Summary of the PSI Workshop, January 18-19 2007

PRECISION MEASUREMENTS AT LOW ENERGY

(Claude Petitjean, PSI)

Goal defined in view of appointing a new laboratoy head:

„The workshop is intended to contribute to an evaluation of the future particle physics research at PSI"

(with the exception of the high energy physics program)

the organisation committee (Heinz Gäggeler, Ralph Eichler, André Rubbia and Klaus Kirch) defined 4 conceivable area's of future activities of „in house" physics :

*Astro-particle physics * Ultracold neutrons * Lepton flavor * Nuclear Physics*

during 2 days (January 18-19, 2007):

- 4 sessions with 2-3 invited talks by prominent speakers in the field
- the participants were invited to present their new ideas by posters
- plenty of time for discussions and viewing posters

(1) fundamental neutron physics (14 posters)
talks by D. Dubbers, H. Rauch, S. Paul

(2) astro-particle physics (4 posters)
talks by G. Hermann, S. Schönert, C. Weinheimer

(3) lepton flavor physics (12 posters)
talks by B.L. Roberts, Y. Kuno

(4) nuclear physics (5 posters)
talks by W. Henning, K. Jungmann, N. Severijns

talks, posters, etc on http://pmle.web.psi.ch

summarize invited talks by one page
showing one highlight

+ show posters relevant for future PSI activities

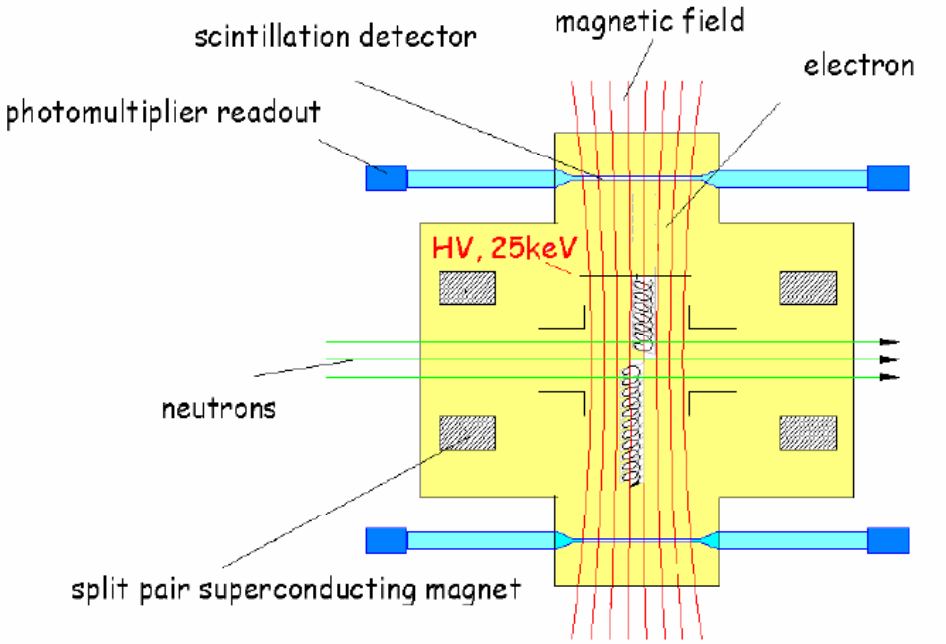
(very incomplete show - sorry!)

1st session on fundamental neutron physics

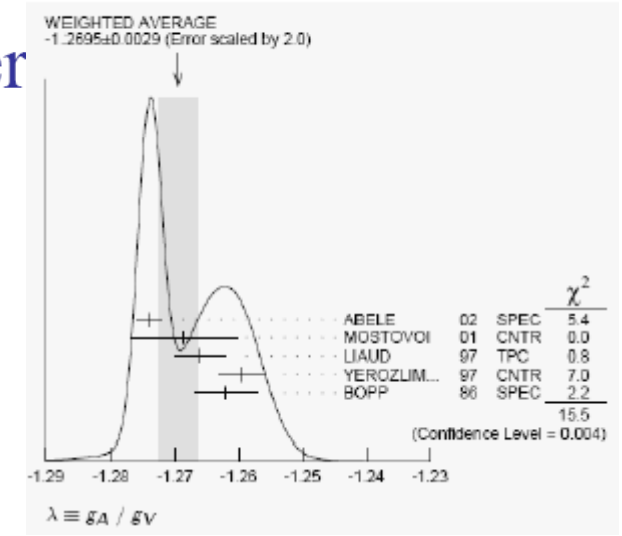
Dirk Dubbers (Univ. Heidelberg)

Neutron Decay and Neutron Oscillations

The PERKEO neutron decay spectrometer

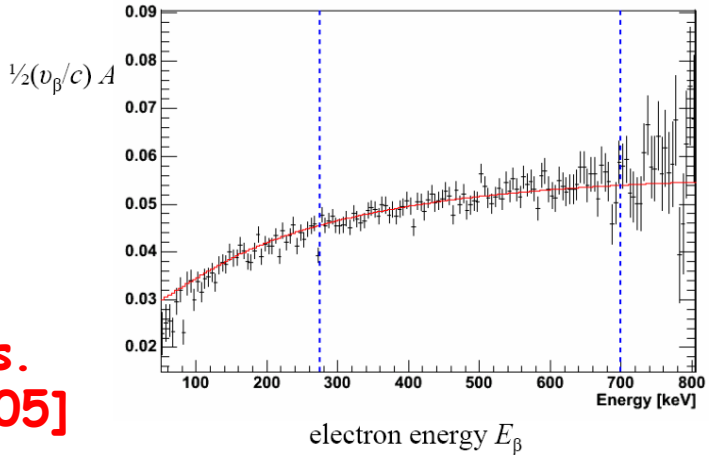


measured: β-asymmetry A
ν_e'-asymmetry B
proton asymmetry C



new β-asym. result A =-0.1195(4)
→ $\lambda = g_A/g_V$ = -1.275(1)

β-asymmetry A:



„clouds" today conc. τ_n: 885.7(8) sec [PDG2004] vs. 878.5(8) sec [Serebrov 2005]

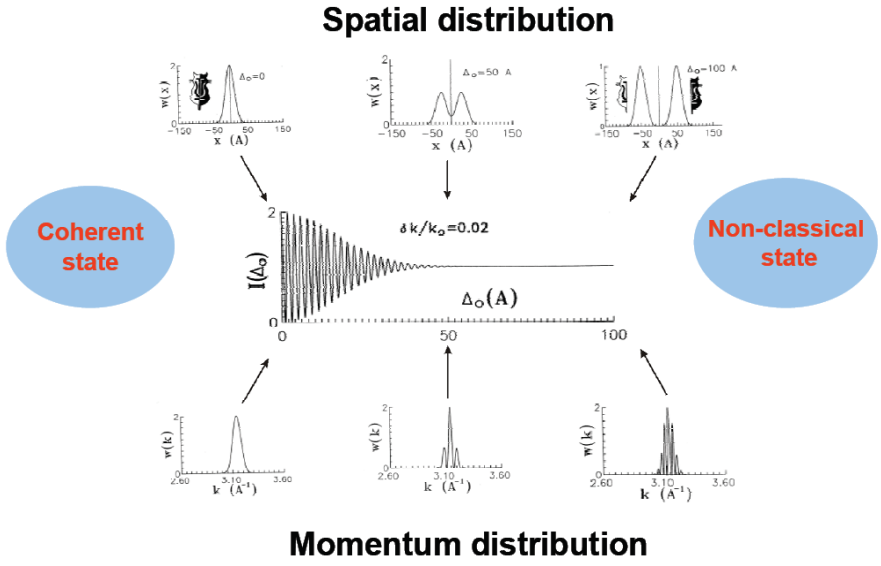
1.2:

Helmut Rauch (TU Vienna)

Quantum Properties of Neutrons

lecture on particle-wave properties, interferometry, quantum state prep.& measurement magnetic noise dephasing and decoherencing, contextuality, topological phases,ultra cold neutrons, phase space transformation

wave packet in ordinary & momentum space



different quantum states

1.3:

Stephan Paul (TU Munich)

Particle and Astrophysics: the neutrons perspective

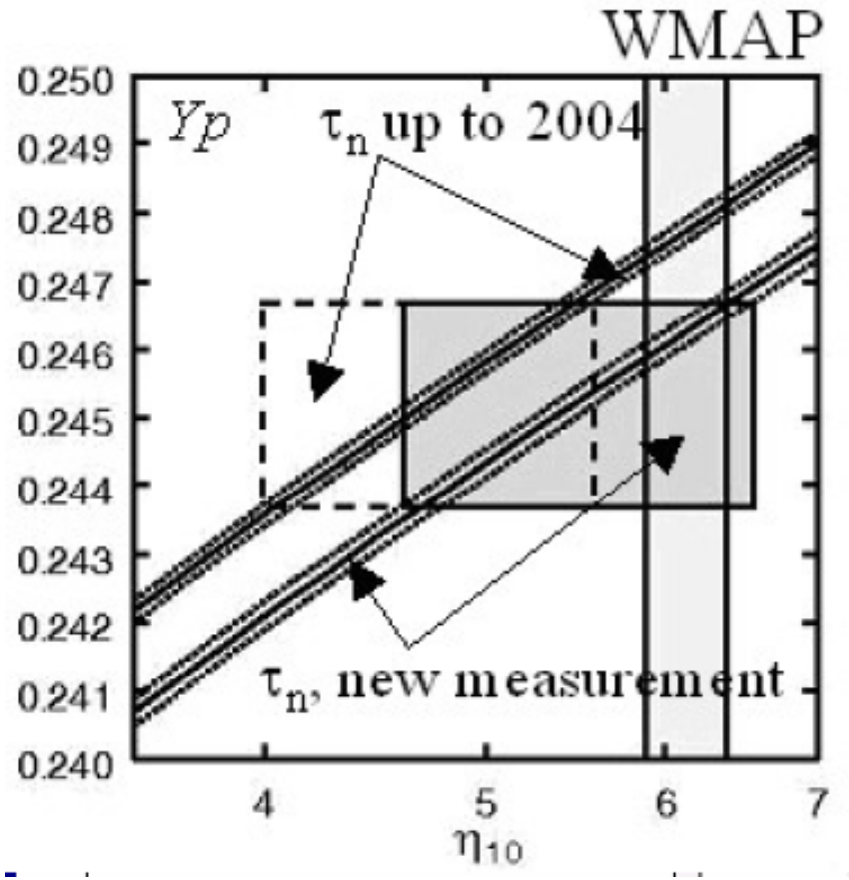
lecture about history of the universe & nucleosynthesis

→neutron lifetime τ_n is one of three important parameters:

η_{10} = $(n_B/n_\gamma) * 10^{10}$ <-> WMAP

Yp = He / p <-> metal-poor stars/galaxies

τ_n = n-lifetime <-> experiments



proposal for new τ_n measurement

Assume: new high-density UCN source (FRMII, PSI)

- UCN (gas-) density: r = 10^3-10^4 cm^{-3}
- B_{max}= 2 T B_{min}= 10-3 T
- Volume: 700 l
- N_{stored} = 10^7 -10^8
- Statistical accuracy:
  - $\Delta t \sim 1s$ per measurement cycle (30 min):
  - $\Delta t \sim 0.1s$ in 2-4 days

selected posters to fundamental neutron physics

- St. Bässler et al. (Mainz): develop ^{3}He magnetometers for EDM exp.
  can be used as clock to search for variation of the clock speed
  with orientation as a test of Lorentz and CPT violation

- A. Frei (TU Munich) proposes new UCN instruments „MEPHISTO",
  and „MINI-D2" for FRM-II neutron source

- R. Picker et al. (TU Munich): develop big new neutron lifetime apparatus
  „PENeLOPE" (Loi to PSI, see extra page), Absorber Experiment „AbEx"

- W. Schott (TU Munich) proposes to study the bound (ep) state after
  n-decay to search for weak skalar & tensor forces

- H.F. Wirth (TU Munich) et al. present first resuts of ν-e angular
  correlations in n-decay with aSPECT experiment (see extra page)

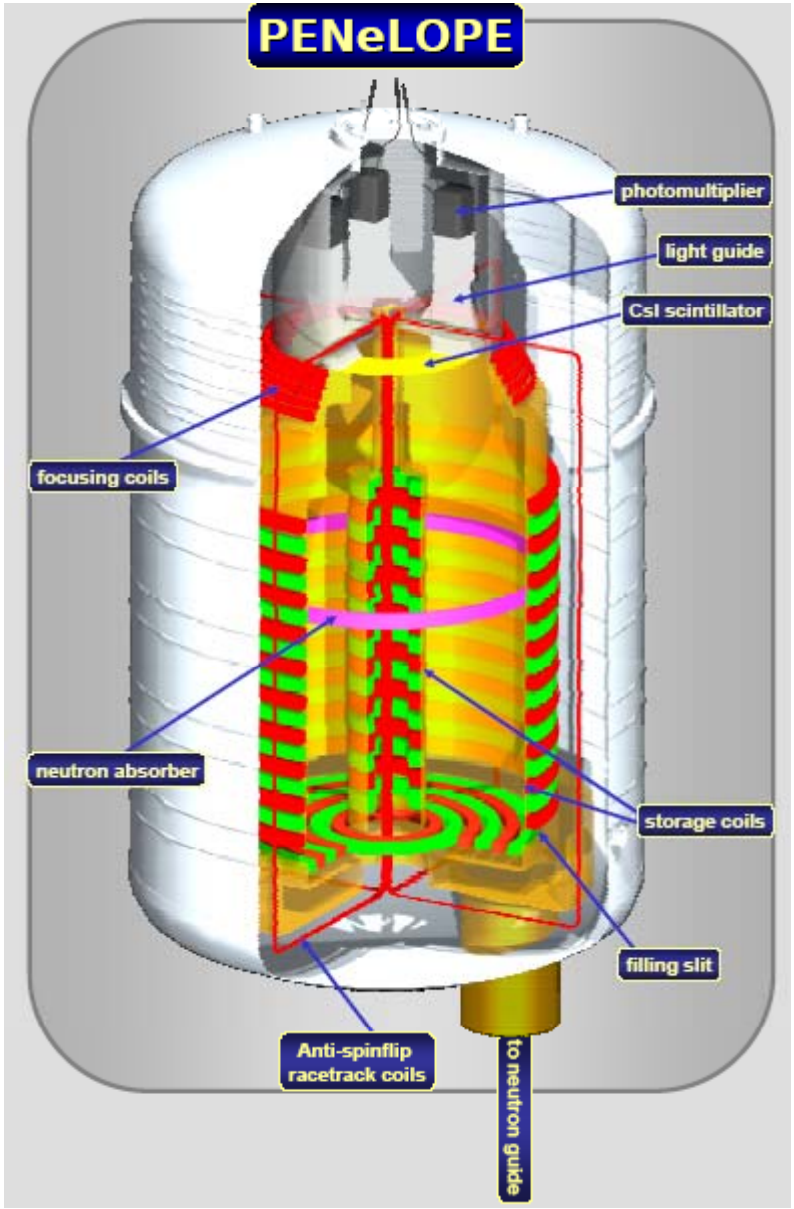
poster: neutron lifetime project - PENeLOPE

(letter of intent to PSI)

- Motivation: unresolved systematic uncertainties of material UCN storage
- Method:
  - magnetic and gravitational storage
  - real-time detection of decay protons

  => storage of 10^7 neutrons in volume of around 750 l
- Minimization or control of systematic effects:
  - avoid zero-field regions
  - monitoring of depolarized UCN
  - shaping of magnetic storage-field
  - removal of marginally trapped UCN through absorber

=> **Goal**: resolve lifetime dilemma and achieve accuracy < 0.1 s

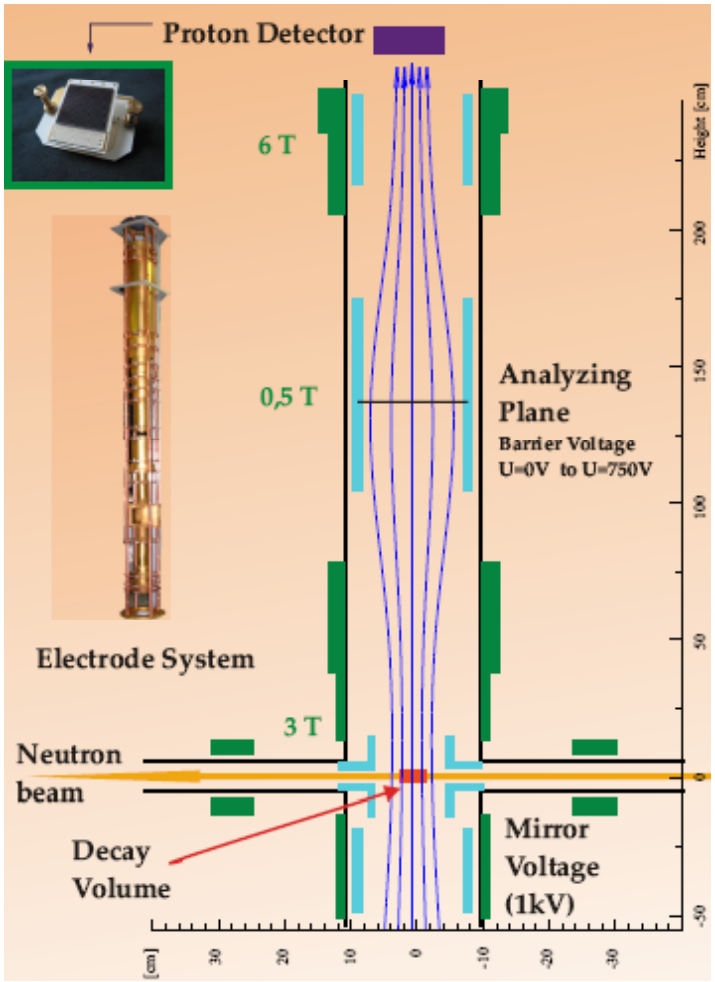


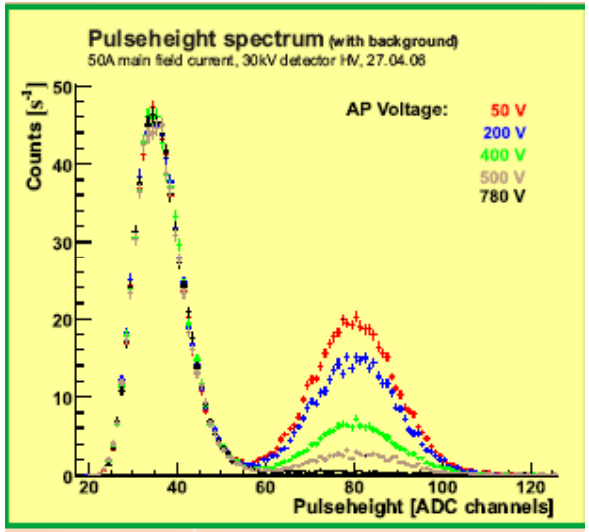
poster by H.F. Wirth et al. (TU Munich)

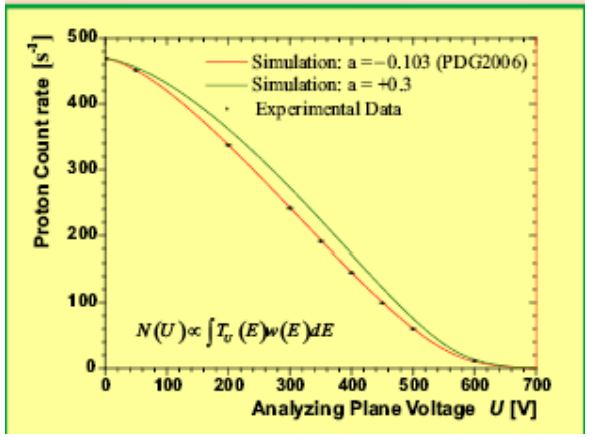
First Results with *a*SPECT

Heinz Angerer[2], Fidel Ayala Guardia[1], Stefan Baeßler[1], Michael Borg[1], Laura Cabrera Brito[1], Klaus Eberhardt[1], Ferenc Glück[1], Werner Heil[1], Igor Konorov[2], Gertrud Konrad[1], Naika Luquero Llopis[1], Raquel Muñoz Horta[1], Marius Orlowski[1], Christopher Palmer[1], Gerd Petzoldt[2], Dennis Rich[3], Martin Simson[2], Yuri Sobolev[1], Hans-Friedrich Wirth[2], and Oliver Zimmer[2]

[1]Institut für Physik, Universität Mainz, [2]Physik Department E18, TU München, [3]Forschungsneutronenquelle Heinz-Maier-Leibnitz-II, TU München





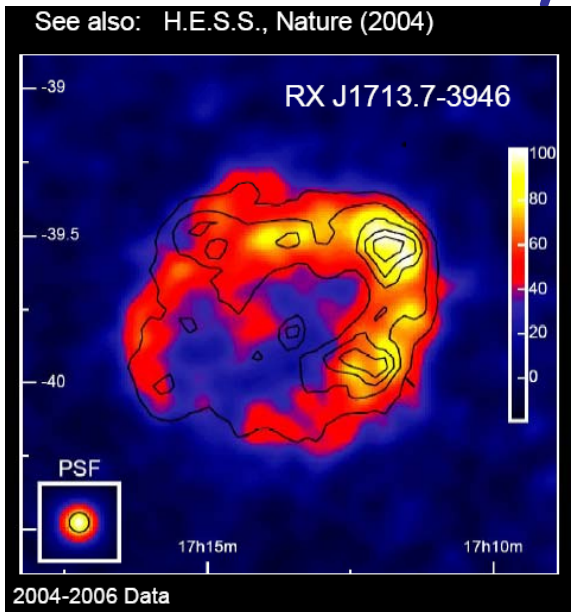


2nd session on astro particle physics

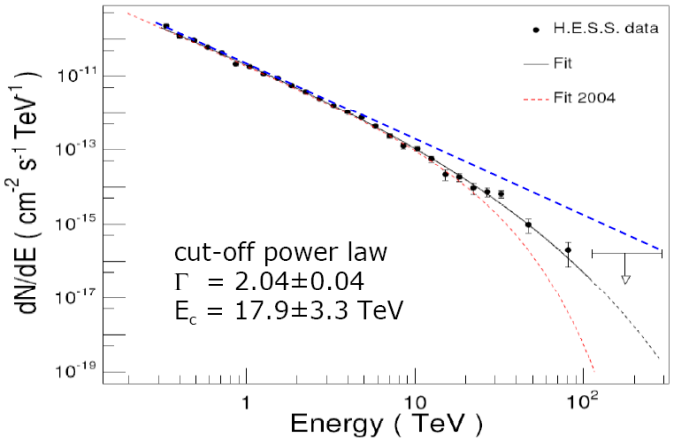
(in reality 2 neutrino physics talks)

2.1: G. Hermann (MPIK Heidelberg)

TeV Gamma-Ray Astronomy H.E.S.S. and beyond



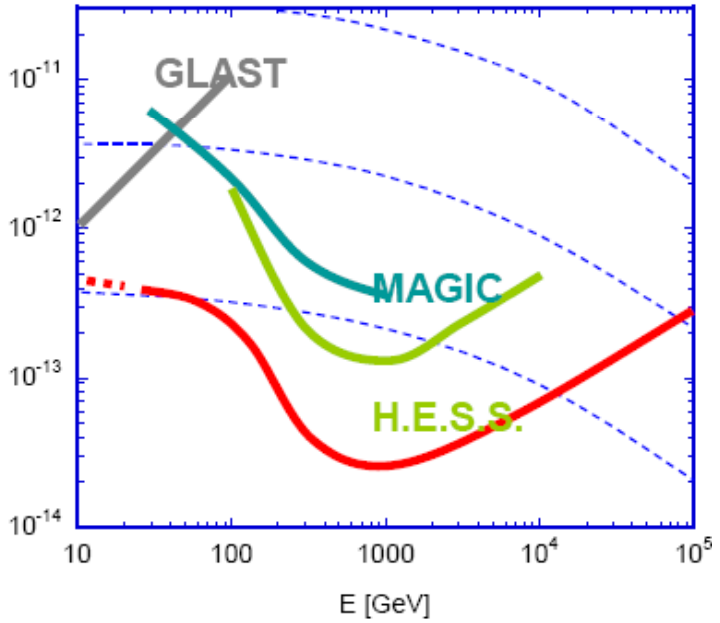
Particle acceleration to beyond 100 TeV



future: Cerenkov Telescope Array

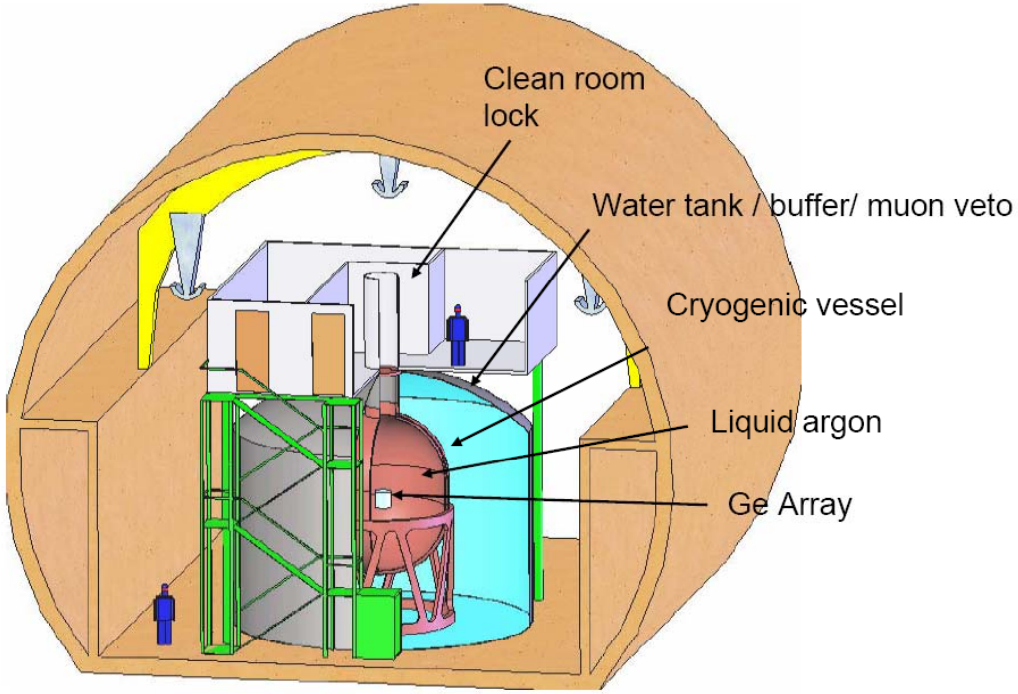
Will need
- O(30-50) telescopes
- O(10000) m² mirror area
- O(50) m² photo sensitive area
- O(50000-100k) electronics channels

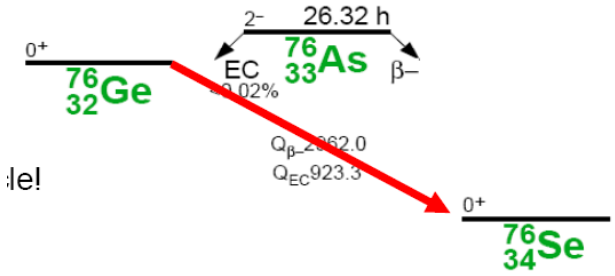
→ Factor of 10 in sensitivity with only factor of 10 in MCHF



2.2: Stefan Schönert (MPIK Heidelberg)

the GERDA neutrinoless double beta decay experiment

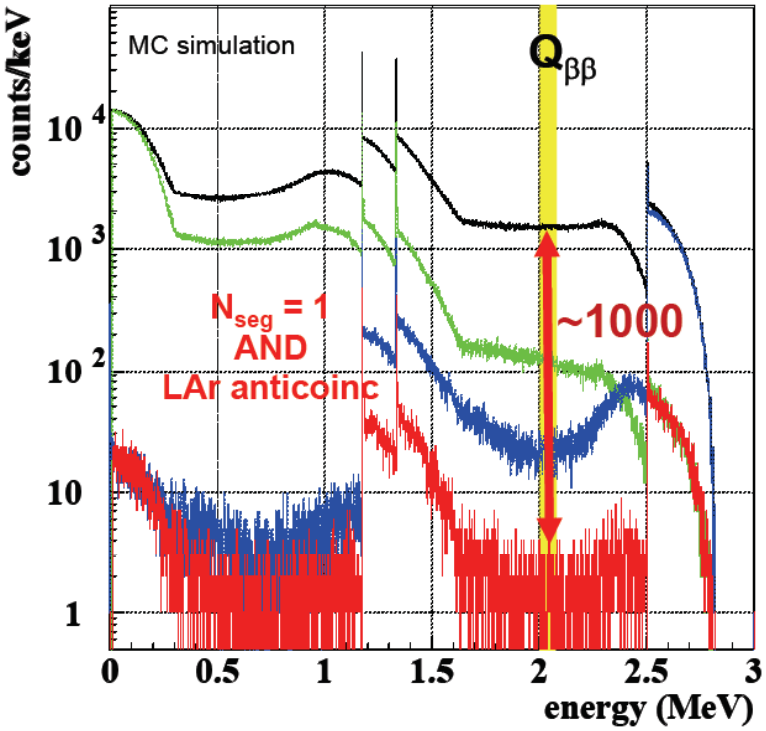




phase III : world wide collaboration

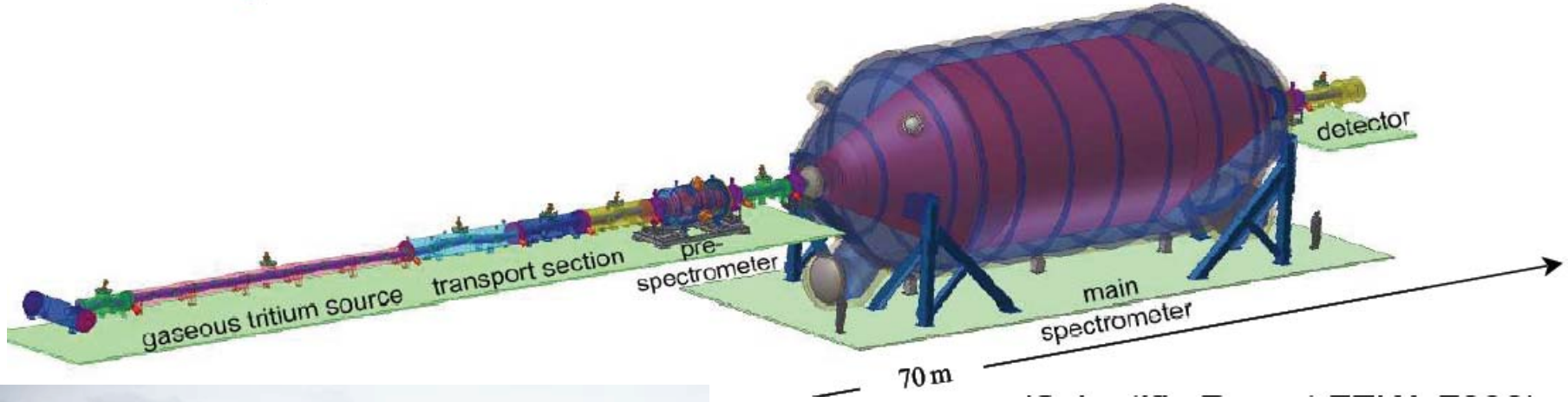
► $T_{1/2} > \sim 10^{28}$ y , $\langle m_{ee} \rangle \sim 10$ meV

needs > 10^3 kg ^{76}Ge



2.3: Christian Weinheimer (Wilhelms University Münster)

the Karlsruhe tritium neutrino experiment KATRIN



new absolute m(ν_e) mass measurement
improve sensitivity from 2.2 eV→0.2 eV

in construction, setup until 2009
data taking 2010-2015

selected posters to astro-particle physics

- W. Hajdas et al. (PSI) present development of miniature a low energy e det. in space, based on the MYTHEN detector developed at SLS

- A. Biland et al. (ETHZ) present a proposal for future high-energy γ-ray astronomy, the „Cerenkov Telscope Array" (CTA)

- E. Suarez-Garcia et al. (PSI, Geneve) present the new γ-ray polarimeter „POLAR" to probe magnetic fields during black hole creation

3rd session on lepton flavor physics

3.1: Lee Roberts (Boston University)

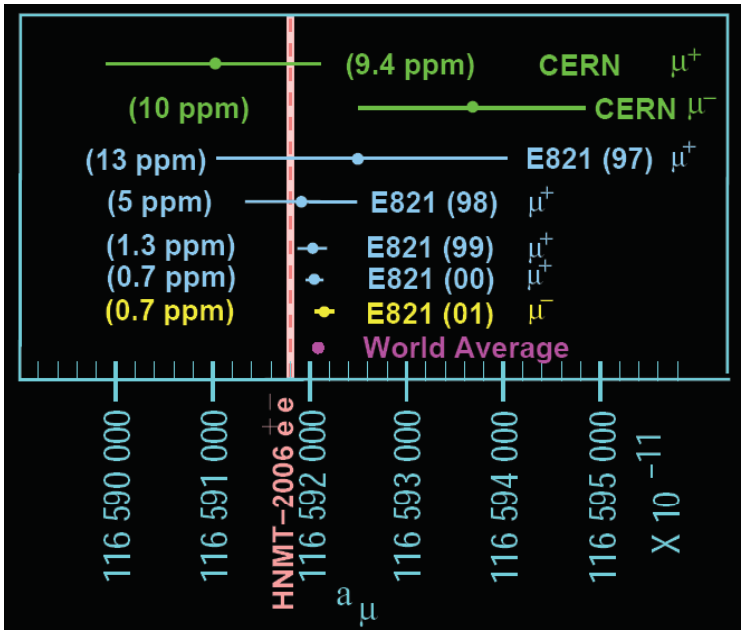
Lifetime and Dipole Moments

new result od (g-2) experiment at BNL

$$a_\mu(sm07) = 11\,659\,178.5(6.1)\times10^{-10}\ (0.44\ \text{ppm})$$

$$a_\mu(E821) = 11\,659\,208.0(6.3)\times10^{-10}\ (0.54\ \text{ppm})$$

$$\Delta_{sm} = a_{exp} - a_{sm} = 29.5(8.8)\times10^{-10}$$



if Δsm would be caused by an EDM:

what value EDM would this correspond to?

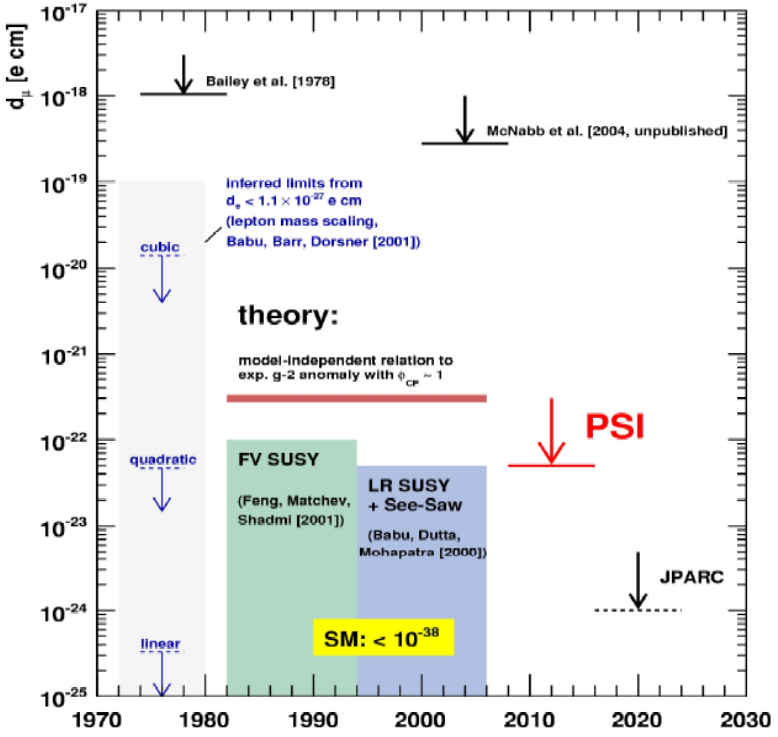
$$|d_\mu| = 1.8(.5)\times10^{-19}\ e\text{cm}$$

obviously this would be exciting.

See: Feng, et al., Nucl. Phys. **B 613** (2001) 366

The present limits are:

$$< 10^{-18}\ \text{(CERN)}$$
$$\sim 10^{-19}\ *\ \text{(E821)}$$



present exp. Limits of electric dipole moments

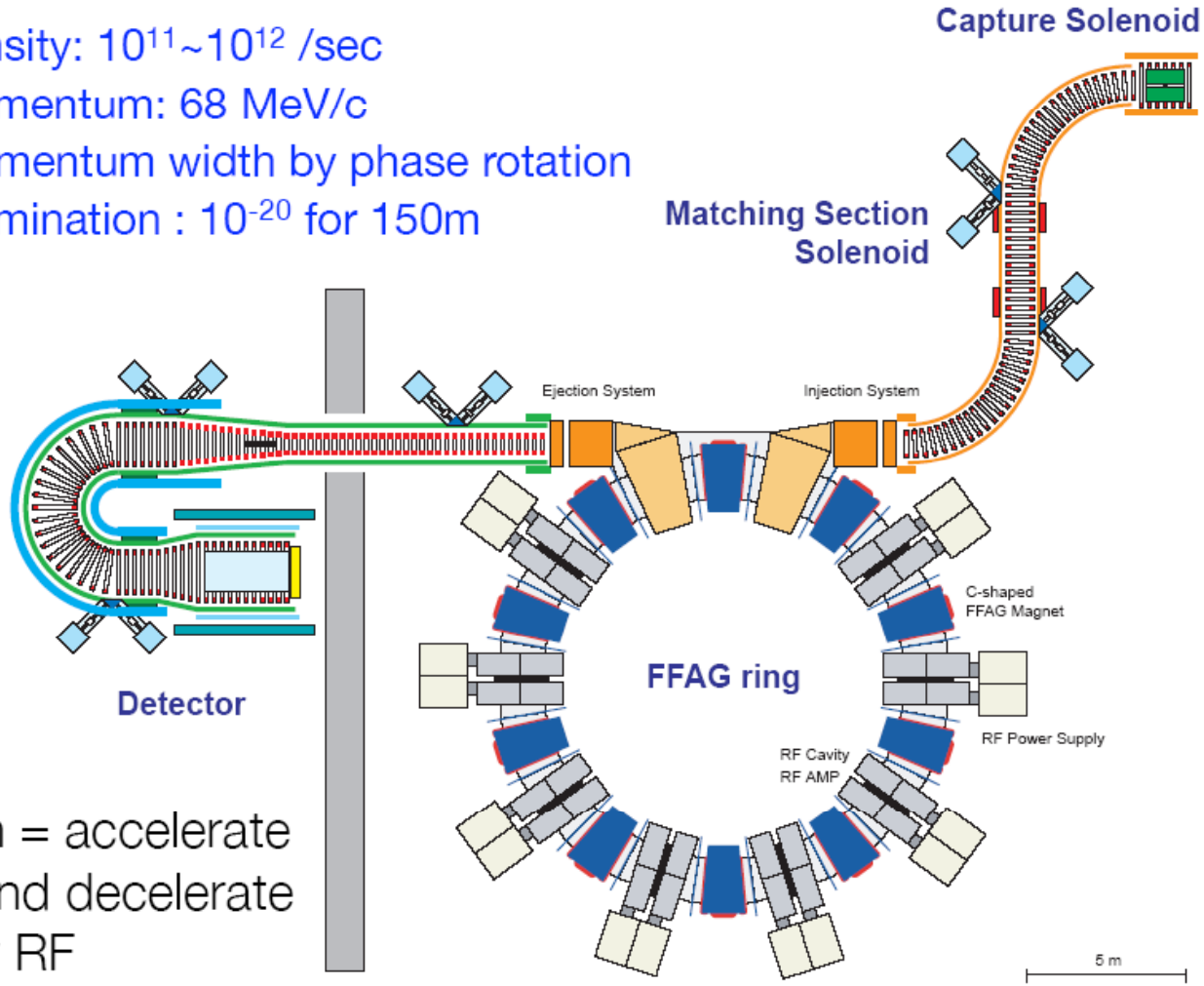
Particle	*Present EDM limit* (e-cm)	*SM value* (e-cm)
n	3×10^{-26} (90%CL)	10^{-32} to 10^{-31}
e^-	1.6×10^{-27} (90%CL)	$< 10^{-41}$
μ	$< 10^{-18}$ (CERN) $\sim 10^{-19}$ * (E821)	$< 10^{-38}$
^{199}Hg	2.1×10^{-28} (95%CL)	

3.2: Yoshi Kuno (Osaka University) **Future Prospects**

# of Searches for Lepton Flavor Violations with Muons

PRISM = Phase Rotated Intense Slow Muon Source (at J-PARC)
ultimate goal: μ→e conversion to 10^{-18}

- muon intensity: 10^{11}~10^{12} /sec
- central momentum: 68 MeV/c
- narrow momentum width by phase rotation
- pion contamination : 10^{-20} for 150m



Phase rotation = accelerate slow muons and decelerate fast muons by RF

selected posters to session 3 (lepton flavor physics)

- A. Adelmann et al. (PSI) propose a search for μEDM using a new compact muon storage ring at PSI (see extra page)
- A. Antognini, R. Pohl et al. Propose precision spectroscopy in electronic and muonic H and He+ as tests of bound-state QED
- D. Taqqu (PSI) proposes high precision spectroscopies of highly excited states in μp and of the 1s-2s transition in Muonium as 20-30 fold improved tests of QED
- F. Bezrukov et al. (EPF Lausanne) propose dark matter sterile neutrino search in the lab using cold target recoil ion momentum spectroscopy
- K. Kirch (PSI) proposes testing gravity with muonium using Mach-Zehnder type interferometry (see extra page)
- B. Lauss (ILL now PSI) presents a proposal for a precision measurement of μd capture as a test of effective field theories (see extra page)
- S. Ritt et al. (PSI) present the prospects for a new $\mu^+ \rightarrow e^+e^-e^+$ search with the technology of the MEG experiment(see extra page)
- W. Ootani (Tokyo) presents possible improvements of the MEG experiment and H. Nishiguchi (Tokyo) in case of MEG discovery a $\mu^+ \rightarrow e^+\gamma$ measurement with polarized μ^+ (see extra page)

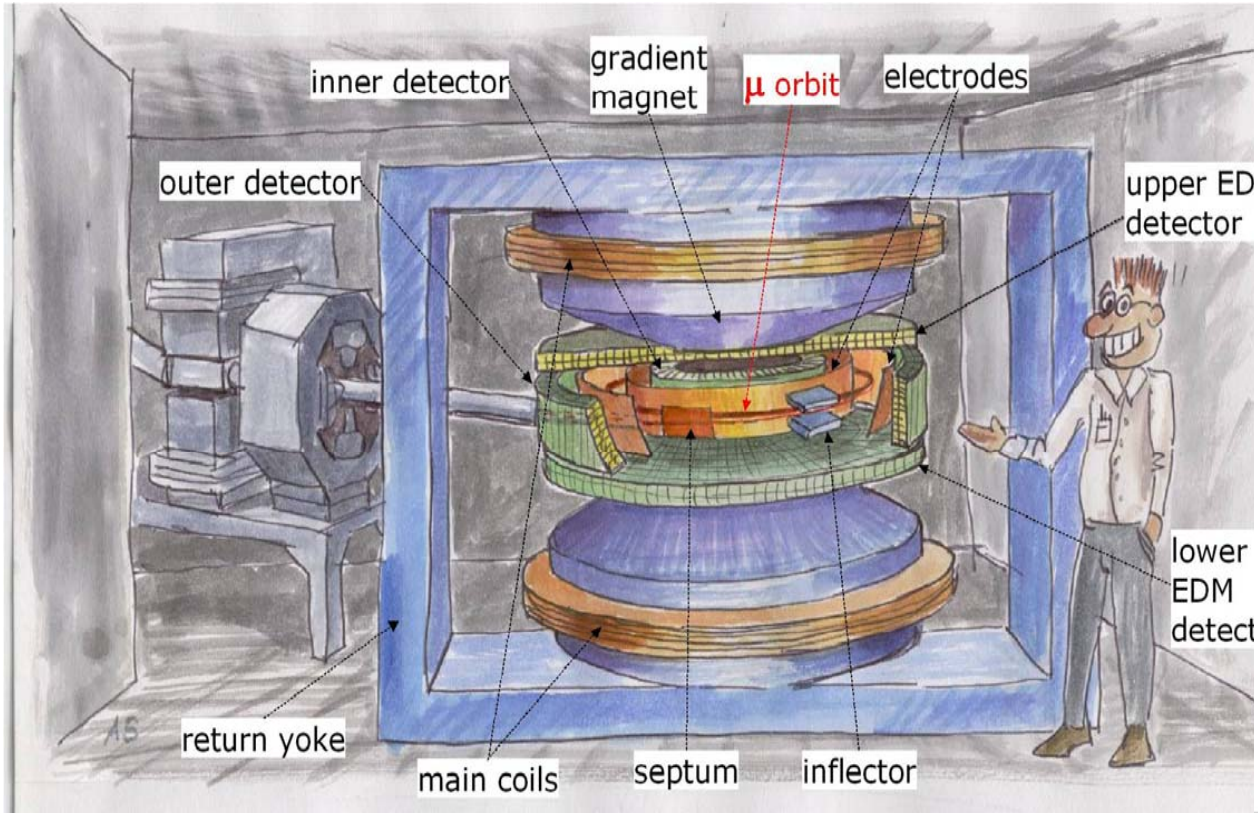
Search for the μEDM using a compact storage ring

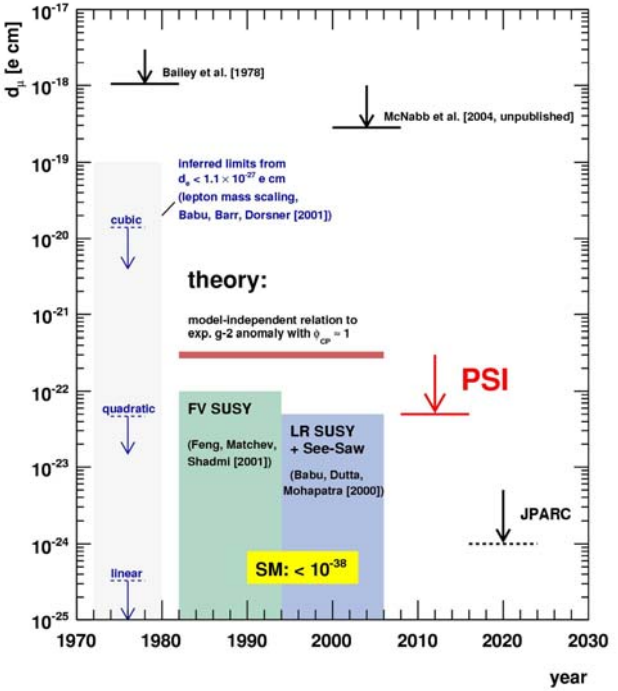
A. Adelmann[1], K. Kirch[1], C.J.G. Onderwater[2], T. Schietinger[1], A. Streun[1]

[1] Paul Scherrer Institut, PSI — [2] Rijksuniversiteit Groningen, NL

- inject from μE1 single longitudinally polarized μ^+ (rate 200 kHz)
- use frozen spin technique (v × B electric field)
- detect μEDM by growing up-down asymmetry
- sensitivity after 1 year beamtime 5×10^{-23} e cm

[also proposed at J-PARK (Aoki et al 20(





poster presented by K. Kirch: Testing gravity with Muonium

Concept of the muonium gravity experiment

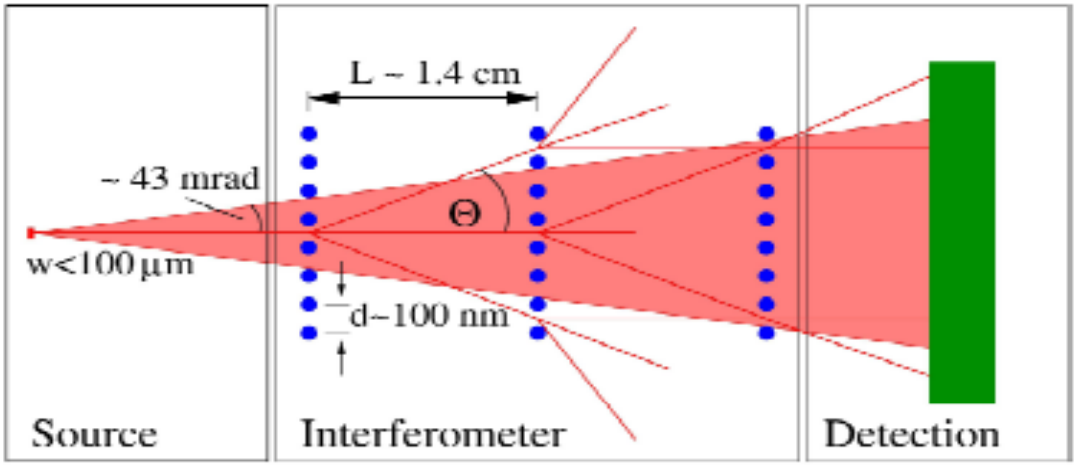
- Muonium source (Taqqu [2006,2007]):
  100μm diameter, 10^5 s^{-1} M atoms, monoenergetic ($\Delta E/E \sim 0.002$),
  velocity: 6300m/s, 1-dim divergence: 40-50 mrad.

- Mach-Zehnder type interferometer accepts full beam divergence.
- 100nm period transmission gratings → diffraction angle $\Theta \sim 5.6$mrad.

- One muon decay length is L∼1.4cm, the distance source – detector about 6cm.

- Gravitational phase shift 0.003 → 50pm shift of fringes at 3rd grating.
- The Sagnac effect (due to earth rotation) is one order of magnitude smaller.

- 200s^{-1} detected M atoms and fringe visibility of 30%.
- Statistical sensitivity: 30% per day for a measurement of the gravitational acceleration g, i.e. 3% in 100 days.



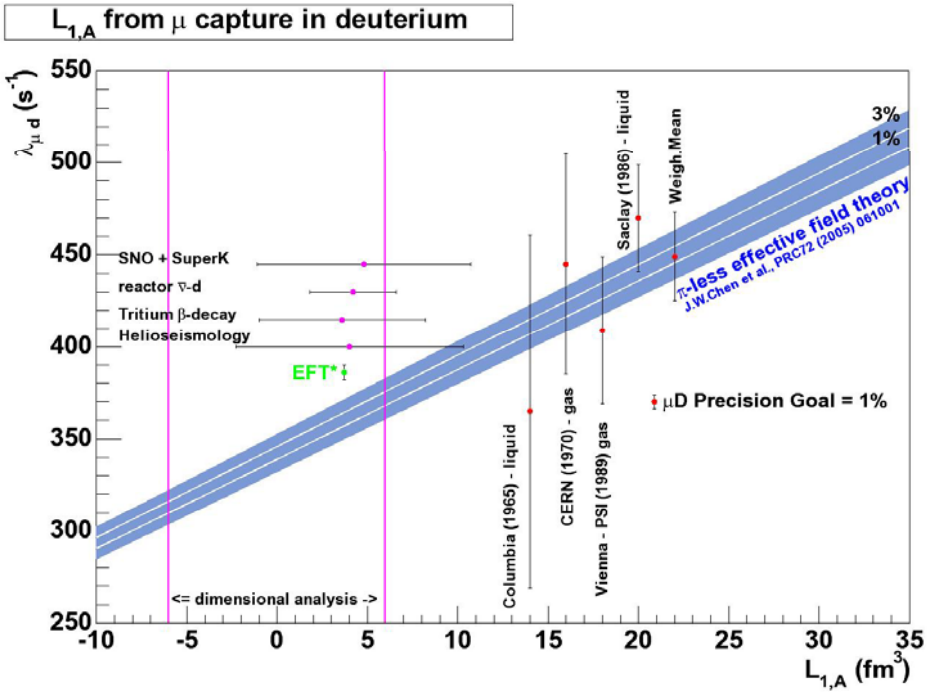
poster presented by B. Lauss:

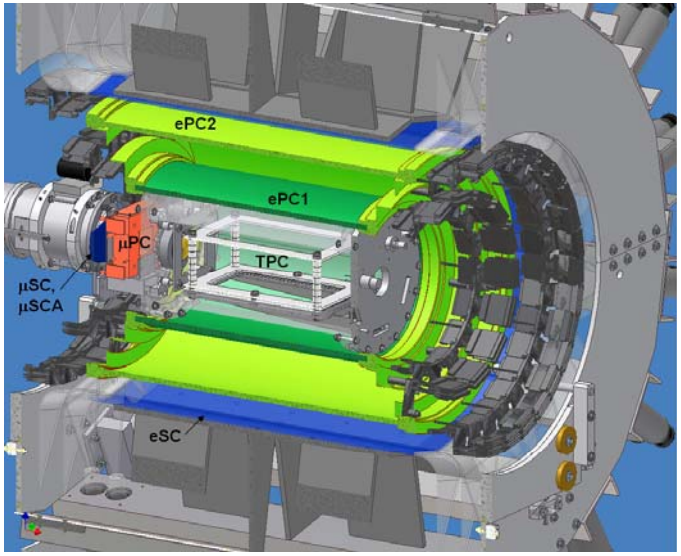
"Calibrating the Sun" via Muon Capture on the Deuteron

$\mu^- + d \rightarrow \nu_\mu + n + n$ as a test of effective field theories

(new proposal prepared by the MuCAP Collaboration)

In effective field theory are *pp*-fusion, νd reactions and muon capture on the deuteron closely related. They share one badly known low-energy constant $L_{1,A}$ - which describes the two-nucleon axial current.
μd capture fixes $L_{1,A}$ important for : pp-fusion cross sections,
solar neutrino rate calculations
absolute solar neutrino rate measurement in the Sudbury Neutrino Observatory
best two-body electro-weak reaction mesaurement



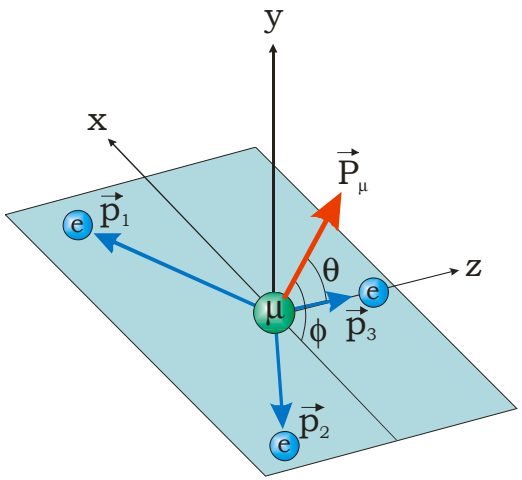


poster presented by the PSI group of MEG

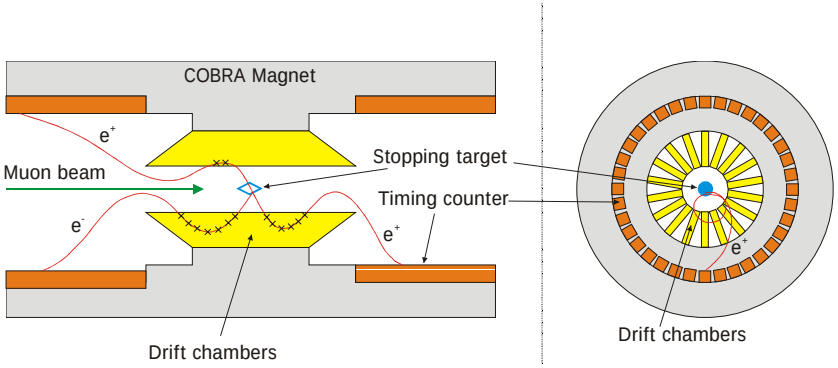
Prospects for a new $\mu^+ \rightarrow e^+e^+e^-$ Experiment

M. Hildebrandt, P.-R. Kettle, S. Ritt - PSI

- A polarized $\mu^+ \rightarrow e^+e^+e^-$ Experiment would reveal three observables A_{P1}, A_{P2}, A_T which are predicted differently by different SUSY theories
- BR($\mu^+ \rightarrow e^+e^+e^-$) ~ 6x10^{-3} BR($\mu^+ \rightarrow e^+\gamma$) makes $\mu^+ \rightarrow e^+e^+e^-$ viable if $\mu^+ \rightarrow e^+\gamma$ will be found at 10^{-12} level
- Modestly modified MEG detector
  - Drift chamber and timing counters completed to 360°
  - Drift chambers reach further in
  - Hollow double cone target
  - All resolutions 6~15x better than SINDRUM experiment
- Background free experiment possible with 150x statistics of SINDRUM
  $\Rightarrow$ BR($\mu^+ \rightarrow e^+e^+e^-$) < 1.0 x 10^{-12} can be improved by more than one order of magnitude



		SUSY GUT SU(5)	SUSY GUT SO(10)
A_{P1}=	$\frac{N(P_{\mu z}>0)-N(P_{\mu z}<0)}{N(P_{\mu z}>0)+N(P_{\mu z}<0)}$	-0.3 - +0.4	≤ 0.1
A_{P2}=	$\frac{N(P_{\mu x}>0)-N(P_{\mu x}<0)}{N(P_{\mu x}>0)+N(P_{\mu x}<0)}$	-0.2 - +0.2	≤ 0.15
A_T=	$\frac{N(P_{\mu y}>0)-N(P_{\mu y}<0)}{N(P_{\mu y}>0)+N(P_{\mu y}<0)}$	≤ 0.15	≤ 0.01

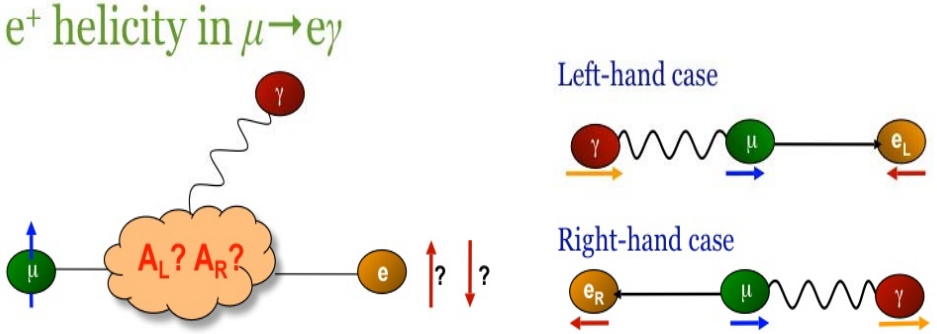


$\mu^+ \to e^+\gamma$ measurement with polarized μ^+ beam

H.Nishiguchi, W.Ootani, S.Mihara - University of Tokyo, *for the MEG collaboration*

- After MEG discovered $\mu^+ \to e^+\gamma$, the experiment can advance from the "*discovery*" to the "*measurement*" phase.
- By the use of a polarized muon beam and a Suitable target, a ***polarized MEG*** can be performed.

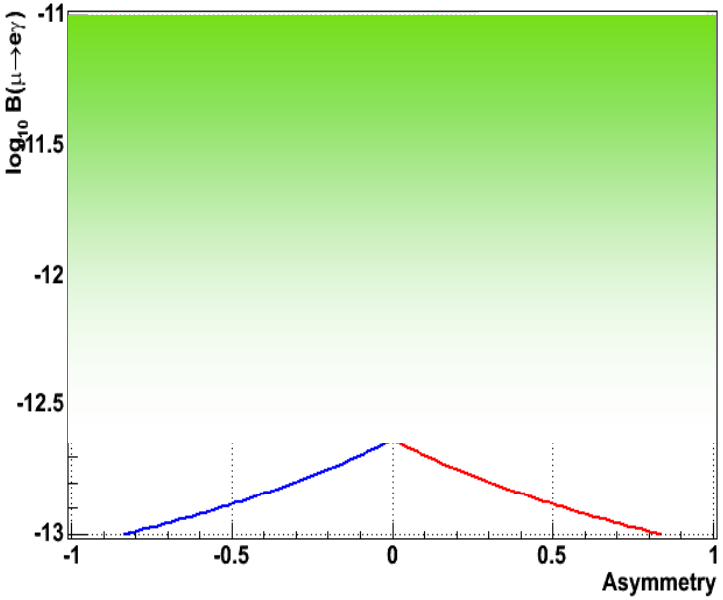
$$\frac{dB(\mu^+ \to e^+\gamma)}{d\cos\theta_e} \propto |A_R|^2(1 - P_\mu \cos\theta_e) + |A_L|^2(1 + P_\mu \cos\theta_e)$$



the asymmetry of the e^+ angular disribution

measuring the e^+ emission angle distribution

polarized beam + depolarization target + MEG



MC study was performed to estimate feasibility

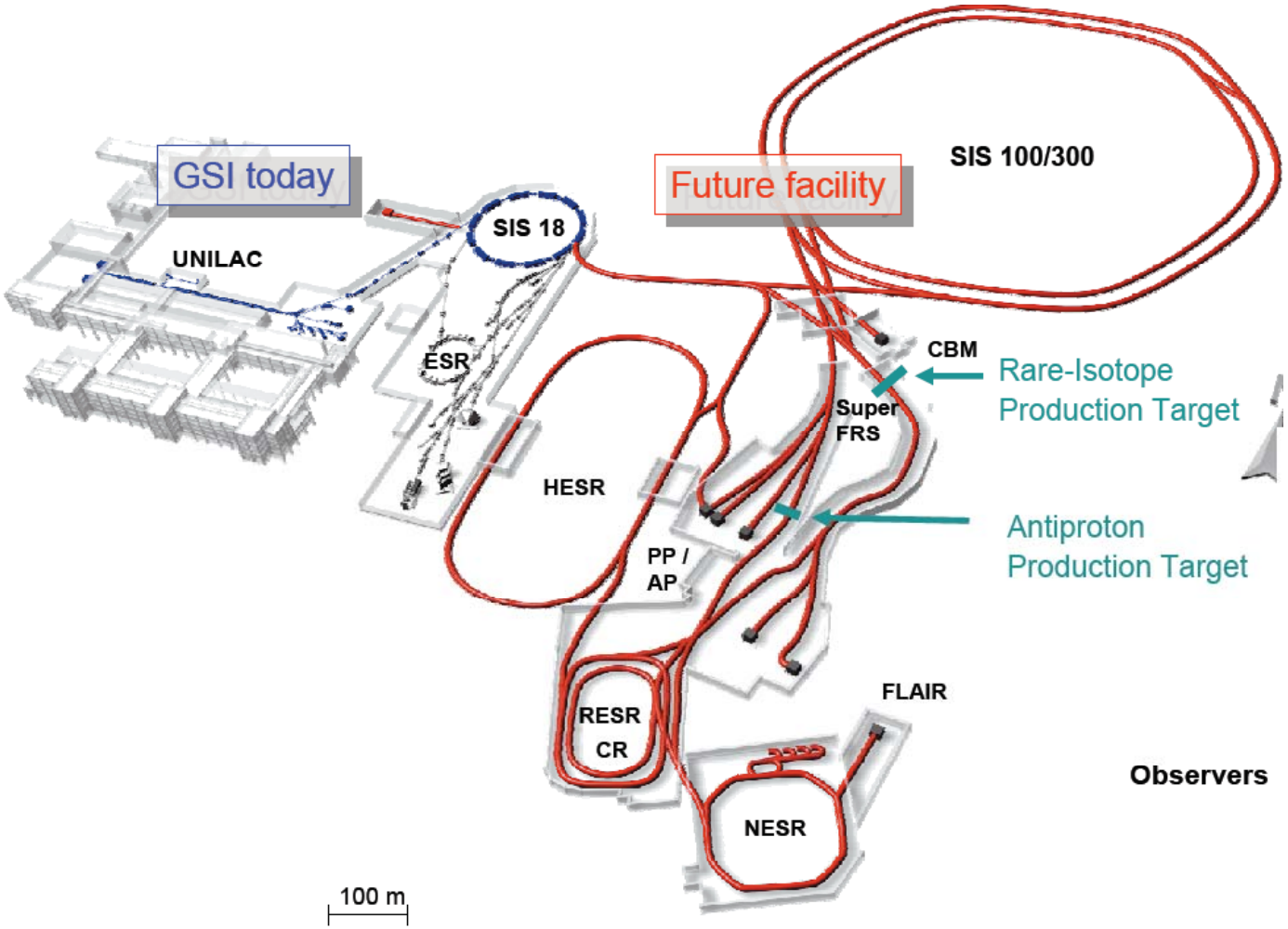
Possible to distinguish A = -1, 0, +1 at 68% C.L. for $Br(\mu^+ \to e^+\gamma) > 10^{-12.5}$ by a polarized MEG

4th session on nuclear physics

4.1: Walter Henning (GSI Darmstadt)

Facility for Antiproton and Ion Research (FAIR project)

new intense beam facilities from anti-protons (0-15 GeV) to U (upto 45 GeV/c) in construction at GSI until 2012 – start of operations in 2012 -2014



- SIS 100: p – U
- SIS 300: heavy ions

- HESR: high energy 3-15 GeV storage ring
- multi storage rings
  CR, RESR, NESR
- RIB up to 1.5 AGeV

4.2: Klaus Jungmann (Univ. Groningen) Research on discrete symmetries with stable and radioactive isotopes

EDM Limits as of summer 2006

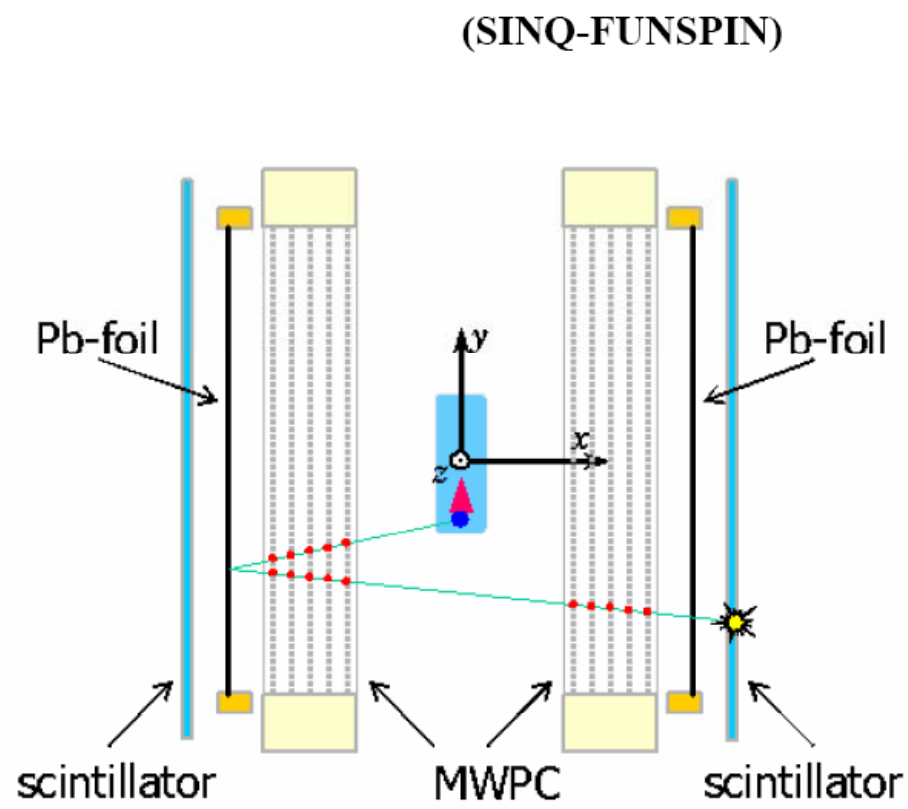
Particle	Exp. Limit [10^{-27} *e* cm]	SM [factor to go]	Possible New Physics [factor to go]
e (Tl)	< 1.6	10^{11}	≤ 1
μ	< 1.05 *10^{9}	10^{8}	≤ 200
τ	< 3.1 * 10^{11}	10^{7}	≤ 1700
n	< 30	10^{4}	≤ 30
Tl (odd p)	< 10^{5}	10^{7}	≤ 10^{5}
Hg (odd n)	< 0.21	10^{5}	various

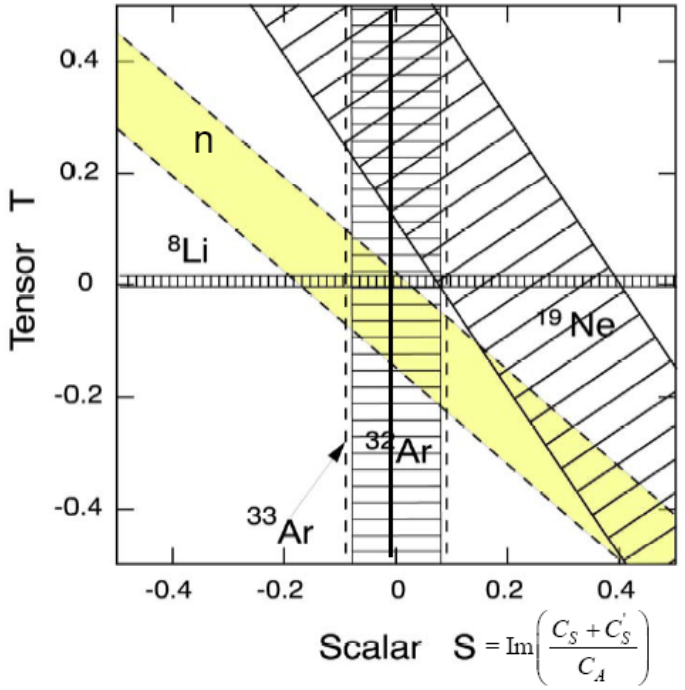
no case is „the best" candididate - we need to test many

4.3: Natal Severijns (Univ. Leuven, Belgium)

Probing exotic weak currents in nuclear β decay

methods: - $F_t(0^+ \rightarrow 0^+)$
- βν-correlation coeff. a (n or nuclei)
- β-asymmetry parameter A (n or nuclei)
- symmetry tests (parity, time reversal violation)





^{8}Li : Sromicki et al., PSI – ETH Zurich

^{19}Ne : F. Calaprice et al., Princeton

^{32,33}Ar : E.G. Adelerger et al., ISOLDE

posters to nuclear physics

- D. Gotta (Mainz) proposes to test effective field theories in pionic atoms and πN, πNN interactions at threshold

- M. Lindroos (CERN) presents the EURISOL project which is a „next generation ISOL facility and plans to use multi-MW proton beams

- M. da Silva et al. (KVI Groningen) present the polarimetry for an EDM search on the deuteron

- J.P. Urrego proposes the development of a solid polarized target for studies of reactions with radioactive ion beams

some conclusions

- all speakers gave impressive views on where the science is standing

- on the posters many new ideas were presented – most often based on the experience of present activities

- the stronghold of ideas came from fundamental neutron physics and flavor physics – that's not surprising, since these fields are where the active researchers have acquired their know-how

- a number of presented ideas (5 - 10) will lead to new proposals for experiments on our proton accelerator