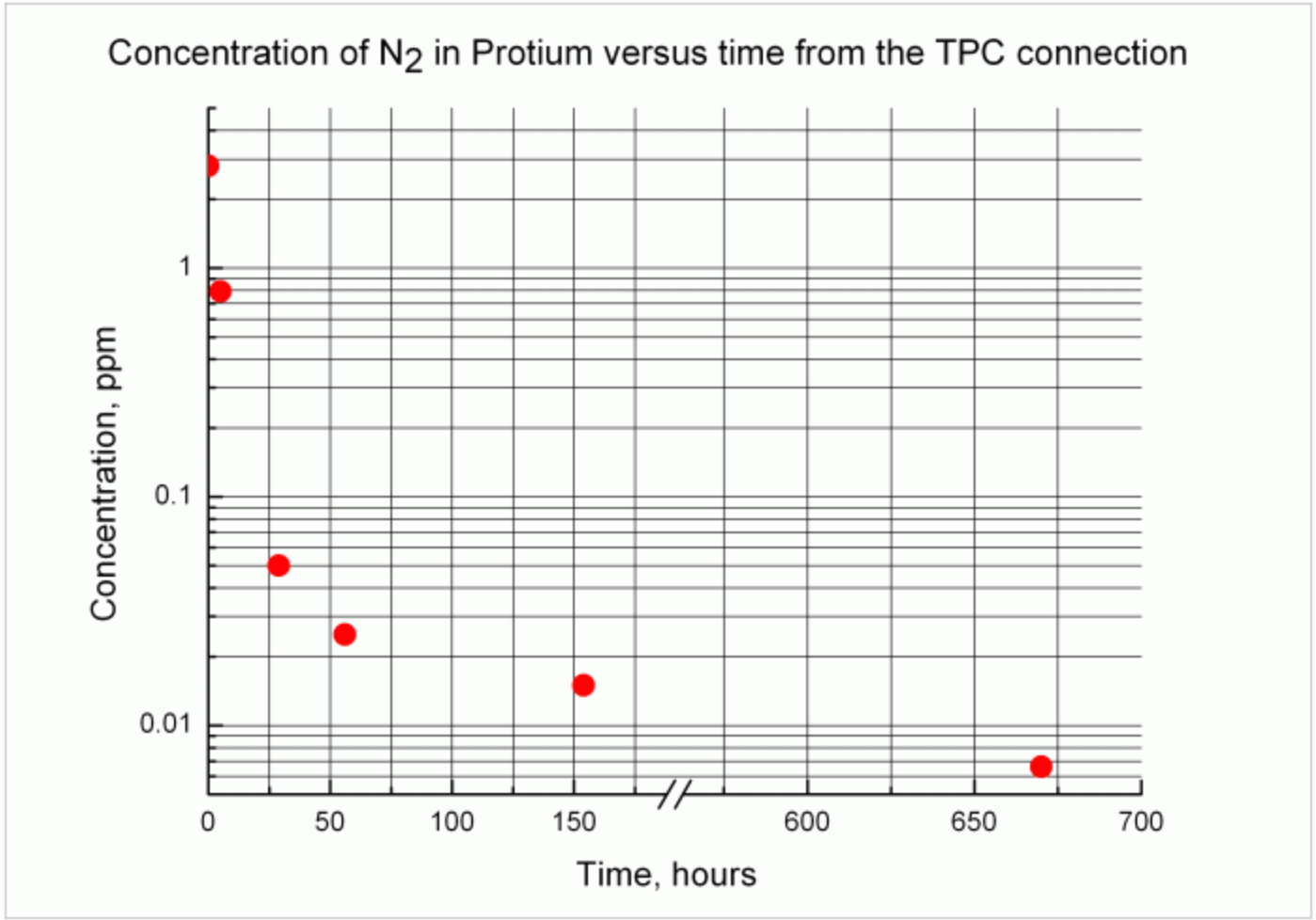
- **Background:**
  Wall stops and diffusion
  Transfer to impurities $\mu p + Z \rightarrow \mu Z + p$
- **Rate and statistics (BR = 10^{-3})**
- **μSR effect for μ^+**



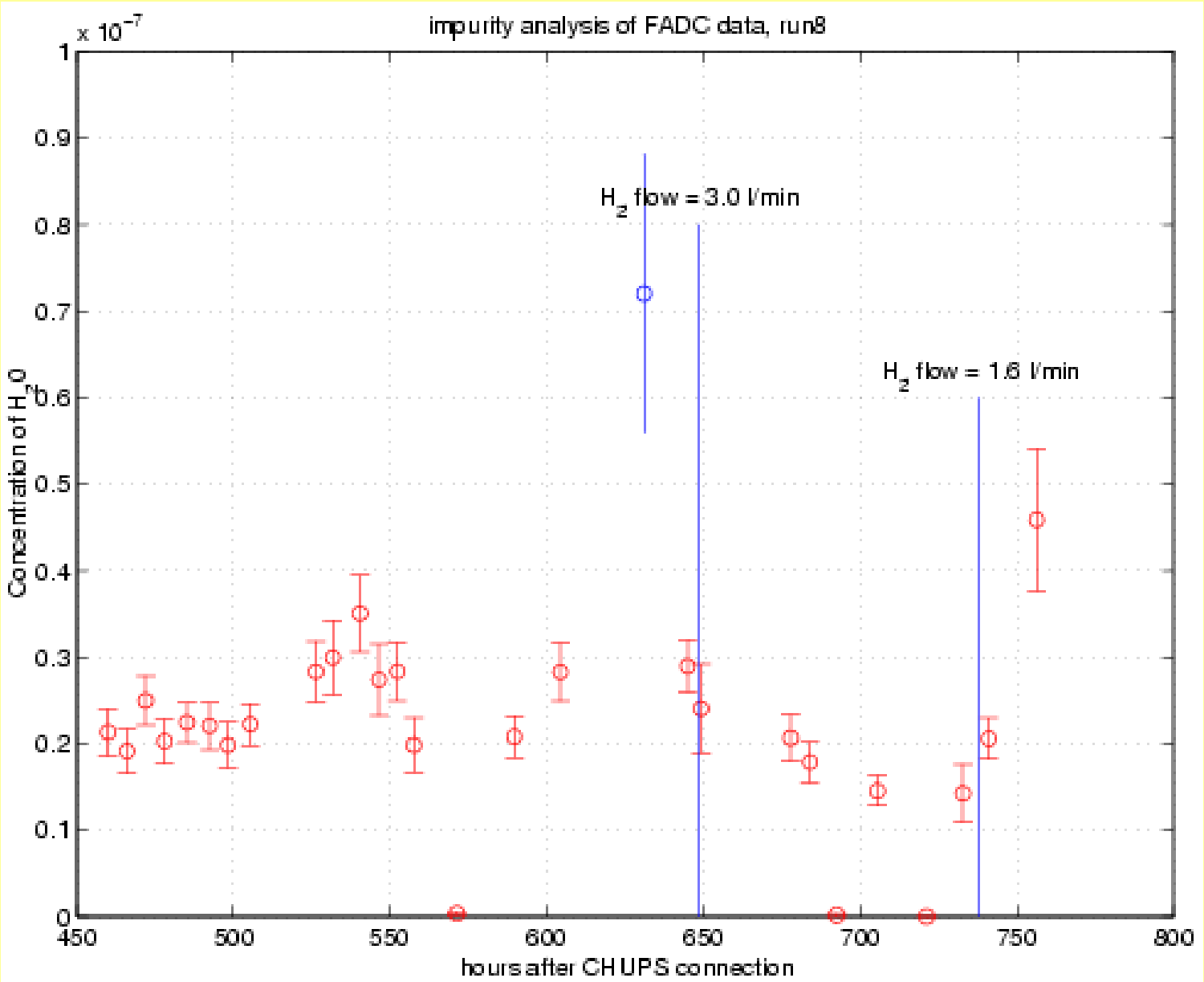

Hydrogen
Liquid N_2
Vacuum
Air
MFC2
MFC3
MFC4
MFC1
PT1
PT2
PT3
SV-1
SV-2
SV-3

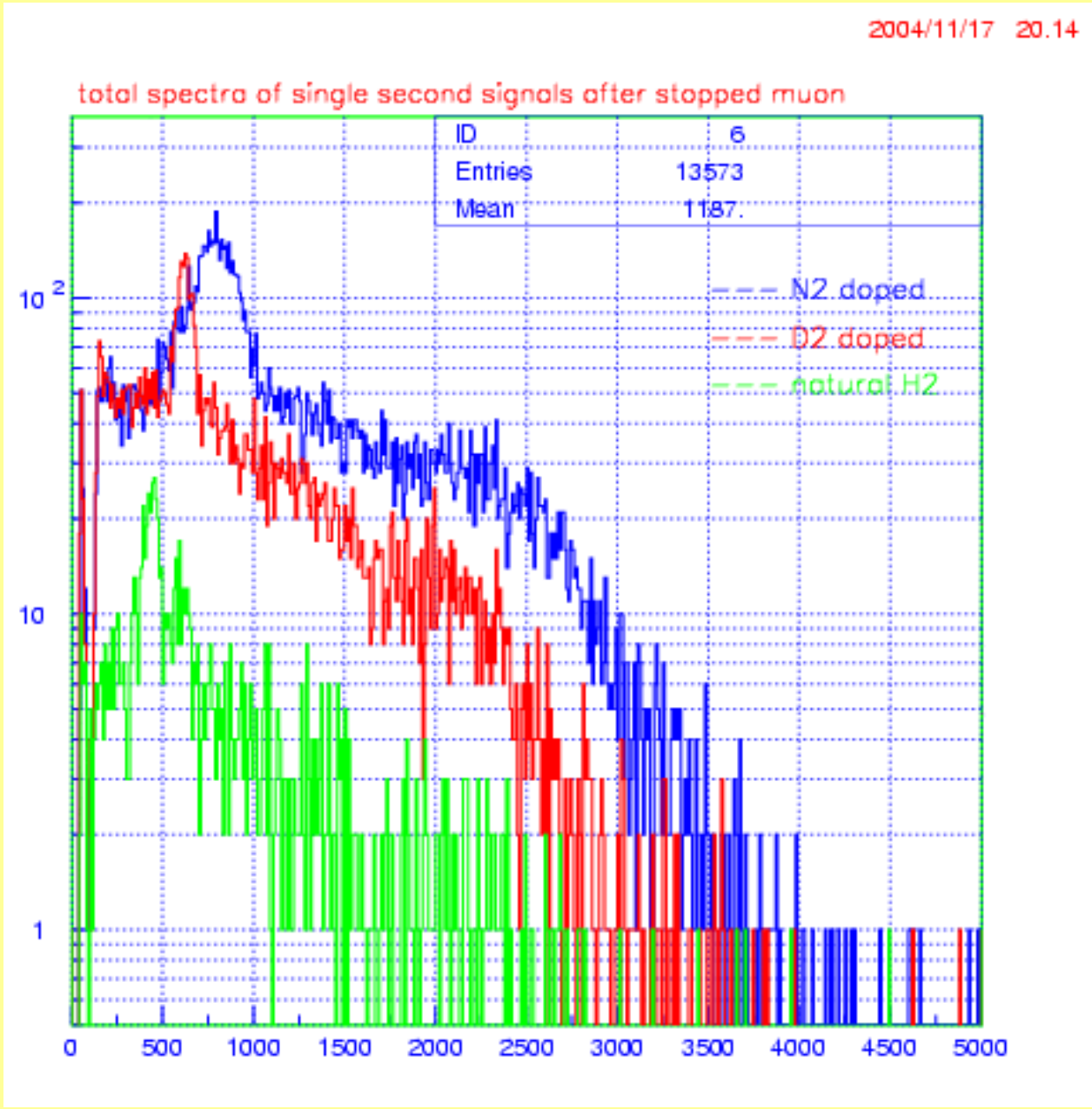






O_2 < 0.001 ppm, N_2 ~0.006 ppm, H_2O ~0.07 ppm

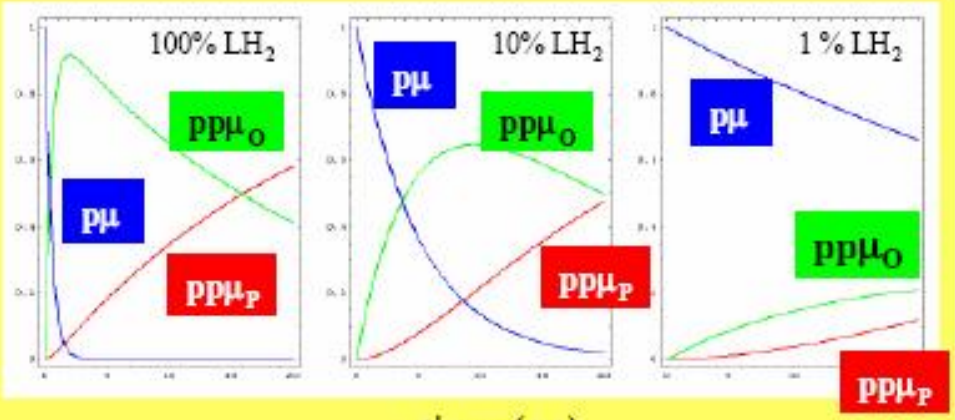

impurity analysis of FADC data, run8
x 10^-7
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Concentration of H2O
H2 flow = 3.0 l/min
H2 flow = 1.6 l/min
450
500
550
600
650
700
750
800
hours after CHUPS connection


2004/11/17 20.14
total spectra of single second signals after stopped muon
ID 6
Entries 13573
Mean 1187.
N2 doped
D2 doped
natural H2
10 2
10
1
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000

experimental strategy

Physics

- **Unambigous interpretation**
  At low density (1% LH_2) mostly capture from **μp(F=0)** atomic state.



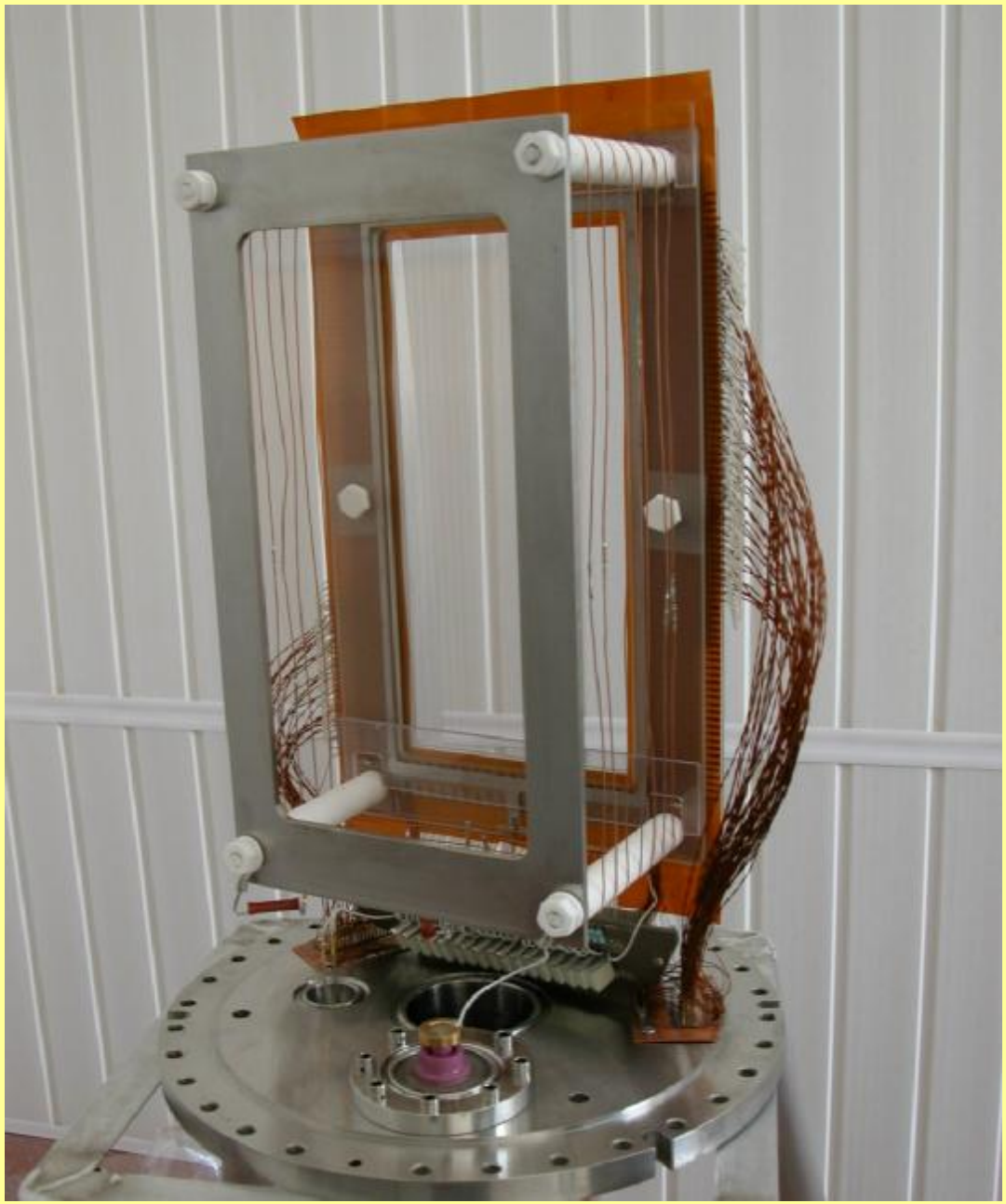
- **Clean muon stop definition:**
  Wall stops and diffusion eliminated by 3-D muon tracking

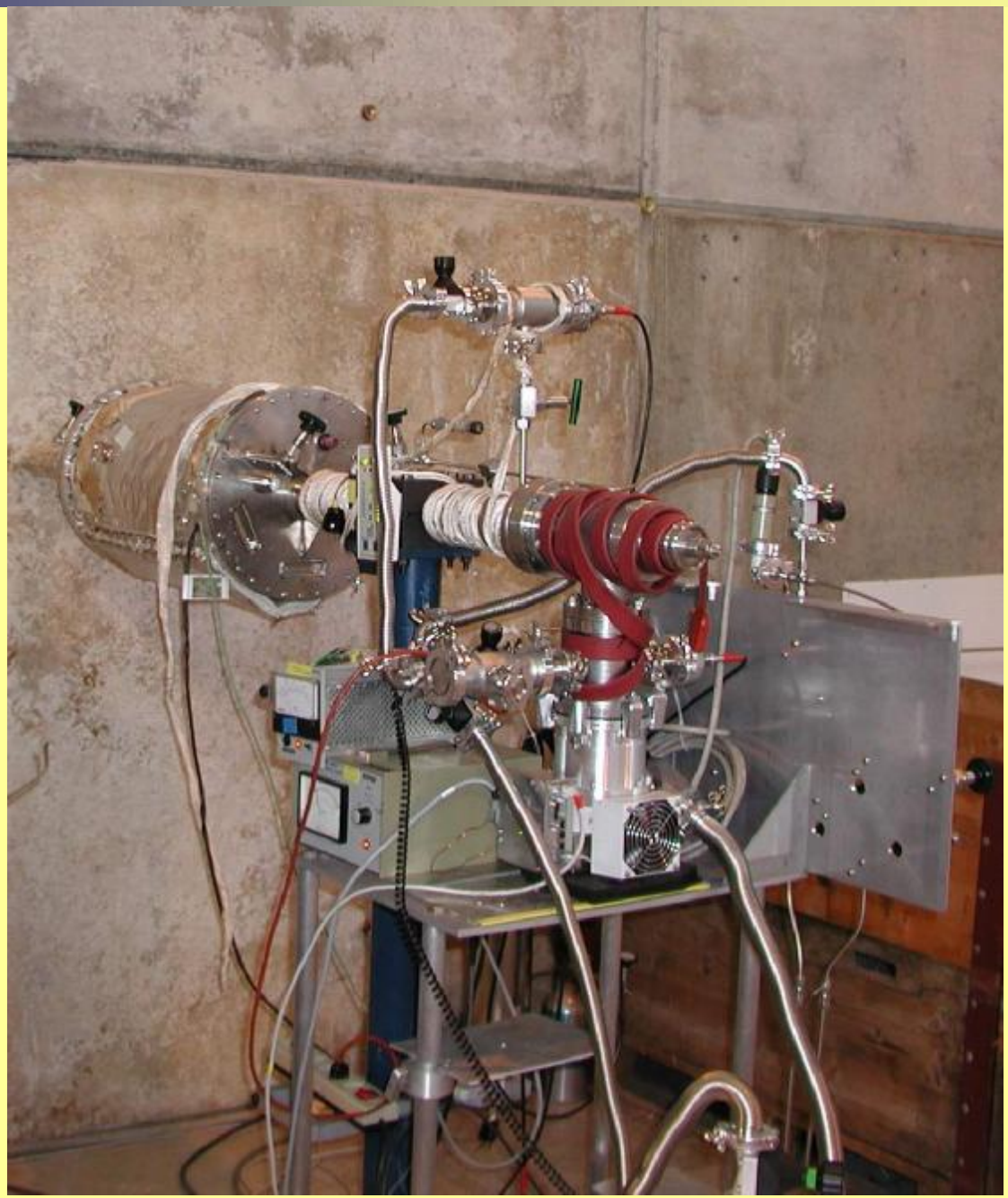
- **In situ gas impurity control** ($c_Z<10^{-8}$, $c_d<10^{-6}$)
  hydrogen chambers bakeable to 150 C, continuous purification
  TPC monitors capture on impurity and transfer to deuterium
  10^{-8} sensitivity with gas chromatograph

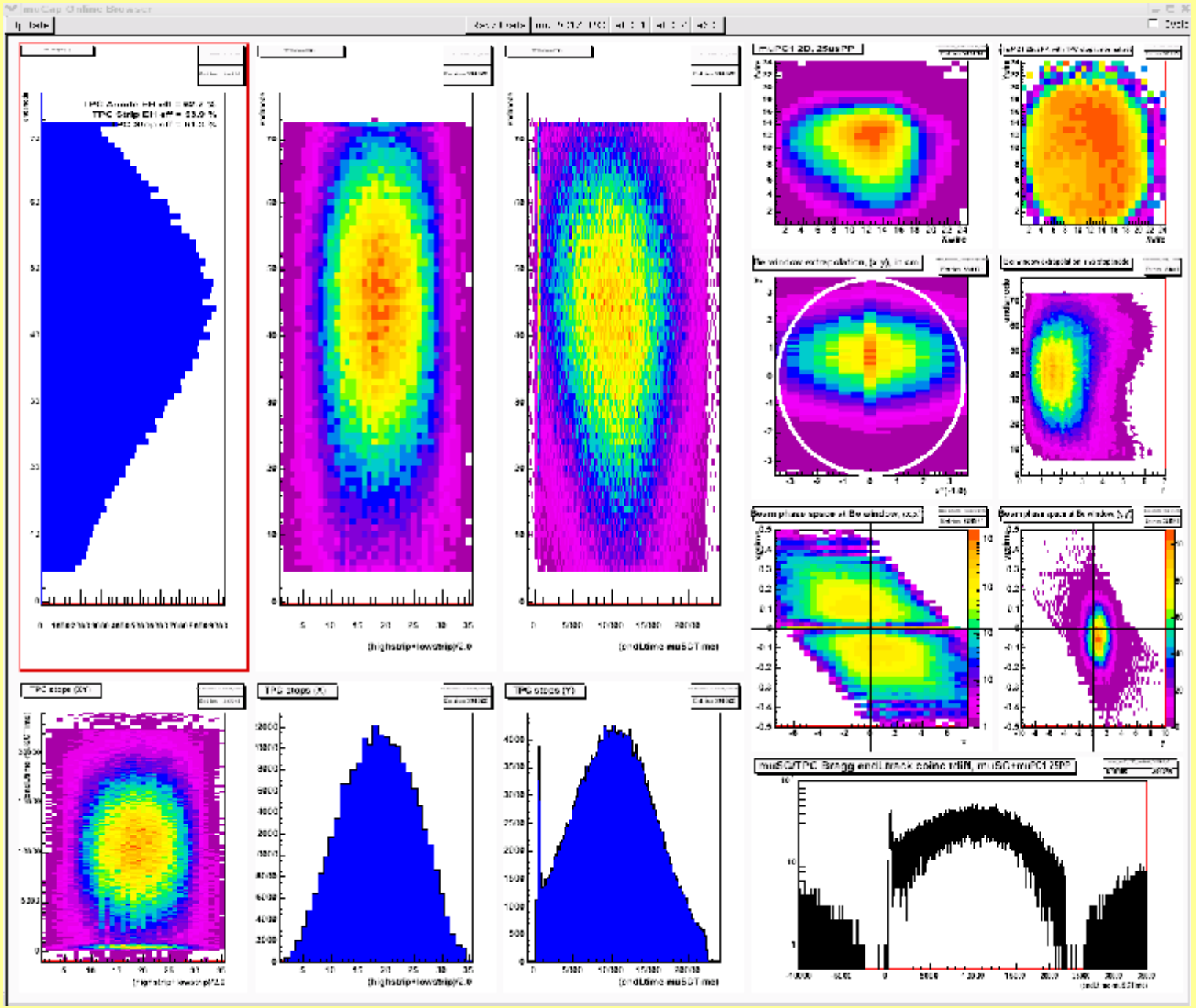
- **μ^+SR**: calibrated with tranverse field 70 G

Statistics

- **10^{10} statistics**: Complementary analysis methods







Анализ газа и протиевой воды на примесь дейтерия.

Анализ газа из объема ТРС (PSI):

(5.6 ± 0.5 ppm) – ноябрь 2003

Анализ газа (ПИЯФ):

(4.3 ± 1 ppm) – май 2004

Анализ газа из воды (ПИЯФ):

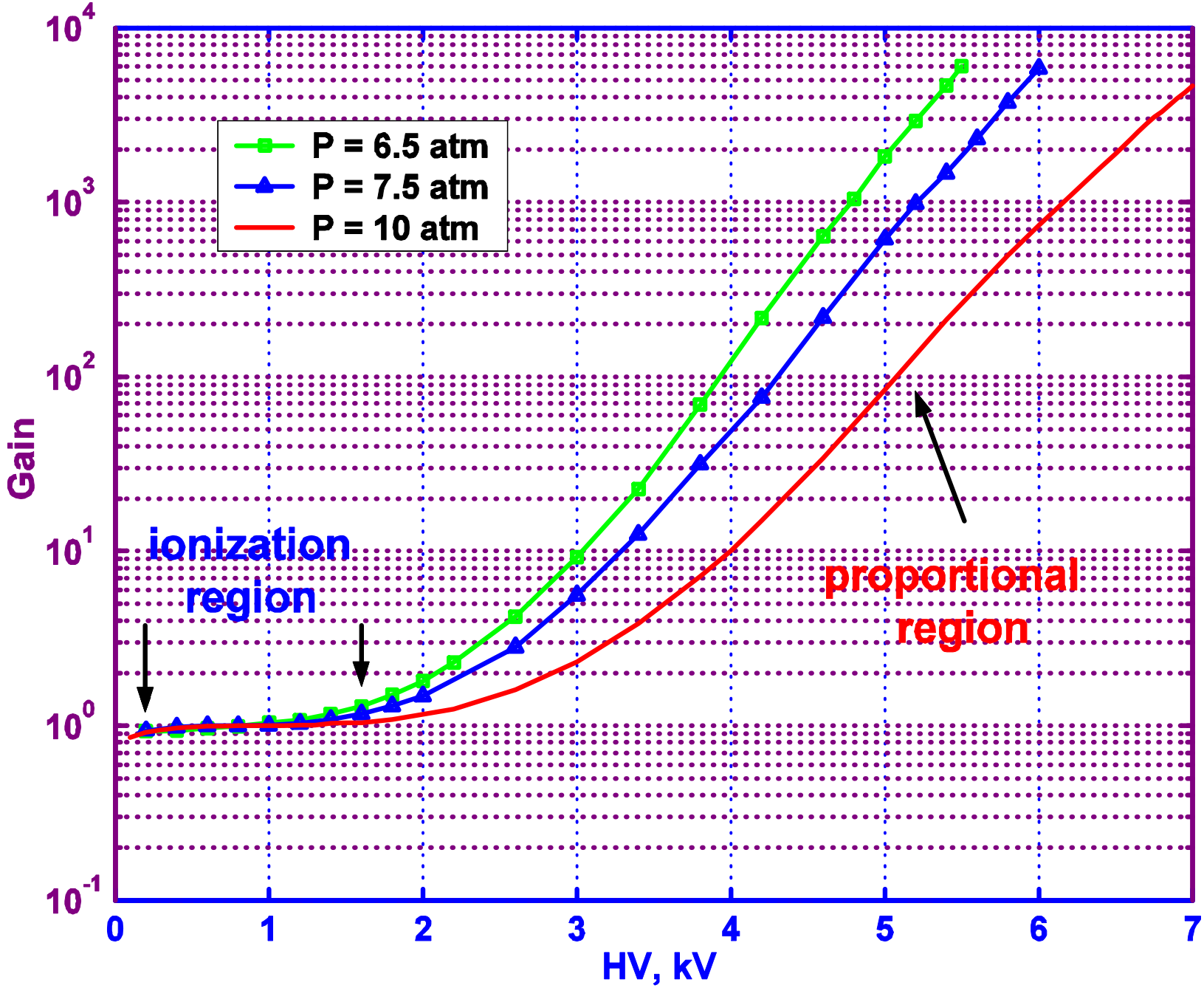
(3.27 ± 0.17 ppm) – июнь 2004

Анализ воды из ПИЯФ, сделан в PSI:

(2.86 ± 0.11 ppm); (1.64 ± 0.11 ppm) газ из Канады

Анализ воды ПИЯФ (сделан в PSI) – сентябрь 2004

(12.8 ± 0.2 ppm)


P = 6.5 atm
P = 7.5 atm
P = 10 atm
Gain
HV, kV
ionization region
proportional region
10^4
10^3
10^2
10^1
10^0
10^{-1}
0
1
2
3
4
5
6
7

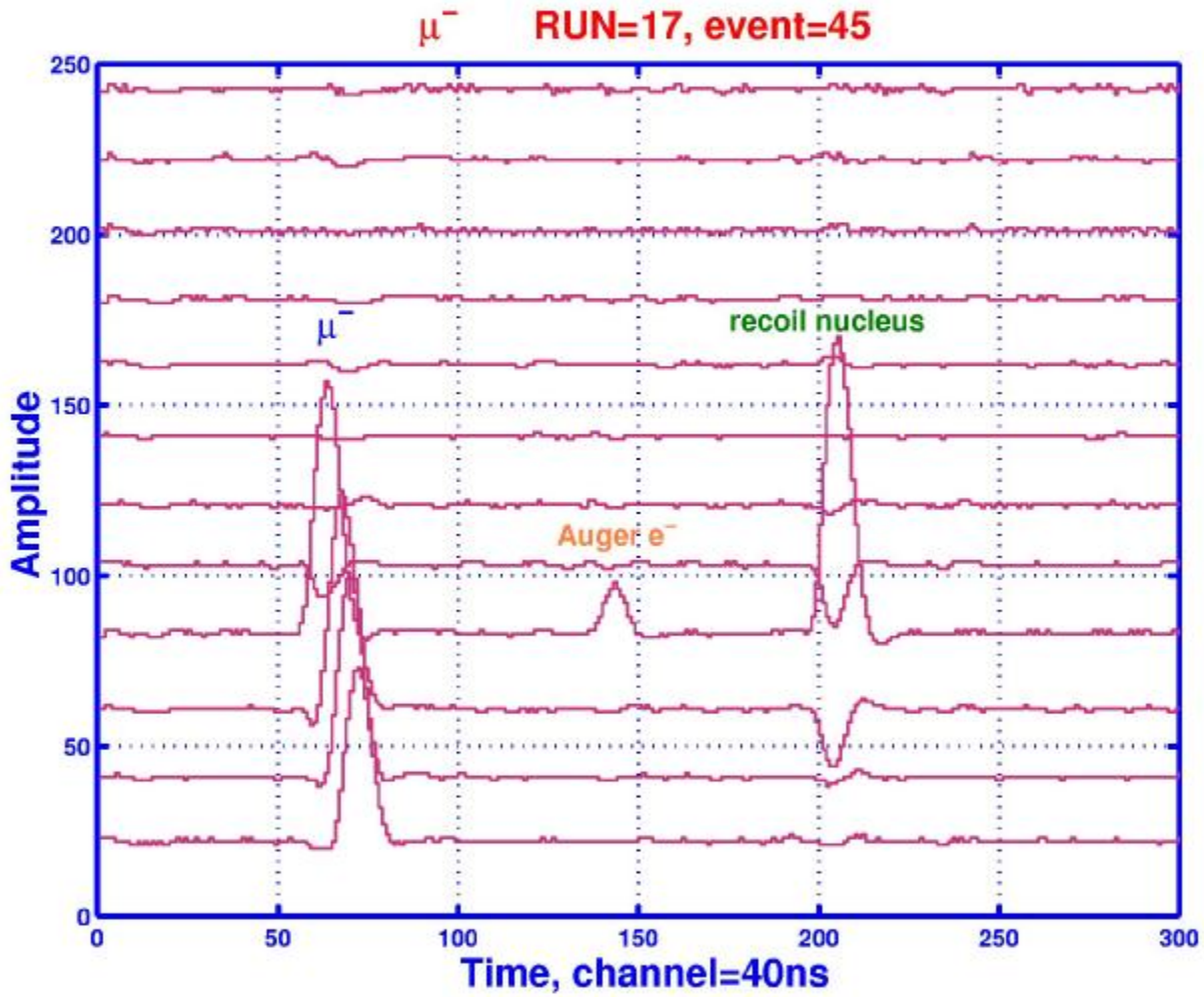


Figure 3: Display of flash ADC's showing typical event with signals from muon, Auger electron and signal from recoil nucleus.

first analysis of run7 μ^+ data

by Claude Petitjean, Nov 2003

(see also electronic muCap analysis report ID=19 of Dec 09, 2003)

useful runs before taking the „clean“ μ^- data:

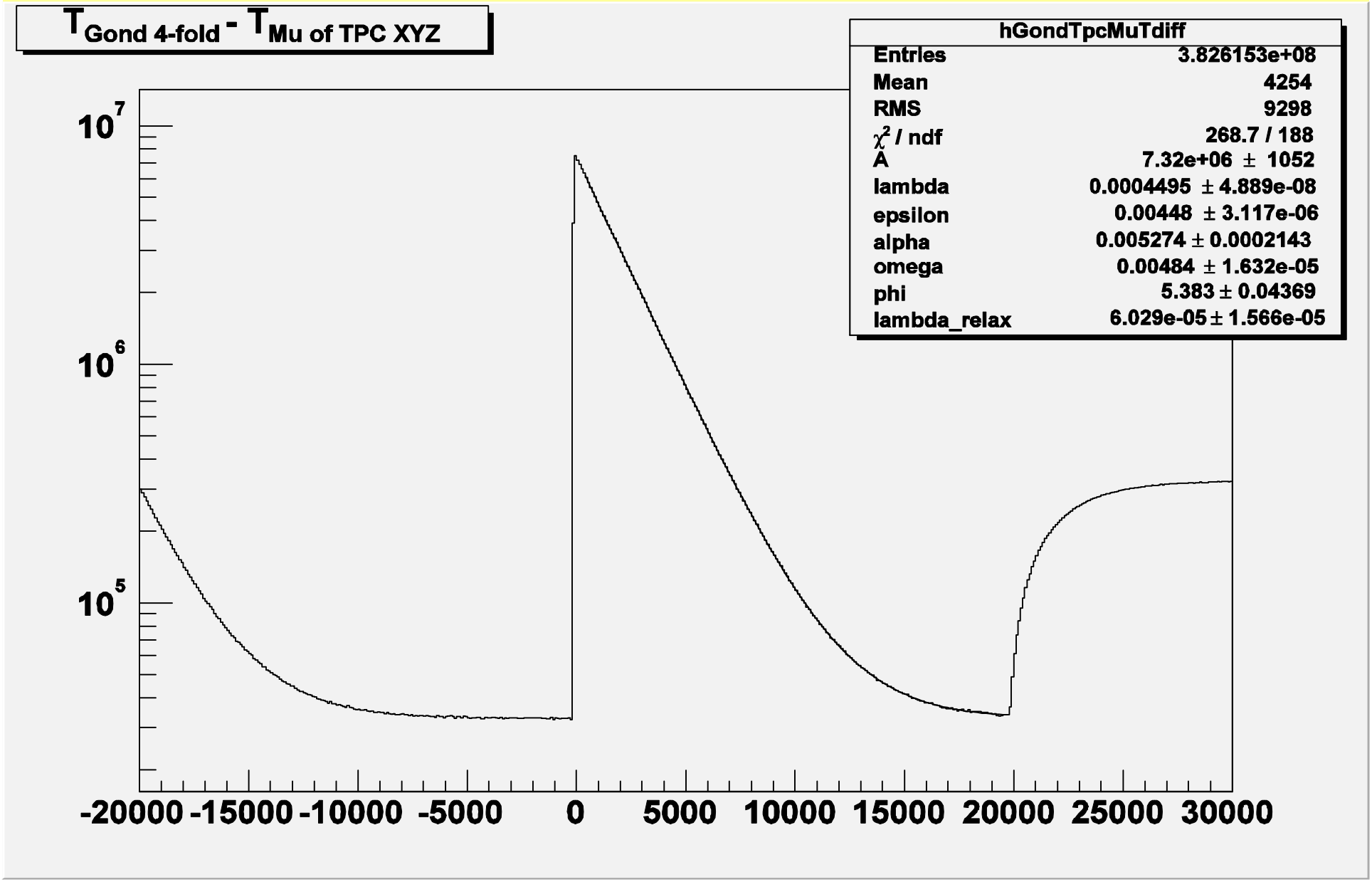
- run group A: # 4403 – 4863, 288 runs from Sept 11 - 15, 2003
- run group C: # 5356 – 5430, 58 runs from Sept 22 - 23, 2003

runs after the clean μ^- data:

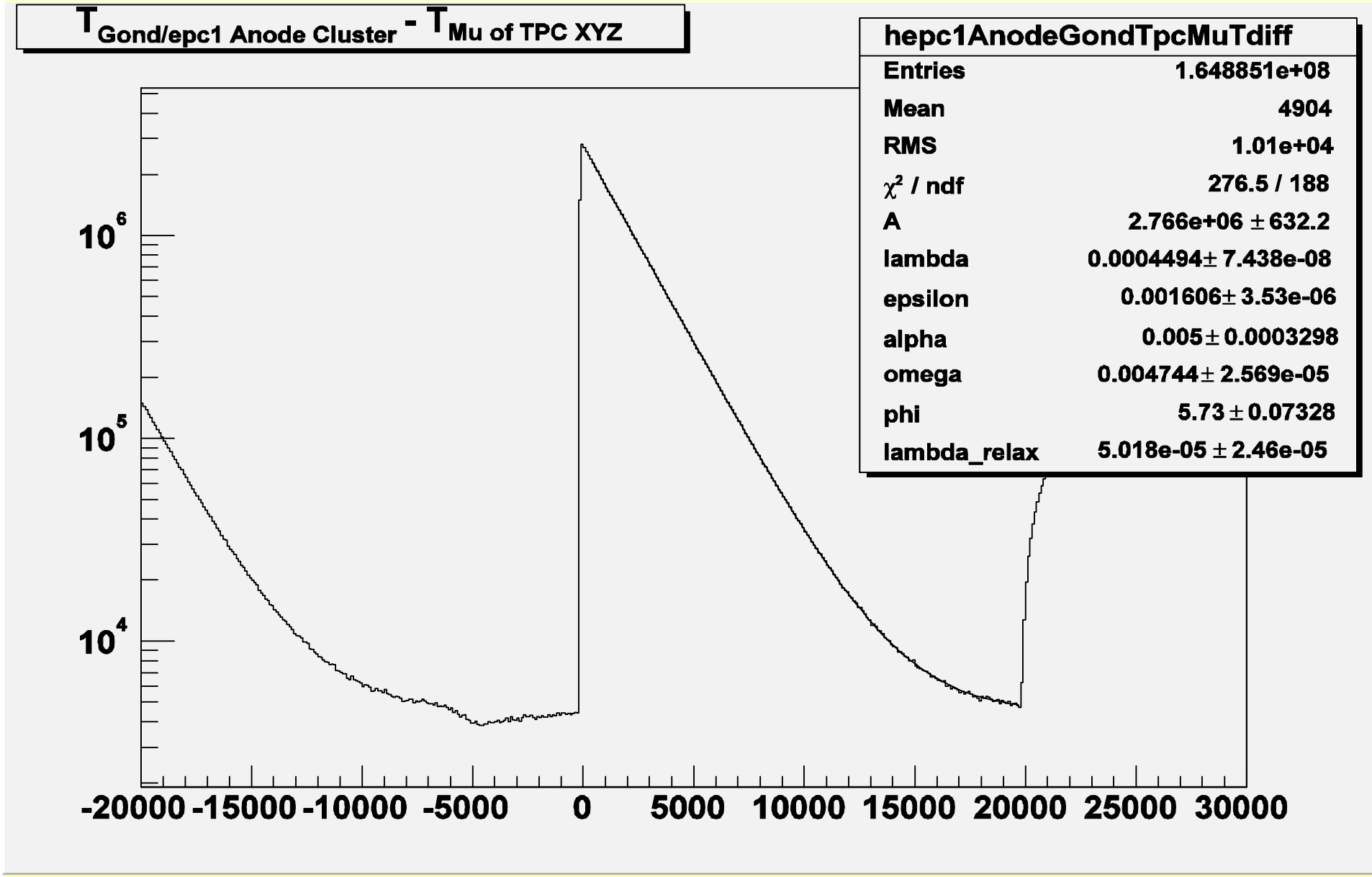
- run group B: # 7404 – 7488, 81 runs on Oct 10, 2003

total statistics of good μ^+ à e^+ decays: $6 \cdot 10^8$ events
statistics of ±20μs – pileup protected events: $2 \cdot 10^8$

sumA group: gondola only – μSR included $\chi^2/N_{df} = 1.43$



sumA: gondola + ePC1 Anodes – μSR incl. χ^2/N_{df} = 1.47



" 2nd International Workshop on the Muon Capture Project "
Petersburg Nuclear Physics Institute, Gatchina, Russia, June 14-18, 2004

Финансирование в 2004 году

Миннаука «Мюон»: 300 Т. руб.

РАН: 600 Т. руб. + 900 Т. руб.

Командировки: 22 чел/мес