μ Physics at the ν Factory

progress report of the Stopped Muons Working Group*

a van der schaaf _ zürich

phase 1:

Neutrino Factory and Muon Storage Rings at CERN

Report of the Stopped Muons Working Group:
Physics with
Low-Energy Muons at a Neutrino Factory Complex
CERN-TH/2001-231 hep-ph/0109217

- physics motivation
- present experimental limitations
- requirements to muon beams

phase 2:

- design the production targets / beam lines
- set priorities inside the program
- work out some experiments in more detail

*:Aysto Baldini Blondel de Gouvea Ellis Fetscher Giudice Jungmann Lola Palladino Tobe Vacchi van der Schaaf Zuber

Physics with Low-Energy Muons at a Neutrino Factory Complex

Stopped Muons Working Group

What could be reached at a Neutrino Factory Complex ?

Stopped Muons Working Group

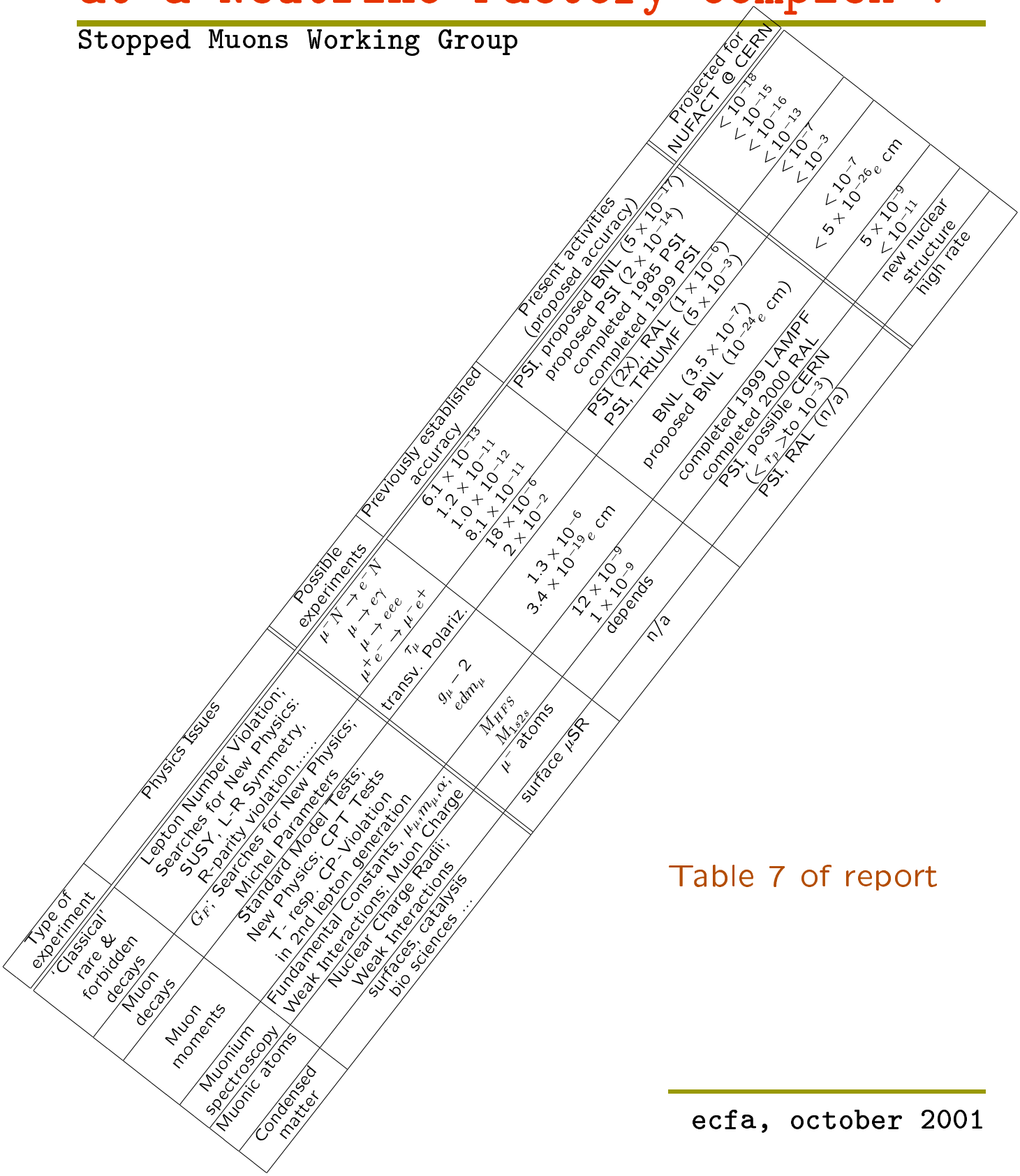


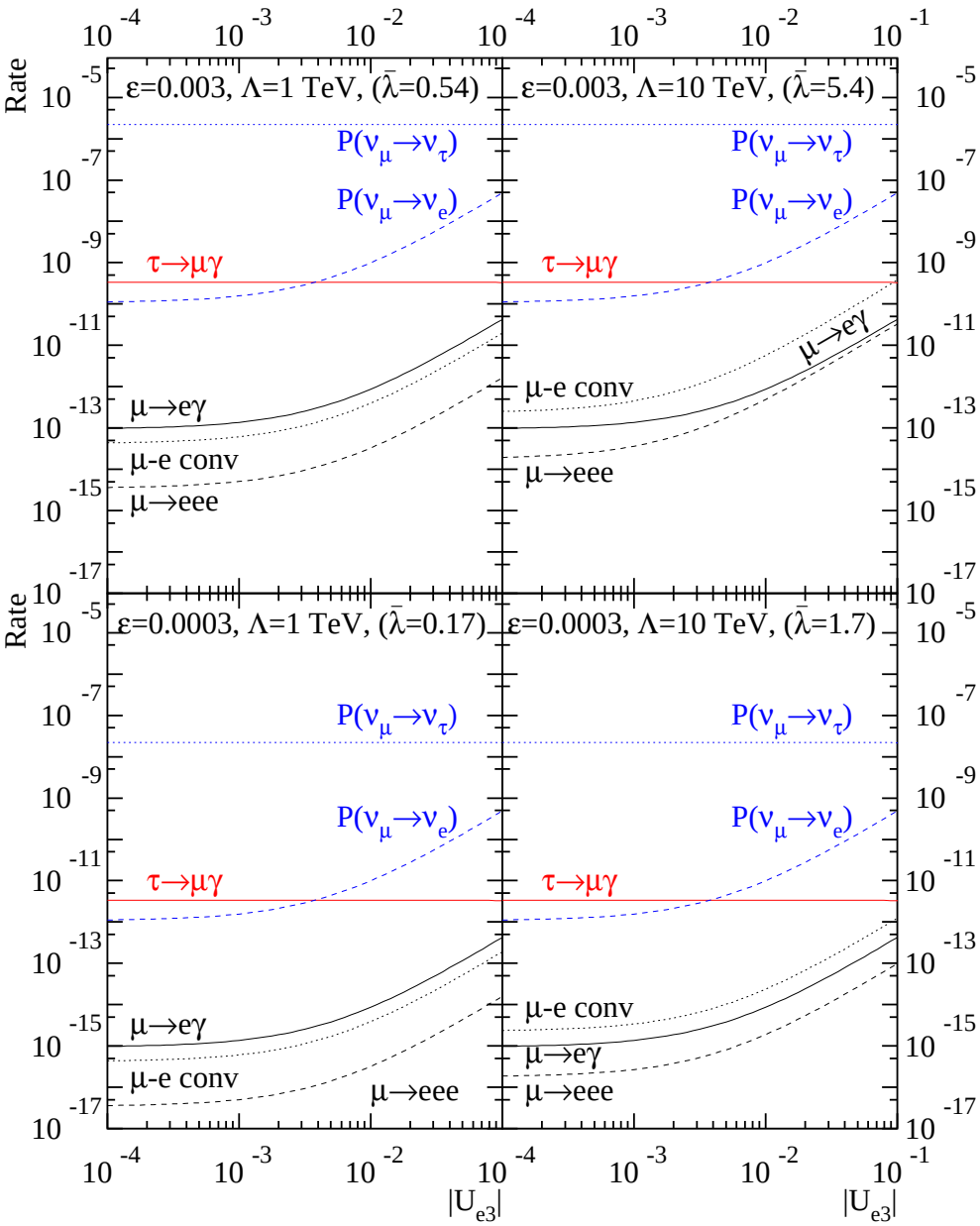
Table 7 of report

Rare muon processes

in models with extra dimensions

A. de Gouvea, G.F. Giudice, A. Strumia and K. Tobe

hep-ph/0107156

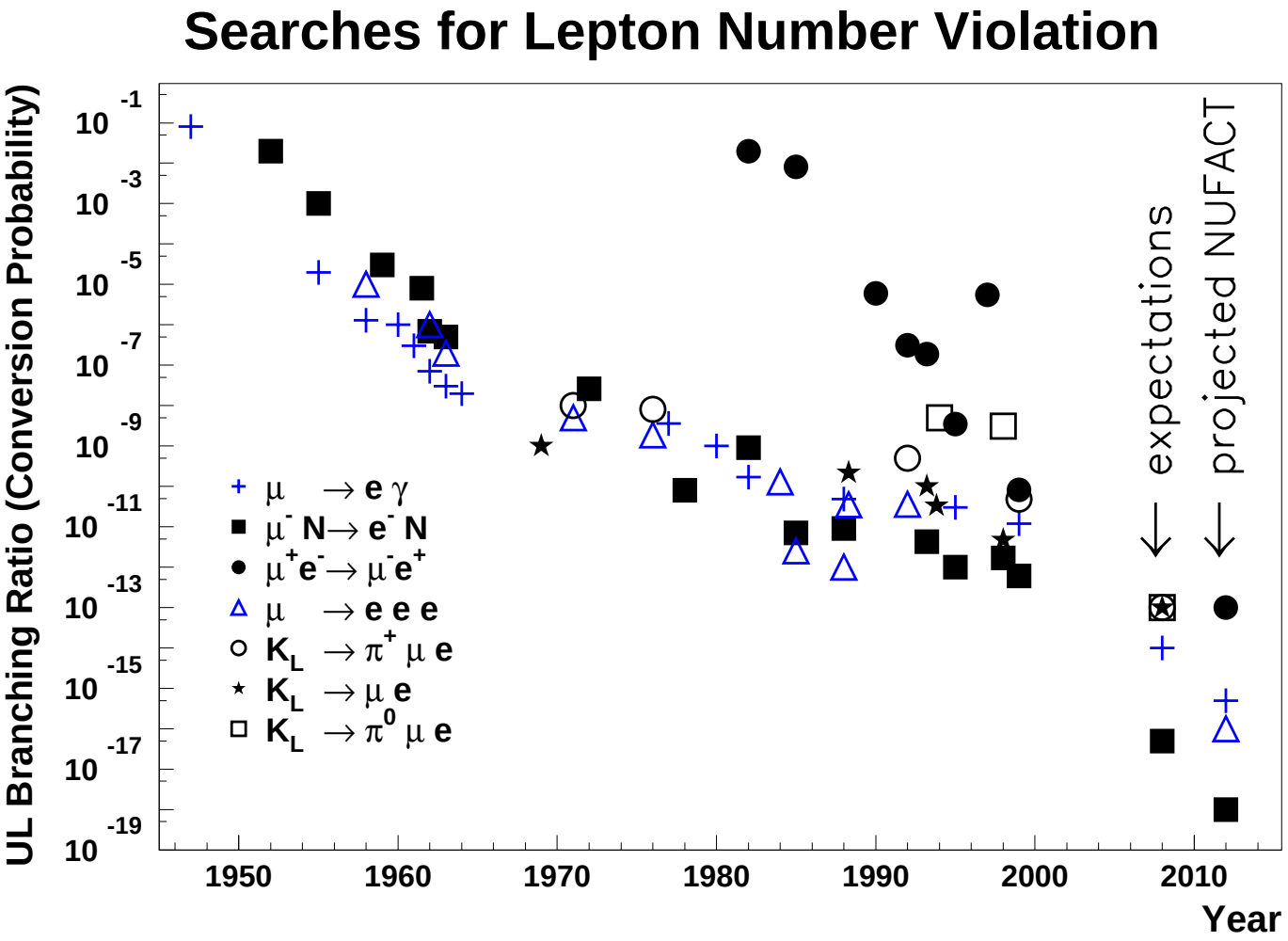


Assumptions: maximal mixing for atmospheric and LMA for solar sector, no CP-violation in ν mixing matrix and hierarchical μ masses.

Charged Lepton Flavor Violation*

historical development

a van der schaaf _ zürich

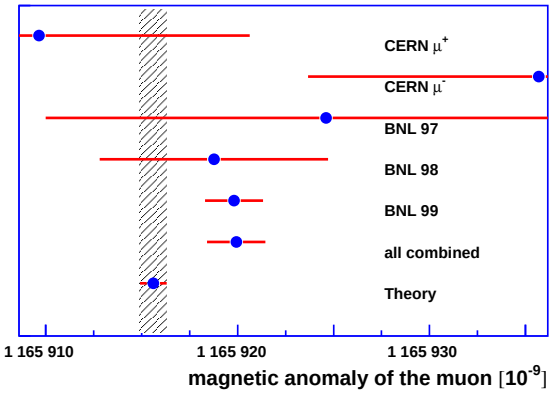


*: see presentation at October 2000 meeting

Muon g-2

BNL E821

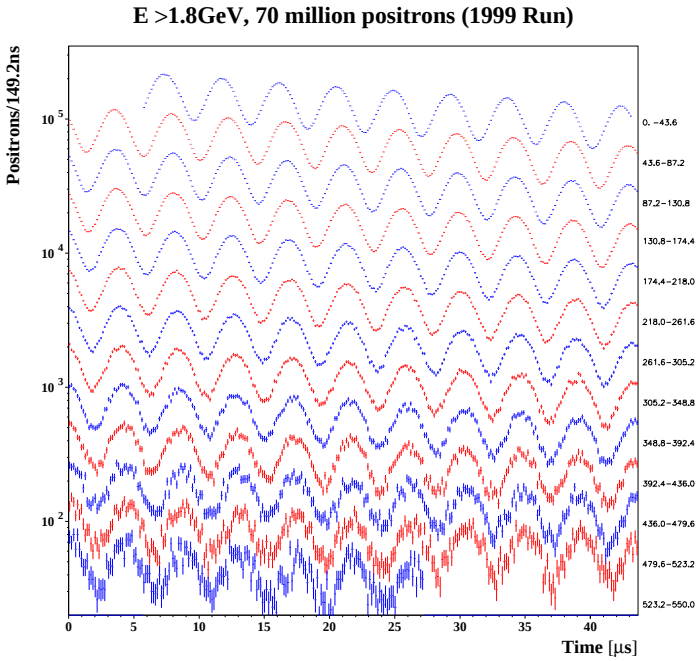
H.N. Brown et al., Phys.rev.Lett.**86** (2001) 2227.



g-2 values from recent measurements and from the calculation by Davier and Höcker

Vernon Hughes:

1. new physics beyond the Standard Model, such as supersymmetry.
2. small statistical probability that the experimental and theoretical values are consistent.
3. although unlikely, there is always the possibility of mistakes in experiments and theories.



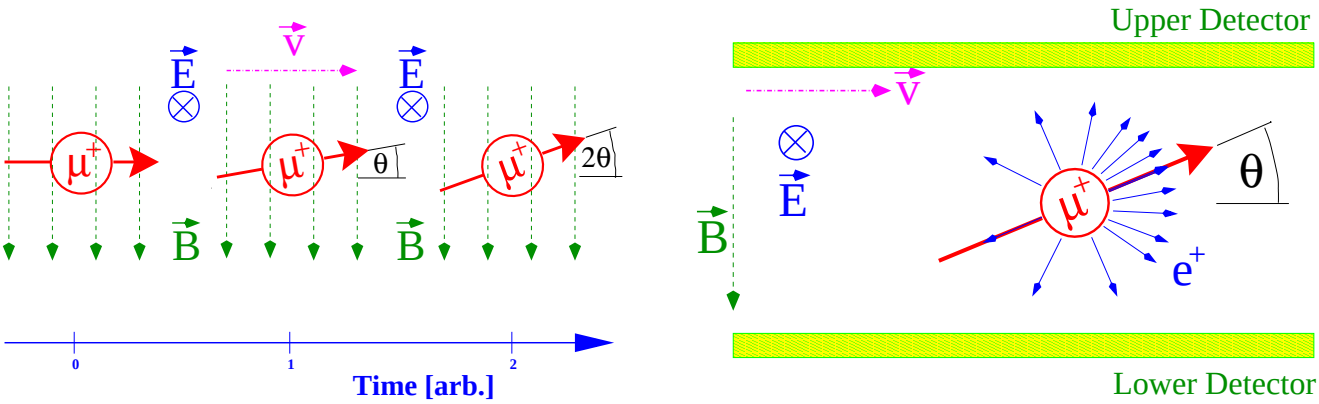
sample of new data: no sign of background after ten dilated 64 μs lifetimes

Muon electric dipole moment

T violation

BNL g-2 collaboration

	edm (e.cm)
Standard Model:	10^{-35}
present limit:	10^{-18}
proposed sensitivity	10^{-24}
electron limit:	10^{-27}



Principle of a novel muon edm measurement.
Muons move in a magnetic storage ring with a radial E field superimposed. Θ would grow with time.

$$\vec{\omega} = -\frac{e}{m}\{a\vec{B} + (\frac{1}{\gamma^2-1} - a)\frac{\vec{\beta}\times\vec{E}}{c} + \frac{\eta}{2}(\frac{\vec{E}}{c} + \vec{\beta}\times\vec{B})\}$$

$$\text{edm}_\mu = \frac{\eta}{2}\frac{e\hbar}{2mc}\ \text{e.cm}$$

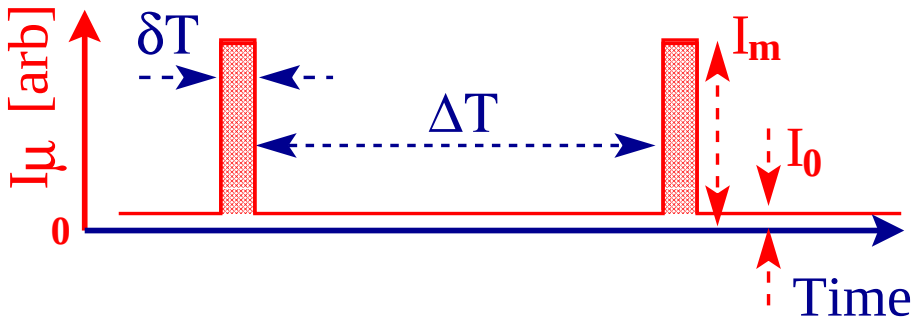
In a g-2 experiment one chooses $\frac{1}{\gamma^2-1} - a = 0$,
i.e. $\gamma = 29.3$

Here one chooses $a\vec{B} + (\frac{1}{\gamma^2-1} - a)\frac{\vec{\beta}\times\vec{E}}{c} = 0$,
i.e. $\gamma = 5$, B=0.24 T, E=2 MV/m.

Muon beam requirements

Tab.6 from report

a van der schaaf _ zürich



Experiment	q	N_μ	I_0/I_m <	δT <[ns]	ΔT >[μs]	E_μ [MeV]	$\Delta p_\mu/p_\mu$ [%]
$\mu^- N \to e^- N^\dagger$	-	10^{21}	10^{-10}	100	1	20	< 10
$\mu^- N \to e^- N^\ddagger$	-	10^{20}	n/a	n/a	n/a	< 20	< 10
$\mu \to e\gamma$	+	10^{17}	n/a	n/a	n/a	1...4	< 10
$\mu \to eee$	+	10^{17}	n/a	n/a	n/a	1...4	< 10
$\mu^+ e^- \to \mu^- e^+$	+	10^{16}	10^{-4}	1000	20	1...4	1...2
τ_μ	+	10^{14}	10^{-4}	100	20	4	1...10
transv. pol.	+	10^{16}	10^{-4}	0.5	0.02	30-40	1...3
$g_\mu - 2$	$\pm$	10^{15}	10^{-7}	50	10^3	3100	10^{-2}
edm_μ	$\pm$	10^{16}	10^{-6}	50	10^3	1000	10^{-3}
M_{HFS}	+	10^{15}	10^{-4}	1000	20	4	1...3
M_{1s2s}	+	10^{14}	10^{-3}	500	10^3	1...4	1...2
μ^-atoms	-	10^{14}	10^{-3}	500	20	1...4	1...5
cond. matter (bio sciences)	$\pm$	10^{14}	10^{-3}	50	20	1...4	1...5

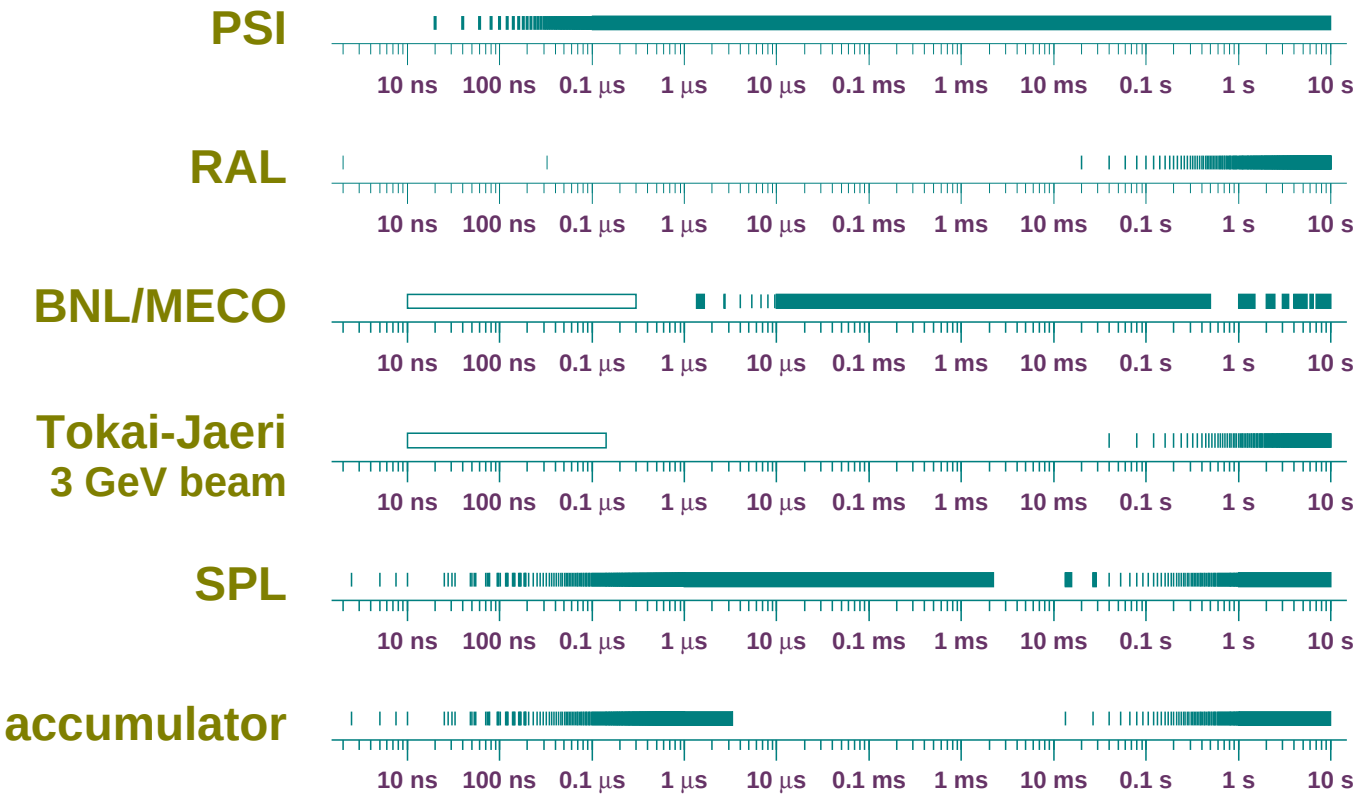
† Scenario in which a pulsed beam is utilized.

‡ Scenario in which a continuous beam after the muon cooling stage is employed.

Proton time structure

comparison with other accelerators

a van der schaaf _ zürich



μ^--e$^-$ conversion (depending on Z)

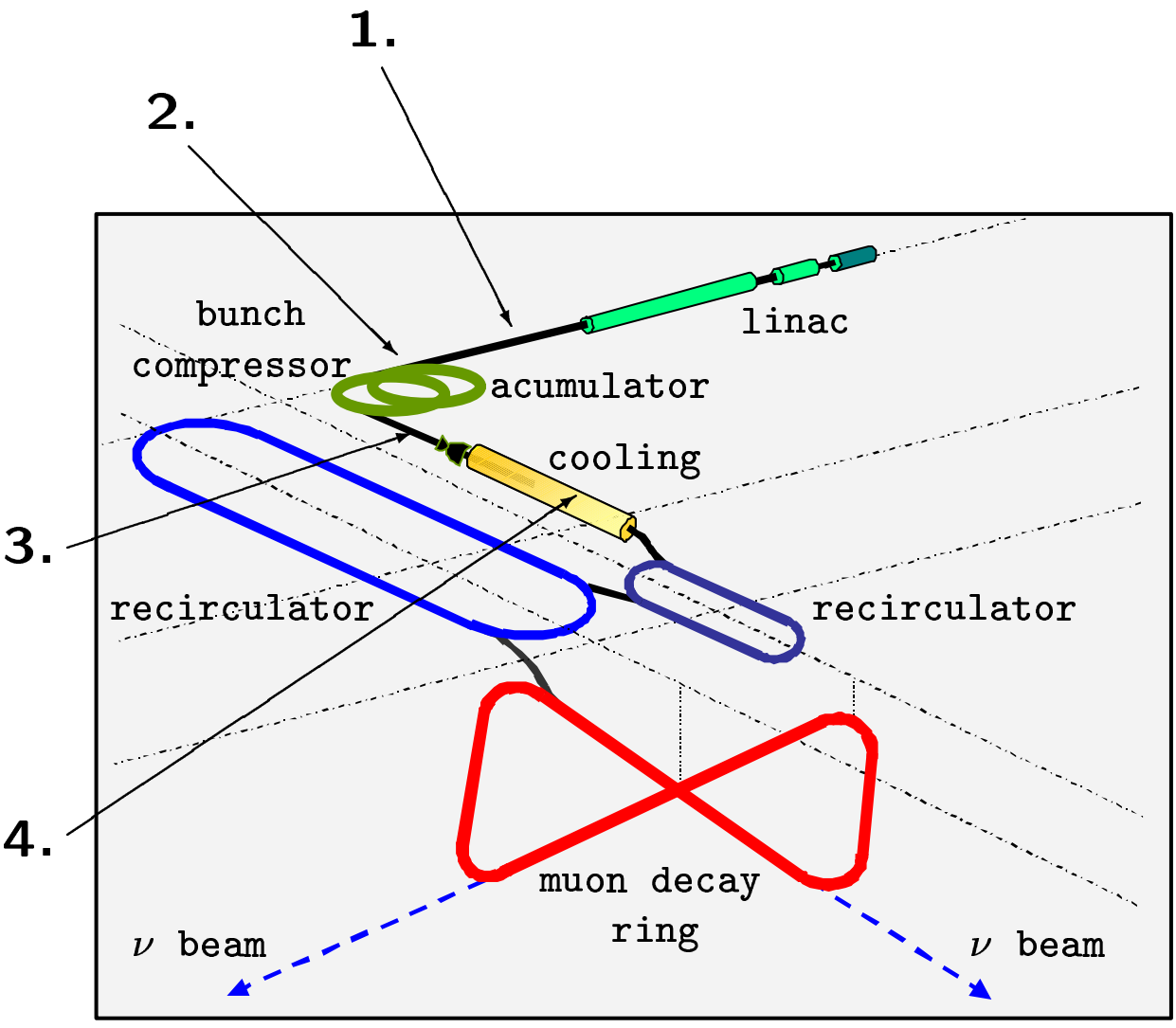
$\mu^+ \to e^+\gamma$, $\mu^+ \to 3e$

(g-2)$_\mu$

beam off / on

Options for slow $\mu^{\pm}$ beams

a van der schaaf _ zürich

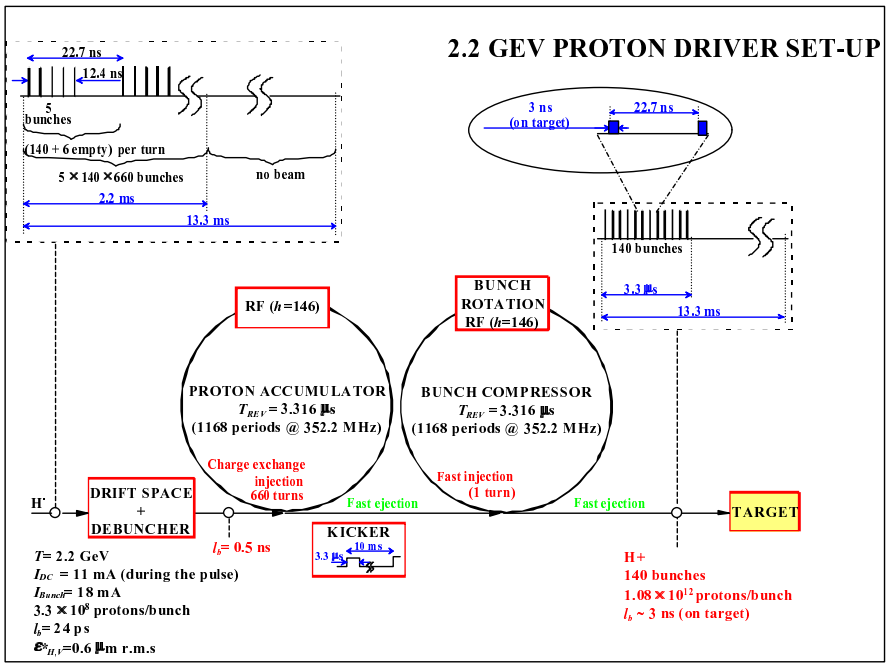


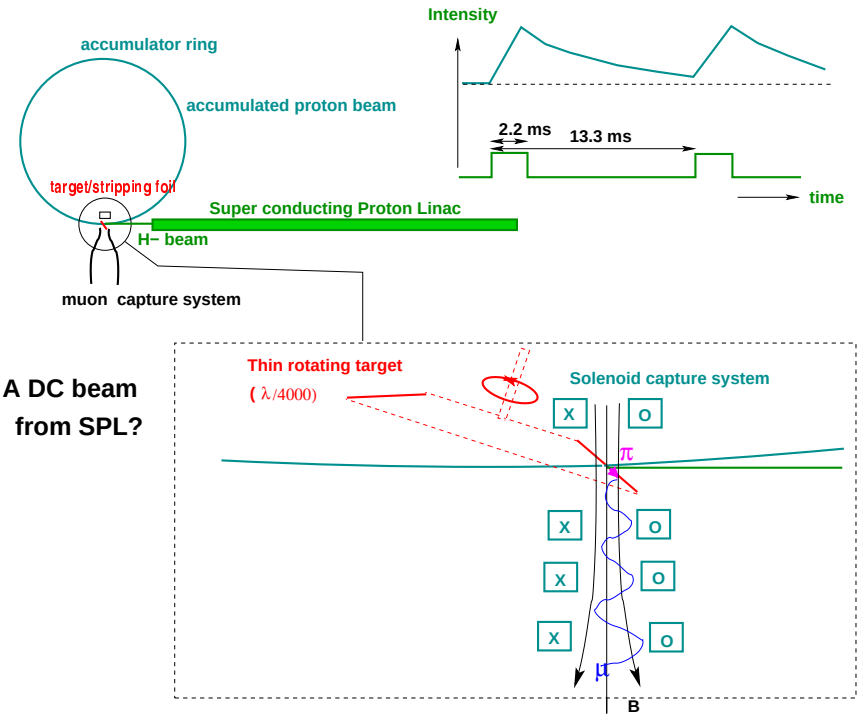
1. target for pulsed beam
2. thin target for quasi-DC beam
3. target for beam with dedicated time structure
4. target for pion-free pulsed beam

Internal target in accumulator

DC beams of surface μ^+ and cloud μ^-

Blondel, Fabre, Gilardoni, Vassilopoulos
CERN Neutrino Factory Note 6





A DC beam from SPL?

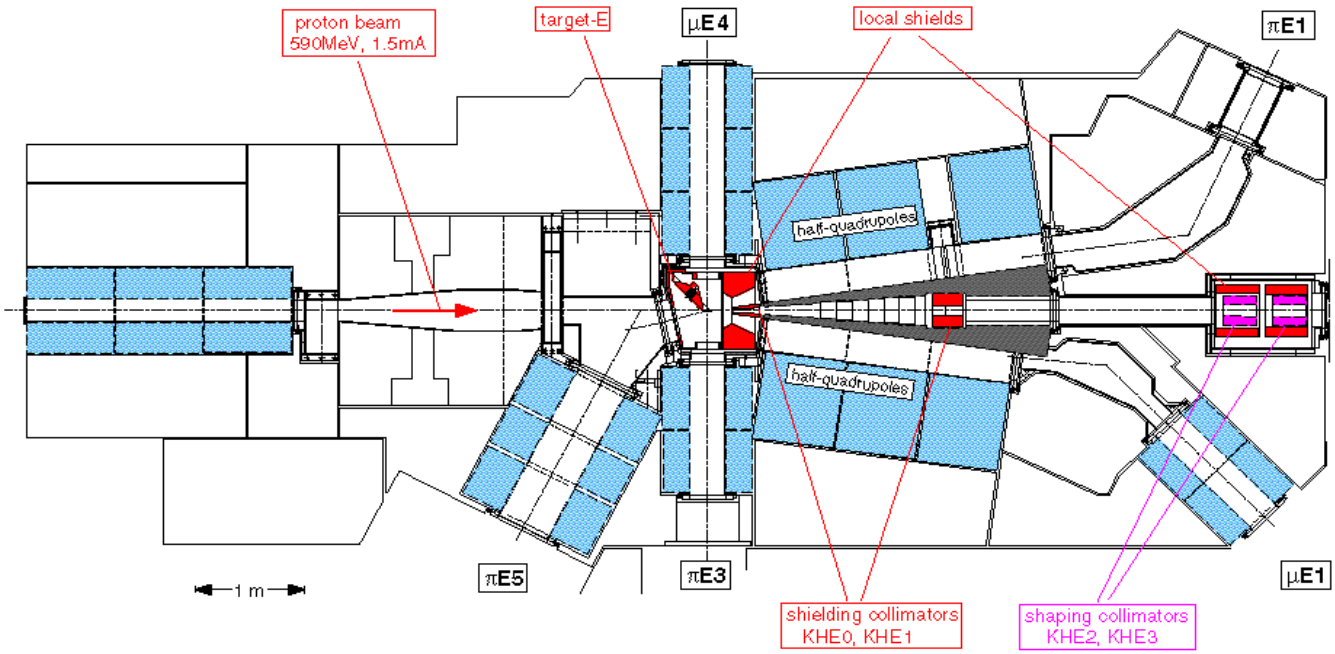
A thin internal target for a quasi-continuous muon beam

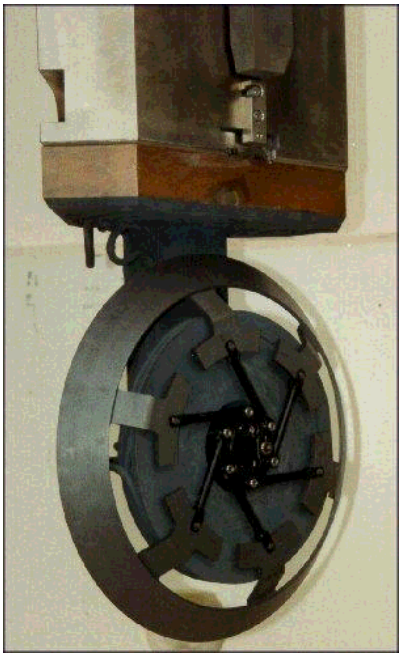
ecfa, october 2001

PSI 6 cm production target

for 1 MW proton beam

a van der schaaf _ zürich





target wheel

- 1.78 g/cm^3 polycrystalline graphite
- mean diameter 45 cm
- length in beam direction 6 cm
- heating 45 kW for I_p=1.5 mA
- cooled by thermal radiation to 1500 K

Outlook

plans of the working group

a van der schaaf _ zürich

- low-energy muon physics contributes to many fields of basic research
- we know the beam intensities and time structures required for significant progress in most areas
- the CERN neutrino factory could deliver 10^{3-4} times more muons than available now
- work to be done:
  - set priorities in the program
  - define production targets and beam lines
  - work out most-promising experiments (μ-e conversion, g-2?)