Wrażenia z
Sympozjum C.E.R.N. Council Strategy Group

Orsay

30ty stycznia -1szy lutego 2006

Ewa Rondio

Seminarium ZFWE, 24 lutego 2006

Przepraszam za „mieszankę językową”
Będę używać fragmentów referatów z sympozjum

Cel sympozjum:

zebranie informacji i opinii środowiska fizyki wysokich energii w Europie

Materiały dostępne w internecie na stronie

http://cern.ch/council-strategygroup

Informacje, dokumenty przesłane dla SG
(input received)
Nagrania video referatów
i dyskusji podczas sympozjum
teksty prezentacji
teksty prezentowanych podsumowań sesji
(Open Symposium/ Final Agenda)

Do czego sympozjum zbierało materiały …

Remit of the Strategy Group (1)

- At a meeting in Zeuthen-Berlin from 2-5/6 May 2006, the Strategy Group shall produce a Draft Strategy Document (DSD) addressing the main lines of Particle Physics in Europe, accelerator-based and non-accelerator based, including R&D for novel accelerator and detector technologies. Representatives of the Observer States, and the chairmen of FALC, ApPEC and NuPECC will be invited to attend the meeting as observers.

- The DSD shall comprise a series of ordered and concise statements, of 1-2 pages, followed by presentations and discussions of the initiatives not exceeding 25 pages.

…

- The term of office of the SG will end at the time of the special Council meeting dedicated to the discussion and approval of the Strategy Document.

Ken Peach

Dalsze kroki

- **Workshop w Zeuthen/Berlin**
  - 2-6ty maja
  - Przygotowanie „Draft Strategy Document” (DSD)
- **Spotkanie CERN Council w Lizbonie**
  - 14ty lipica 2006
  - CEL: Jednomyślne przyjęcie DSD

The Strategy Group

- **Co-chairpersons**
  - T. Åkesson Lund University
  - K. Peach Oxford University
- **Preparatory group**
  - R. Aleksan Saclay
  - S. Bertolucci Frascati-INFN
  - A. Blondel Geneva University
  - M. Cavalli-Sforza IFAE
  - R. Heuer DESY
  - F. Linde NIKHEF
  - E. Rondio Soltan Institute for Nuclear Studies, Warsaw
  - B. Webber Cambridge University
- **Directors**
  - R. Aymar CERN CEO
  - M. Calvetti Director of LNF-INFN
  - E. Coccia Director of LNGS-INFN
  - J. Engelen CERN CSO
  - R. Eichler Director of PSI
  - A.Wagner Chairperson of the DESY Directorate
  - J. Womersley Director of EPP @ RAL
  - G. Wormser Director of LAL/Orsay
  - J. Zinn-Justin Director of Dapnia
- **Scientific secretary**
  - M. Mangano CERN
- **Members from delegations**
  - W. Majerotto Institut für Hochenergiephysik, Vienna
  - R. Gastmans Katholieke Universiteit, Leuven
  - J. Chyla Institute of Physics, Prague
  - H. Boggild Niels Bohr Institut, Copenhagen
  - J. Tuominiemi Helsinki Institute of Physics
  - J. Feltesse DAPNIA
  - G. Herten Albert-Ludwigs Universität Freiburg
  - D. Nanopoulos Academy of Athens
  - G. Vesztergombi KFKI Hungarian Academy of Sciences
  - L. Cifarelli University of Bologna
  - S. Stapnes Univ. of Oslo
  - J. Nassalski Soltan Institute for Nuclear Studies, Warsaw
  - G. BarreiraLIP
  - M. Aguilar CIEMAT, Madrid
  - B. Åsman Stockholm University
  - Sybrand de Jong, University of Nijmegen
  - A. Clark University of Geneva
  - R. Wade PPARC

CERN observers invited to Zeuthen, + APPEC, NuPEC, FALC…

OPEN SYMPOSIUM ON

EUROPEAN STRATEGY FOR PARTICLE PHYSICS

under the aegis of the CERN Council Strategy group

January 30th - February 1st, 2006
Laboratoire de l'Accélérateur Linéaire
Orsay, France
http://symposium.lal.in2p3.fr

Scientific Committee
Torsten Åkesson *(chair)*
Roy Aleksan
Sergio Bertolucci
Alain Blondel
Matteo Cavalli Sforza
Rolf Heuer
Frank Linde
Michelangelo Mangano
Ken Peach *(chair)*
Ewa Rondio
Bryan Webber

Local Organizing Committee
Jean Eric Campagne
Christian Helft
Hélène Kérec
Nicole Mathieu *(chair)*
François Richard
Guy Wormser
Zhiqing Zhang

Secretariat
Catherine Bourge
Catherine Eguren

IN2P3 · Faculté des sciences d'Orsay · cea · LAL

Jak wyglądała organizacja

Przyjechało do Orsay ponad 450 uczestników

Transmisja przez internet trwała cały czas

maksymalna liczba osób jednocześnie
śledzących obrady - ponad 70
całkowita liczba różnych IP ponad 350

Otwarcie obrad - Enzo Iarocci (*La Sapienza, Rome*)

Informacja organizacyjna, cele itd.

Sesja wprowadzająca „Overviews”

2 referaty:

The physics landscape - Gian Giudice (*CERN, PH-TH*)

The infrastructure: present and future options
- John Womersley (*RAL*)


Wednesday 01 February 2006
Closing Session
Lunch break
Strategy Group Closed Session

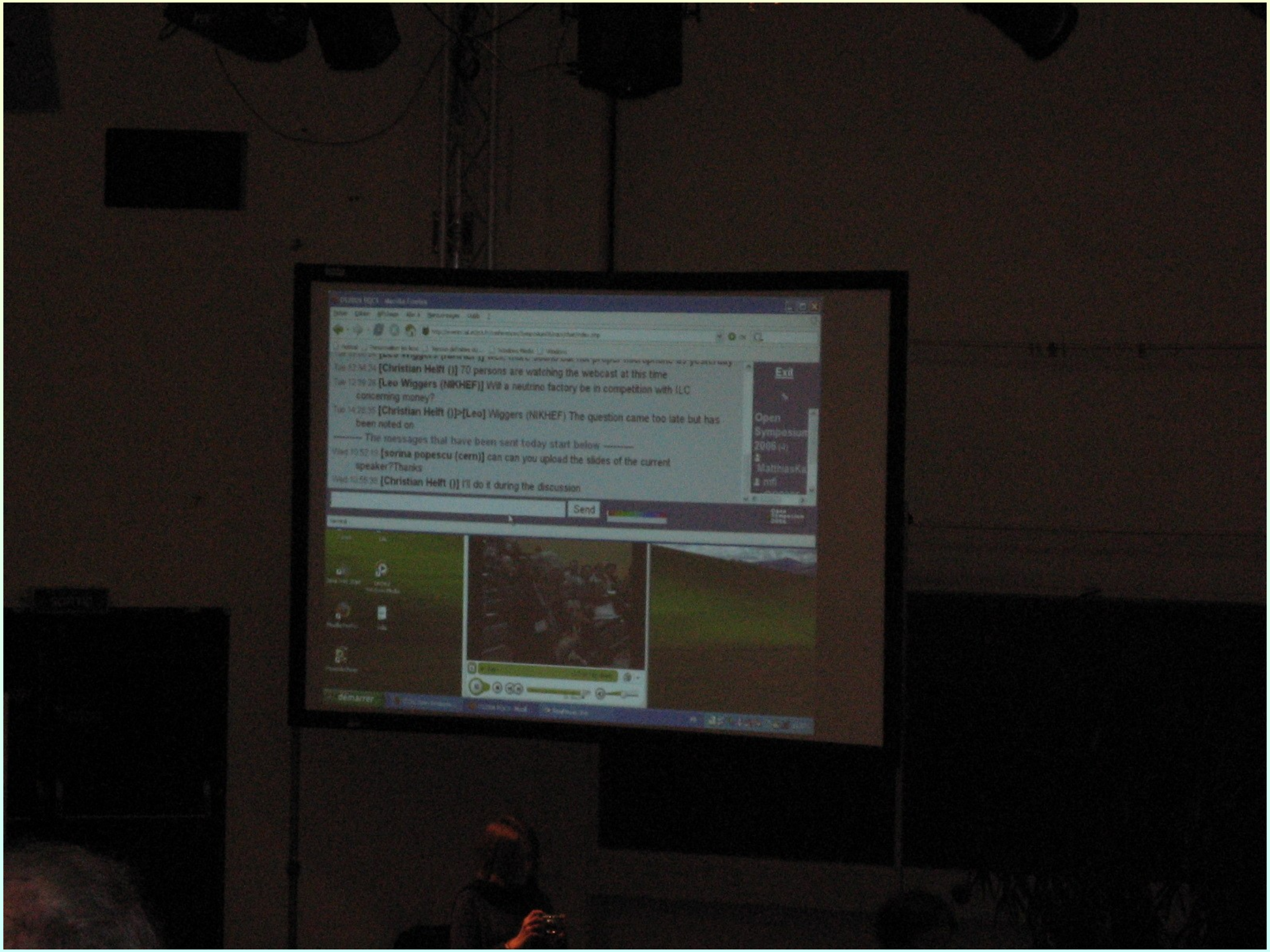
Po sesji otwierającej odbyło się:

- **8 sesji tematycznych**

  każda składała się
  z 40 minut prezentacji
  (jeden lub 2 referaty)
  50 minut dyskusji

- **Sesja podsumowująca**

  z prezentacjami podsumowań dyskusji podczas poszczególnych sesji
  całościowym podsumowaniem i opisem dalszych kroków
  dyskusją dotyczącą spraw ogólnych



[Christian Helft ()] 70 persons are watching the webcast at this time

[Leo Wiggers (NIKHEF)] Will a neutrino factory be in competition with ILC concerning money?

[Christian Helft ()]>[Leo] Wiggers (NIKHEF) The question came too late but has been noted on

——— The messages that have been sent today start below ———

[sorina popescu (cern)] can can you upload the slides of the current speaker?Thanks

[Christian Helft ()] I'll do it during the discussion

Sesje tematyczne :

- The Physics of the High Energy Frontier - Klaus Desch (*Freiburg Univ.*)
- Accelerators for the High Energy Frontier - Pantaleo Raimondi (*LNF*)
- Theoretical Particle Physics in Europe - Nigel Glover (*IPPP, Durham)*
- Flavour physics -Andreas Hoecker (*CERN, PH*)
- Theoretical aspects of neutrino physics - Patrick Huber (*Uni.Wisconsin*)

  Neutrino physics: experiments and infrastructure - Anselmo Cervera (*Univ of Geneva*)
- Precision measurements - Gerco Onderwater (*Groningen, KVI*)
- Non-accelerator particle and astroparticle physics - Nathalie Palanque-Delabrouille (*DAPNIA, Saclay*)
- QCD dynamics - Jonathan Butterworth (*University Collge London*)

  Relativistic Heavy Ions - Jean-Yves Ollitrault (*SPhT, Saclay*)

Największe emocje wzbudziły pierwsze 2 sesje czyli „High energy frontiers”

- Wrażenia z nich przedstawi Filip Żarnecki

- Prezentacja fizyki teoretycznej

  – obejmuje głównie statystyczne zestawienia cytowań

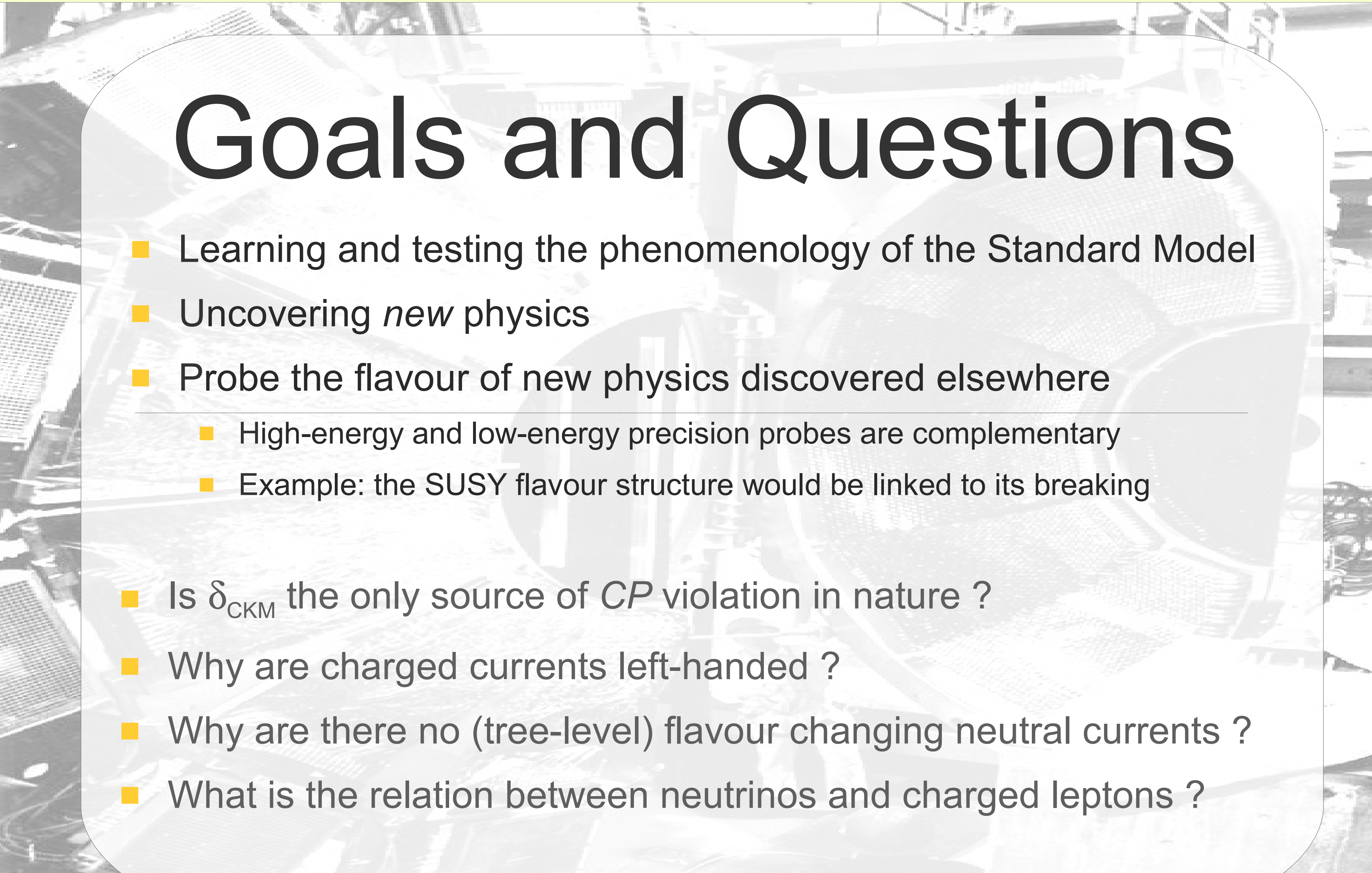
  nie będzie tu omawiana

- Pozostaje 5 sesji

  przedstawię podsumowania referatów,

  tematy do dyskusji

  wnioski z podsumowań prowadzących sesje



Goals and Questions

- Learning and testing the phenomenology of the Standard Model
- Uncovering *new* physics
- Probe the flavour of new physics discovered elsewhere

  - High-energy and low-energy precision probes are complementary
  - Example: the SUSY flavour structure would be linked to its breaking

- Is δ_{CKM} the only source of *CP* violation in nature ?
- Why are charged currents left-handed ?
- Why are there no (tree-level) flavour changing neutral currents ?
- What is the relation between neutrinos and charged leptons ?

digression: Flavour Strategies: Setting the Stage

Measurement proposals should be examined as a function of their capabilities to:

■ properly derive the fundamental parameters of the theory (requires control of the (mostly) hadronic uncertainties)	example: $\sin(2\beta)$ counter example: ε'/ε
■ be competitive with other measurements with the same focus	huge number of examples, but also a few counter examples …
■ best (but not mandatory): be either *not* sensitive, or *very* sensitive probes to new physics	CKM angle γ from $B \rightarrow DK$ and through $B\bar{B}$ mixing
■ However (!): also the somewhat "less prominent" measurements can be crucial to improve our description/understanding of the theory (QCD)	form factors, distribution functions, cross sections, tests of lattice QCD

Planned experiments that were not ratified

Approved experiments (mostly in construction)

New proposals

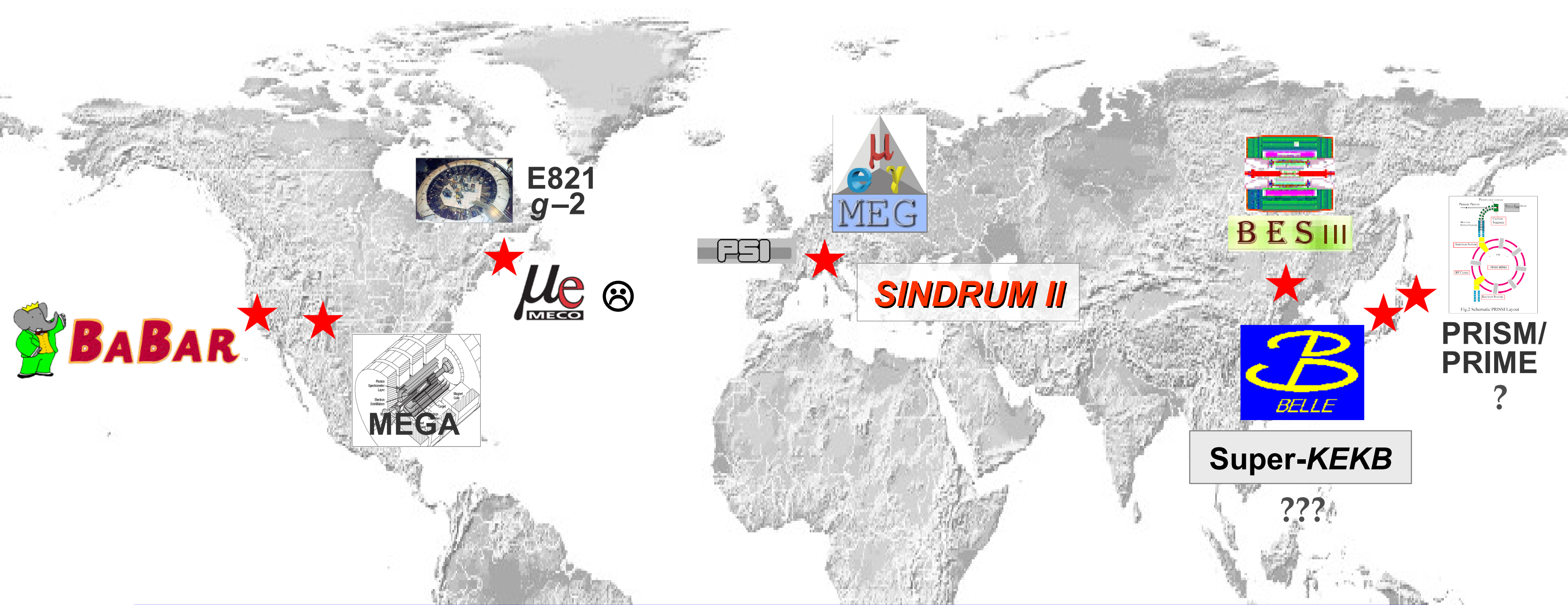
Currently running or recently ended programs

CKM Physics and *CP* Violation

Worldwide Experimental Facilities

Charged-Lepton Physics & LFV

Worldwide Experimental Facilities



Present and future experiments

Not shown on this map: experiments searching for electron and muon electric dipole moments

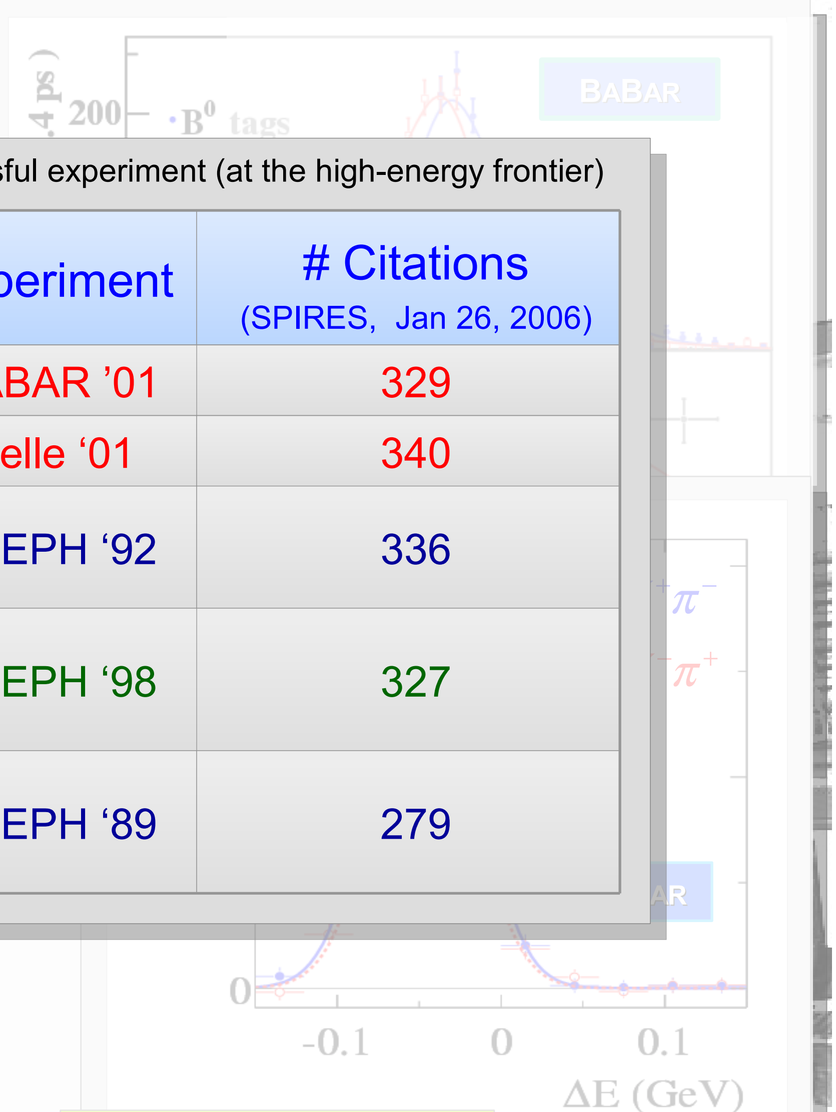
Discovery of *CP* Violation in the *B* System

- *CP* Violation due to the interference of decays

compare the impact of *B*-flavour physics with another successful experiment (at the high-energy frontier)

Title (of physics paper)	Experiment	# Citations (SPIRES, Jan 26, 2006)
"Observation of CP violation in the B^0 system"	BABAR '01	329
	Belle '01	340
"Searches for new particles in Z decays using the Aleph detector"	ALEPH '92	336
"A measurement of the inclusive $b \to s\gamma$ branching ratio"	ALEPH '98	327
"Determination of the number of light neutrino species"	ALEPH '89	279

$\mathrm{Prob}(\bar{B} \to \bar{f})$ ą $\mathrm{Prob}(B \to f)$



$A_{CP} = -(11.5 \pm 1.8)\%$

The CKM Matrix: State of the Art

EPS 2005

Measurement of Wolfenstein parameters:

- λ from $|V_{ud}|$ (nuclear transitions) and $|V_{us}|$ (semileptonic *K* decays)

  → combined precision: 0.5%; unitarity problem solved

- A from $|V_{cb}|$ (inclusive and exclusive semileptonic *B* decays)

  → combined precision: 1.8%

- $\bar{\rho}$, $\bar{\eta}$ from (mainly) CKM angle measurements:

  → combined precision: 20% (ρ), 7% (η)

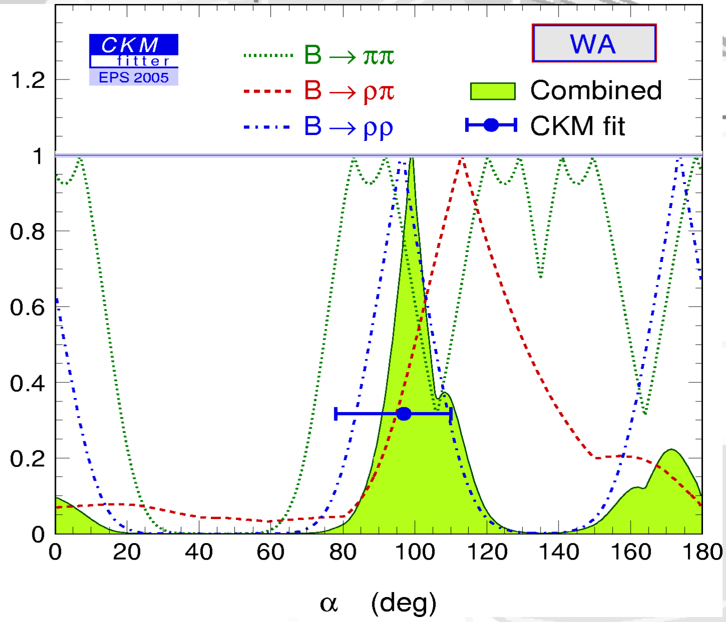
Results on the CKM angles:

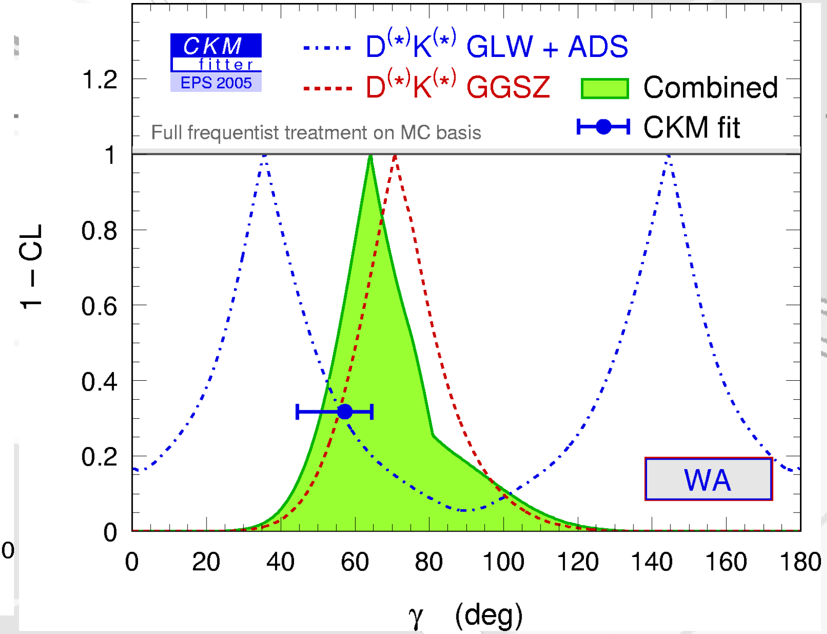
$$\alpha = \left(99\,^{+13}_{-8}\right)^\circ$$

$$\beta = \left(21.7\,^{+1.3}_{-1.2}\right)^\circ$$

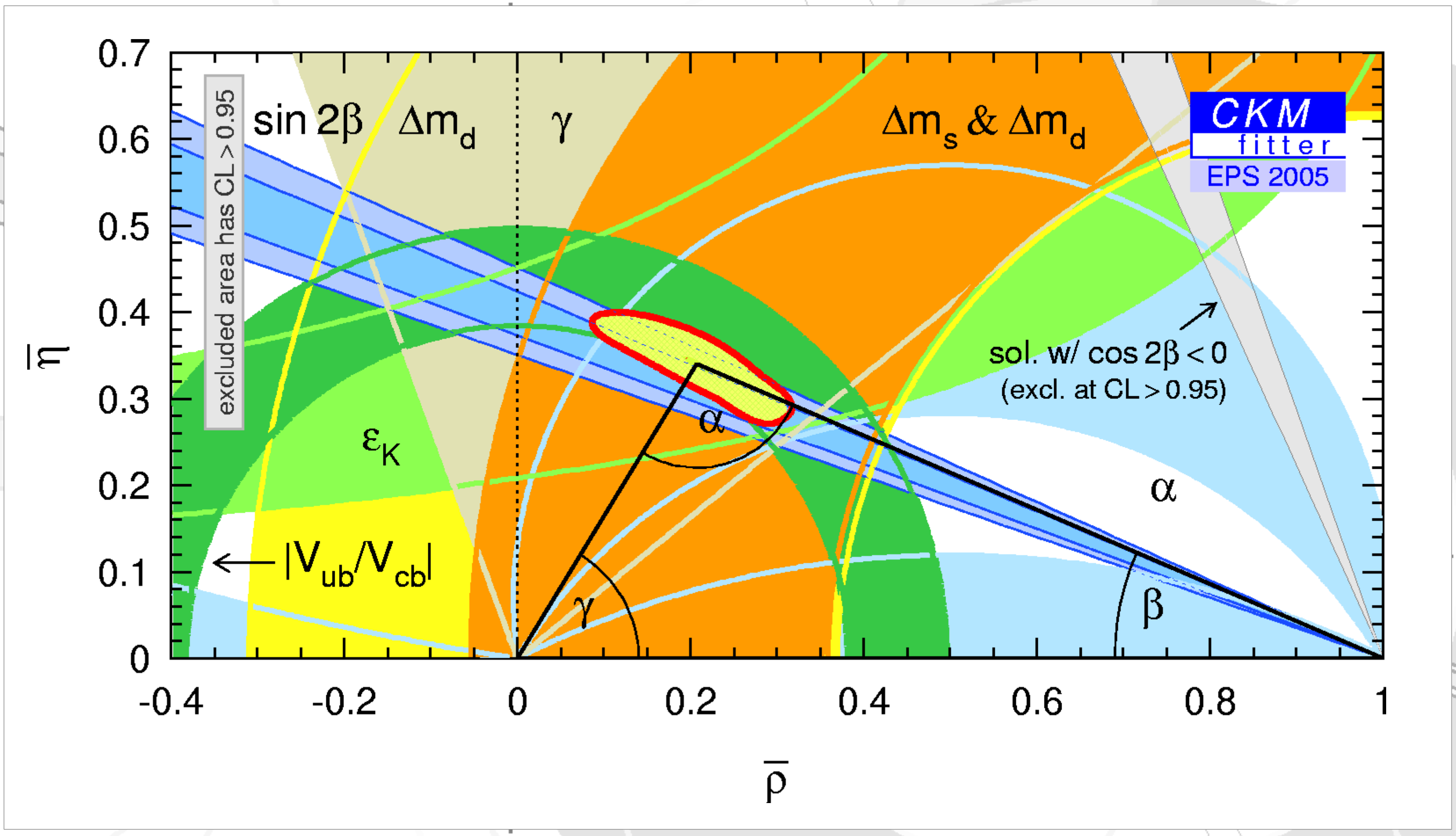
$$\gamma = \left(63\,^{+15}_{-12}\right)^\circ$$

$$\Sigma = \left(184\,^{+20}_{-15}\right)^\circ$$





The Unitarity Triangle from the global CKM fit

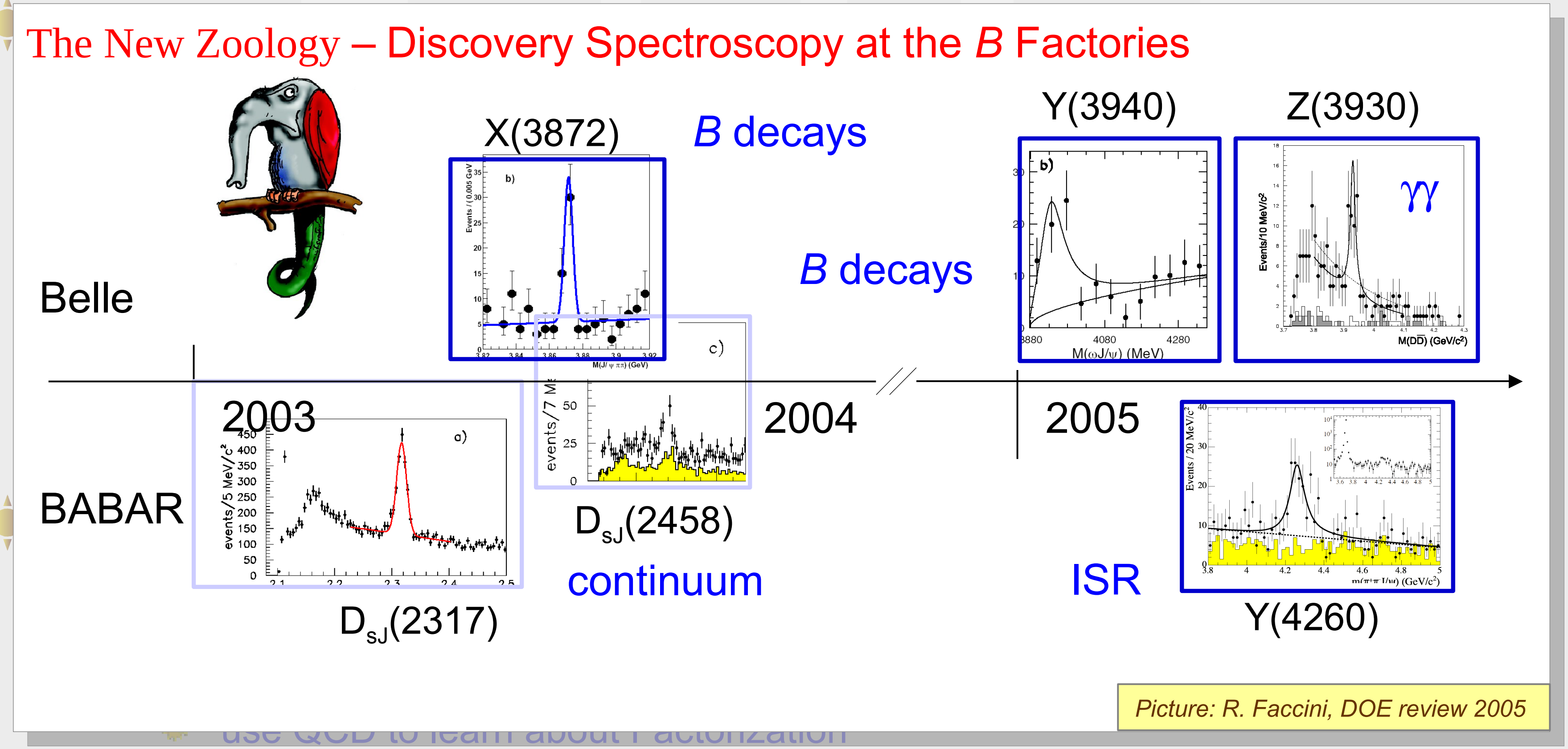


Inputs:

- $\left|\frac{V_{ub}}{V_{cb}}\right|$
- Δm_d
- Δm_s
- $B \to \tau\nu$
- $|\varepsilon_K|$
- $\sin 2\beta$ & $\cos 2\beta$
- α
- γ

No hint for new physics

There are many more Results !



The New Zoology – Discovery Spectroscopy at the *B* Factories

Belle

BABAR

X(3872)

B decays

B decays

Y(3940)

Z(3930)

2003

2004

2005

$D_{sJ}(2317)$

$D_{sJ}(2458)$

continuum

ISR

Y(4260)

Picture: R. Faccini, DOE review 2005

Example of interpretations: Y(4260)

Threshold effect

Close,Page,hep-ph/0507199

Conventional charmonium: (cc) bound states (+mixing,+coupled channels)

Llanes-Estrada,hep-ph/0507035;

Charmonium hybrids: ccg

Zhou,hep-ph/0507025;Kou,Pene,hep-ph/0507119; Close,Page,hep-ph/0507199

Example of interpretations: Y(4260)

Tetraquarks ccqq

Zhou,hep-ph/0507025;

Molecules (cc)(qq)

Liu,Zeng,Li,hep-ph/0507177;

Diquark-antidiquark (cq)(cq)

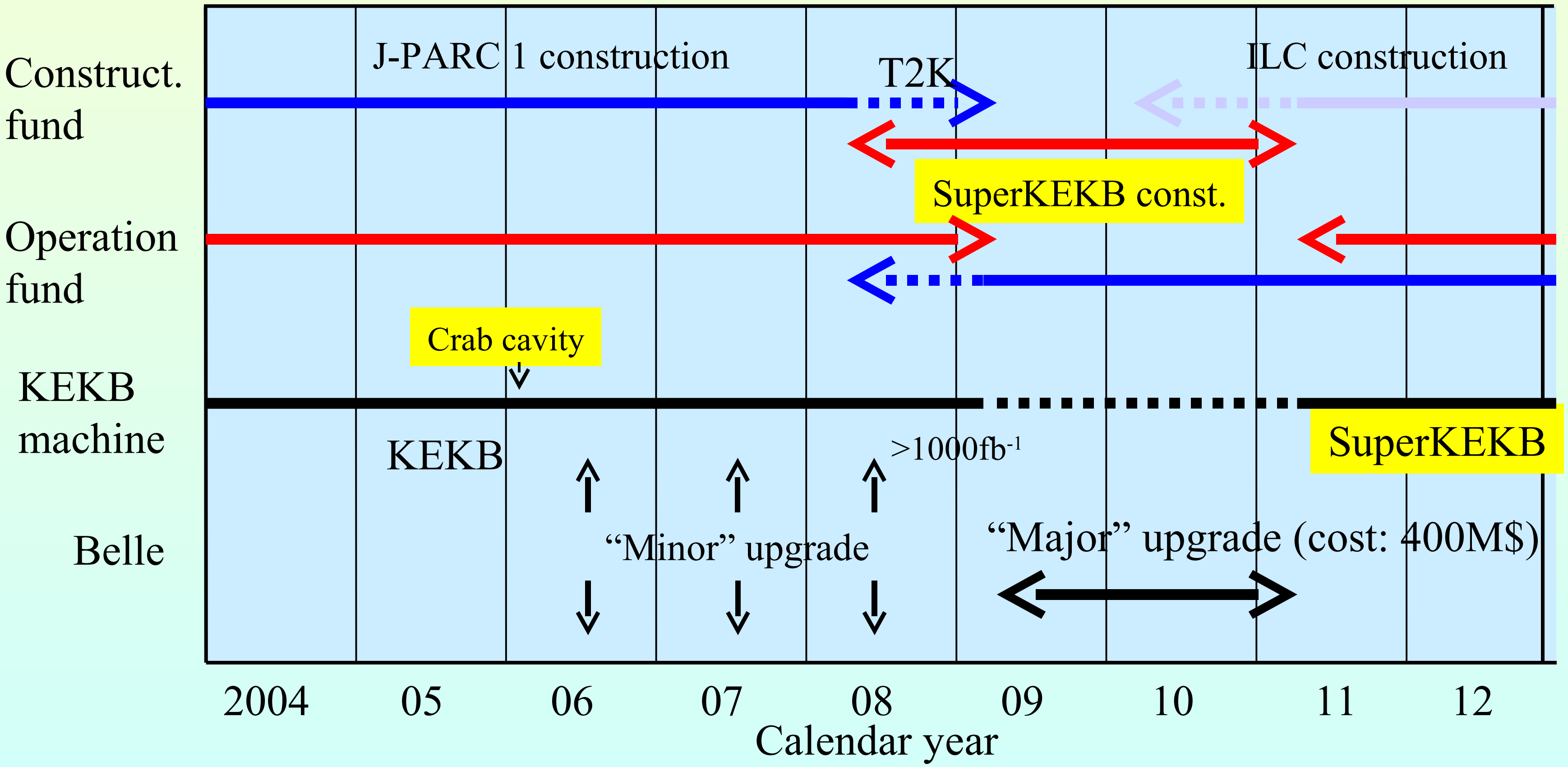
Maiani,Riquez,Piccinini,Polosa,hep-ph/0707062;

Plany na przyszłość

Super B Letter of Intent (KEK Report 2004-4) in April 2004

A Super B proposal was submitted from KEK to MEXT in August 2005.

KEKB/Belle project receives a grade of S (i.e. A+) in gov. reviews



Ken Peach

A Linear Super-*B* Factory

- Recent workshop: http://www.lnf.infn.it/conference/superbf05/ ; publication: physics/0512235
- Promising new idea using synergy with ILC research

P. Raimondi, WS Hawaii 2005

➡ achieve $L \sim 10^{36}\,\text{cm}^{-2}\text{s}^{-1}$ through very small beam-spot size: $(\sigma_x,\sigma_y) = (4\mu\text{m}, 0.028\mu\text{m})$

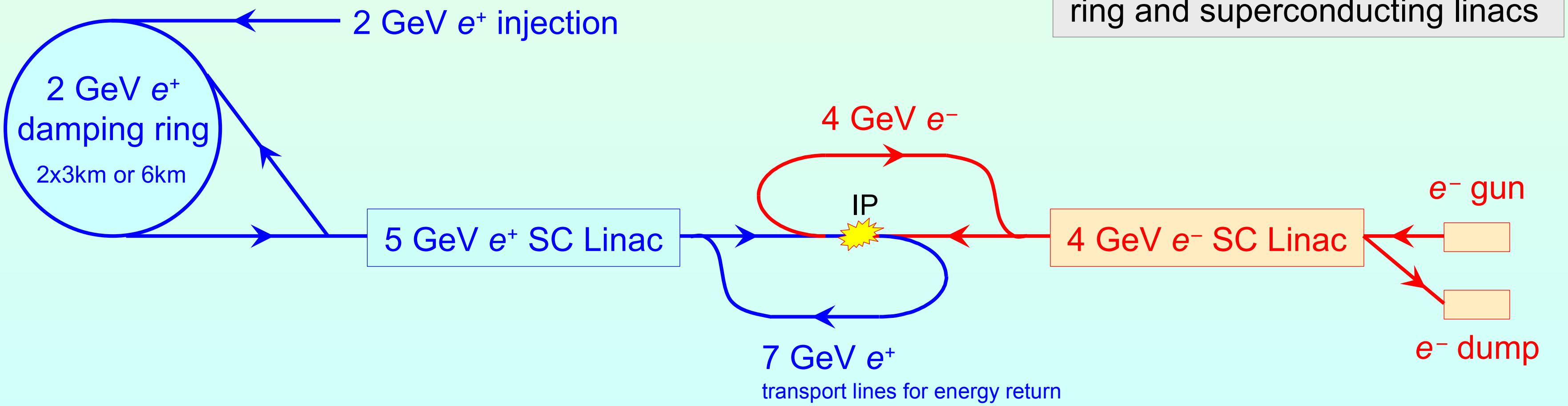
(yields luminosity enhancement of >10^3 compared to original SLAC-Super-*B* design)

$$L = \frac{N^+ N^- n_b f_c H_D}{4\pi\ \sigma_x \sigma_y}$$

Beam-beam “disruption” parameter

➡ achieve small transversal emittance in damping ring with short damping time (< 1.5ms)

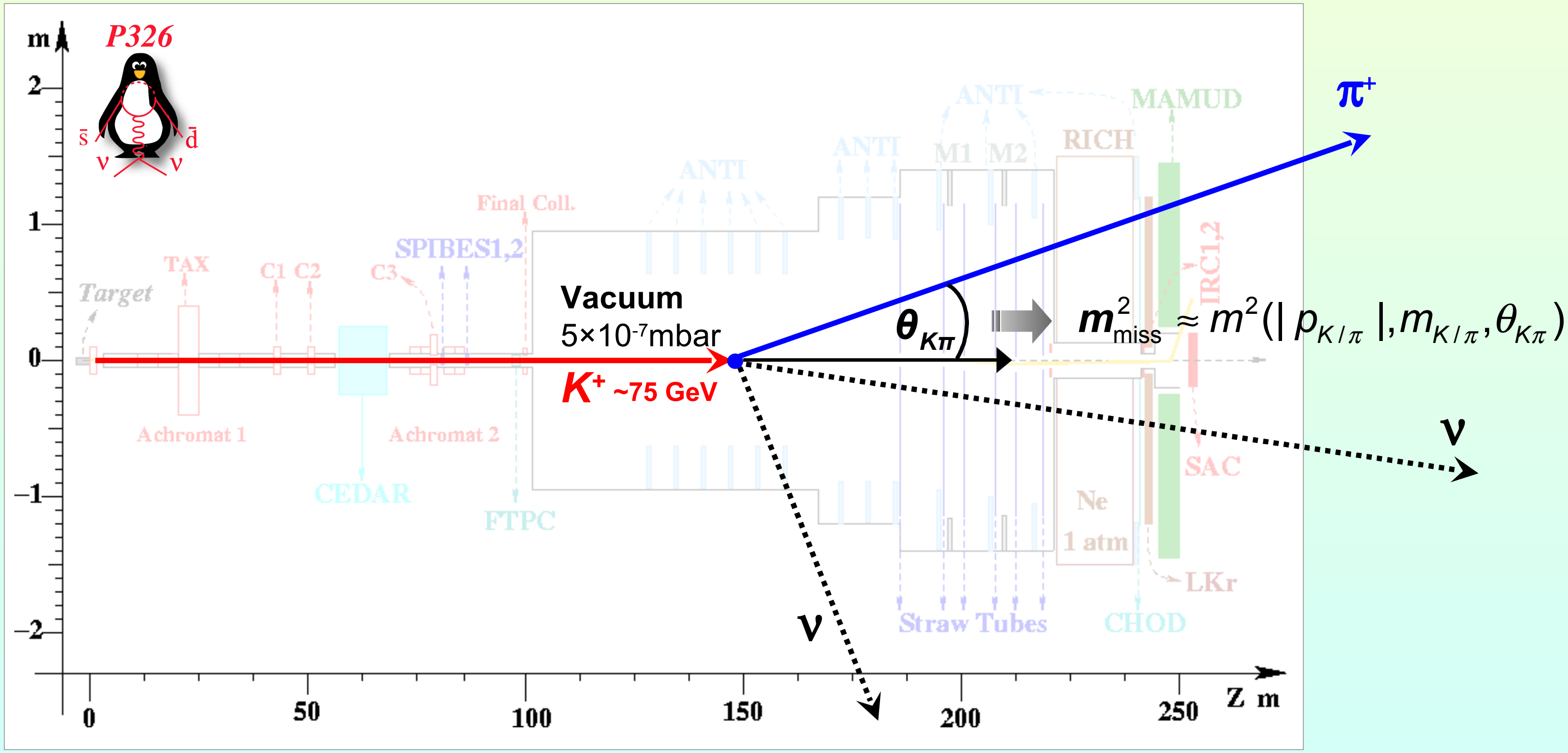
- Several design alternatives under examination



SBF layout with one damping ring and superconducting linacs

The Experimental Challenge

- Experimental proposals for K^+ at CERN and JPARC; attack K_L subsequently
  - achieve more than 100 SM signal events over a magnitude less background
  - all experiments use ultra-hermetic background vetos (~10^{-12} rejection factor)
  - different techniques: stopped kaons (E787/949) or fast kaons (75 GeV, P-326)



Located in the same hall of NA48

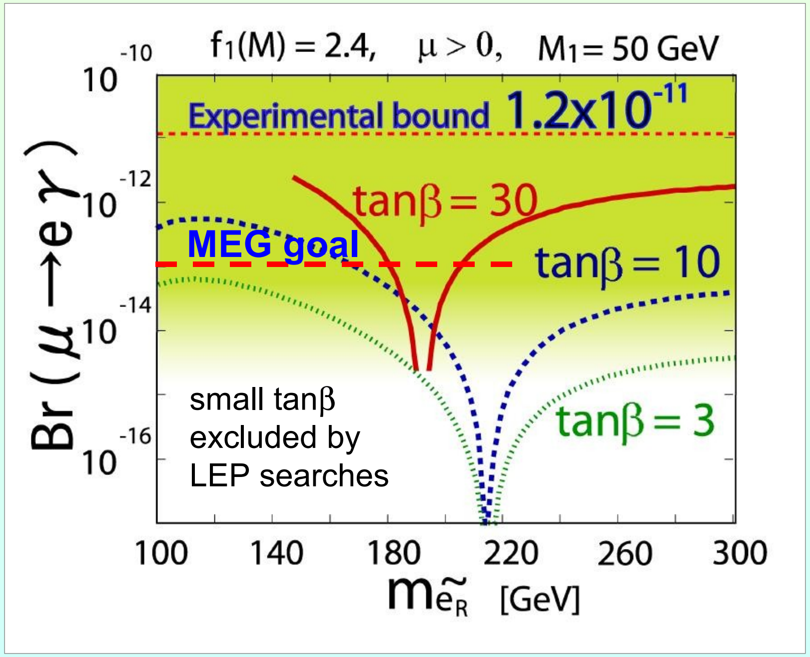
LFV: Present Exp. Bounds and SUSY Contributions

- New experiments, Super-*B*, MEG (PSI) and PRISM (JPARC), may reach SUSY domain

	Present UL (90% CL)	Future Experiments	SUSY-GUT reach(*)
$\tau^- \to \mu^- \gamma$	6.8×10^{-8} [BABAR, 211 fb^{-1}]	10^{-9} – 10^{-10} [Super-*B*, 50 ab^{-1}]	10^{-9}
$\mu^- \to e^- \gamma$	1.2×10^{-11} [MEGA]	~ 10^{-13} [MEG]	10^{-13}
$\mu^- N \to e^- N$ conversion	6.0×10^{-13} [SINDRUM II]	~ 2×10^{-17} [MECO ☹] ~ 10^{-18} [PRIME@PRISM (?)]	10^{-14}

(*)*source: PR. Kettle, PSI*

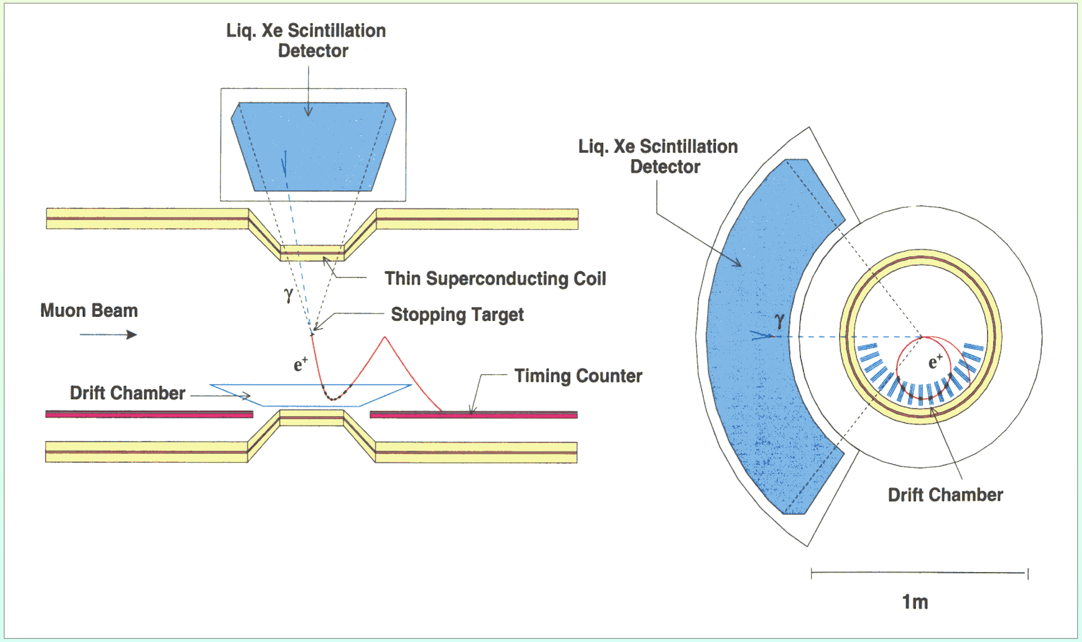
SUSY-GUT



J. Hisano et al. PL B391, 341 (1997)

The MEG $\mu^+ \rightarrow e^+\gamma$ Experiment @ PSI

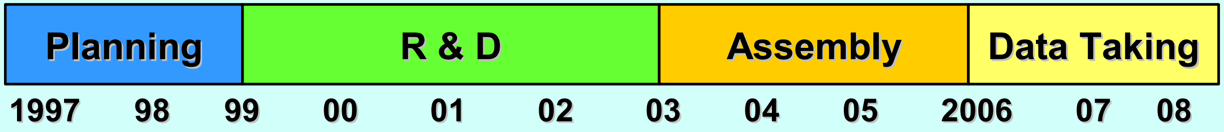
- Signal reconstruction:
  - stopped μ^+ beam: monoenergetic
  - back-to-back decay particles
  - require time coincidence
- Background sources:
  - radiative $\mu^+ \rightarrow e^+\nu\nu\gamma$, or accidental photon
  - e^+ annihilation in flight
  - neutron-induced background



Experimental requirements:

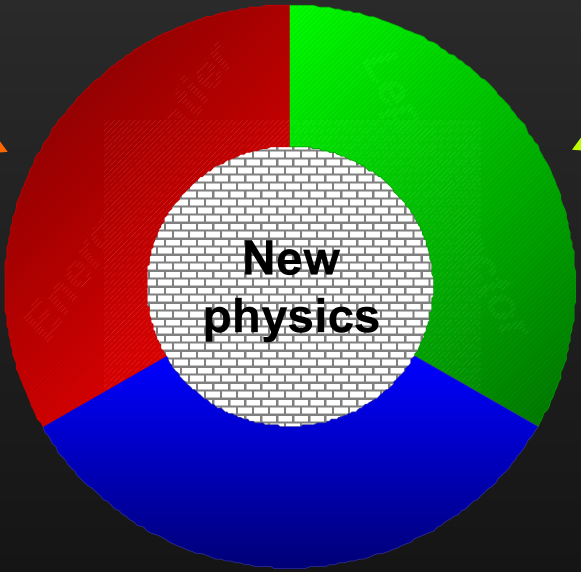
- high stop density (>10^7 μ/sec, from π decay at rest)
- high res. γ detection
- solenoid and tracking chamber to measure p_{e+}
- timing for e^+ (σ ~ 40ps)

- MEG timeline:



“A Unified and Unbiased Attack on New Physics”

T. Browder, FNAL Seminar, 2006



LHC, ILC

mass spectrum
interactions

ν experiments,
g_μ–2, $\mu\rightarrow e\gamma$, EDM, …

ν mass and mixing
CPV and LFV

τ LFV
τ CPV

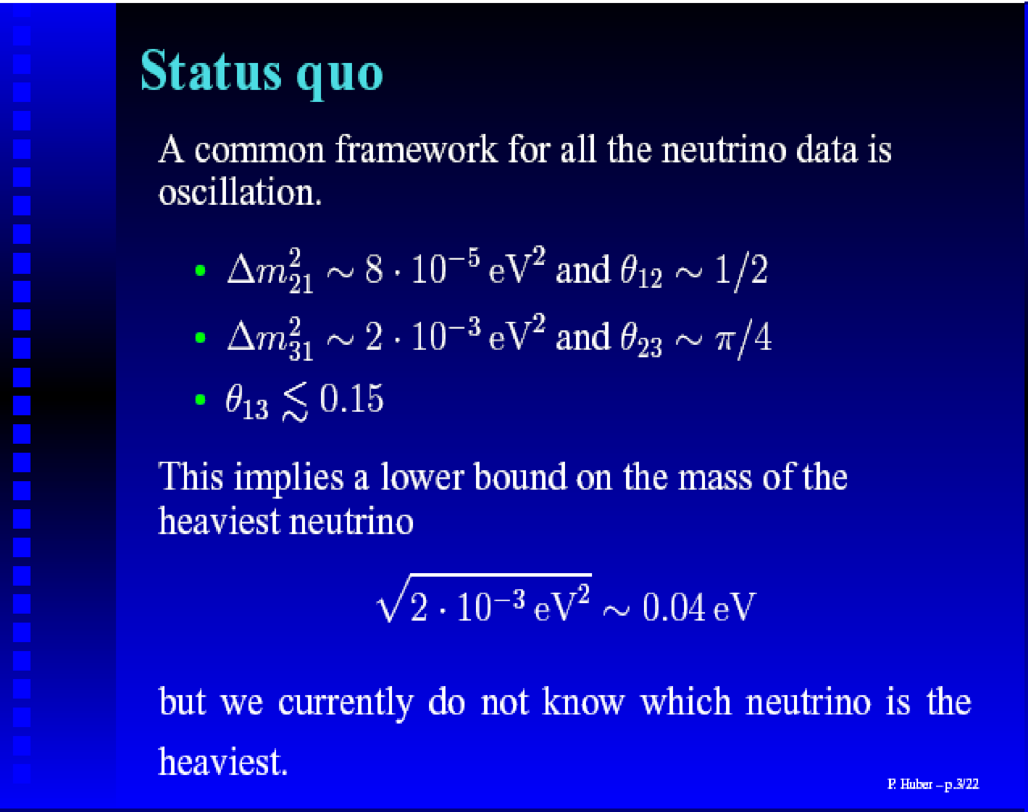
flavour mixing
CPV phases

Super-*B* factory, LHCb, *K* experiments…

Fizyka neutrin: 2 referaty

I. Teoretyczny – Parick Huber

- Przegląd aktualnego stanu wiedzy i najważniejszych problemów do rozwiązania



Status quo

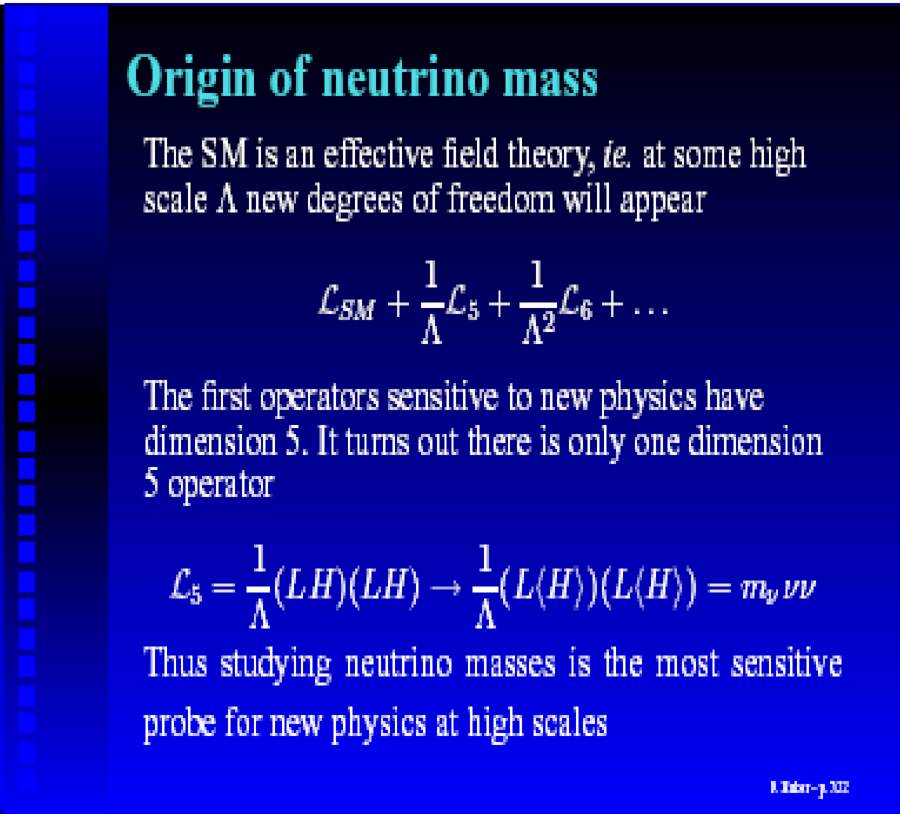
A common framework for all the neutrino data is oscillation.

- $\Delta m^2_{21} \sim 8 \cdot 10^{-5}\,\mathrm{eV}^2$ and $\theta_{12} \sim 1/2$
- $\Delta m^2_{31} \sim 2 \cdot 10^{-3}\,\mathrm{eV}^2$ and $\theta_{23} \sim \pi/4$
- $\theta_{13} \lesssim 0.15$

This implies a lower bound on the mass of the heaviest neutrino

$$\sqrt{2 \cdot 10^{-3}\,\mathrm{eV}^2} \sim 0.04\,\mathrm{eV}$$

but we currently do not know which neutrino is the heaviest.



Origin of neutrino mass

The SM is an effective field theory, *i.e.* at some high scale Λ new degrees of freedom will appear

$$\mathcal{L}_{SM} + \frac{1}{\Lambda}\mathcal{L}_5 + \frac{1}{\Lambda^2}\mathcal{L}_6 + \ldots$$

The first operators sensitive to new physics have dimension 5. It turns out there is only one dimension 5 operator

$$\mathcal{L}_5 = \frac{1}{\Lambda}(LH)(LH) \rightarrow \frac{1}{\Lambda}(L\langle H\rangle)(L\langle H\rangle) = m_\nu \nu\nu$$

Thus studying neutrino masses is the most sensitive probe for new physics at high scales

Key measurements

In the context of GUT scale right handed neutrinos it is very difficult to establish a one-to-one correspondence between high and low-energy observables.

A given model, however, usually has generic predictions for low energy observables. Therefore studying neutrinos allows to gain considerable insight into phenomena which otherwise would be inaccessible.

Colliders can not probe this kind of physics, since any effects in scattering amplit

m_{GUT}, at LHC this would be e

Key measurements

The most sensitive low energy observables are

- Majorana vs Dirac mass – $0\nu\beta\beta$
- Absolute m_ν – Katrin, Cosmology
- How large is θ_{13}? – Oscillation
- Which one is the heaviest neutrino? –$0\nu\beta\beta$, Katrin, Oscillation
- Is θ_{23} maximal? – Oscillation
- lation? – Oscillation
- eutrinos? – Oscillation

In 2025 I'll be 49, what about you?

Neutrino oscillation -

The second consequence of the

there can be a resonant convers

The condition for the resonance is

$$\Delta m^2 \simeq A$$

Obviously the occurrence of this resonance depends on the signs of both sides in this equation. Thus oscillation becomes sensitive to the mass ordering

	ν	$\bar{\nu}$
$\Delta m^2 > 0$	MSW	-
$\Delta m^2 < 0$	-	MSW

Some personal remarks

- Can neutrinos shed light on the flavor problem
- What if LSND is true?
- Is there a connection between neutrinos and supersymmetry?
- Can neutrinos test large extra dimensions?

2. Referat doświadczalny-

Anselmo Cervera - *Univ.de Genève*

1st step: transition era

Ongoing: 2005-2010

- Improve the precision on the atmospheric parameters looking at ν_μ disappearance
- Confirm (atm. osc)=($\nu_\mu \rightarrow \nu_\tau$) and first look at $\nu_\mu \rightarrow \nu_e$

2 nd step: θ_{13} era

Approved/Proposed: 2008-2015

- Demonstrate visibility of sub-leading transitions:

  $\nu_\mu \rightarrow \nu_e$, $\nu_e \rightarrow \nu_e$

- Explore θ_{13} down to 2^0 (today $<10^0$)

3 rd step: precision era

To be prepared: 2015-2025

$\theta_{13} > 3^0$ — Known by 2011 — $\theta_{13} < 3^0$

- Existing facilities could reach it
- … but with very small sensitivity to δ_{CP} and mass hierarchy

- No access for ongoing experiments at that time

Cleaner and more intense beams + bigger detectors

The role of Europe

Past experiments
- NOMAD, CHORUS, Chooz, Gallex, Macro

CERN to GS ***(2006)***
- Opera

Double-Chooz ***(2008)***
- First dedicated attempt to θ_{13}

T2K ***(2009)***
- Major contribution to near detectors ND280 (2009) and 2Km (2011)
- 120 people from 23 European institutes
- CERN recognised experiment

Detector and accelerator R&D
- Liquid Argon TPC (experience from ICARUS)
- Silicon PMTs
- Beyond OPERA ECC studies
- BENE
- Accelerator: HARP, MERIT, MICE

We must be important players in the Precision Era

Beta-beam

Pure ν_e or $\bar{\nu}_e$ beam ➡ small beam systematics and backgrounds

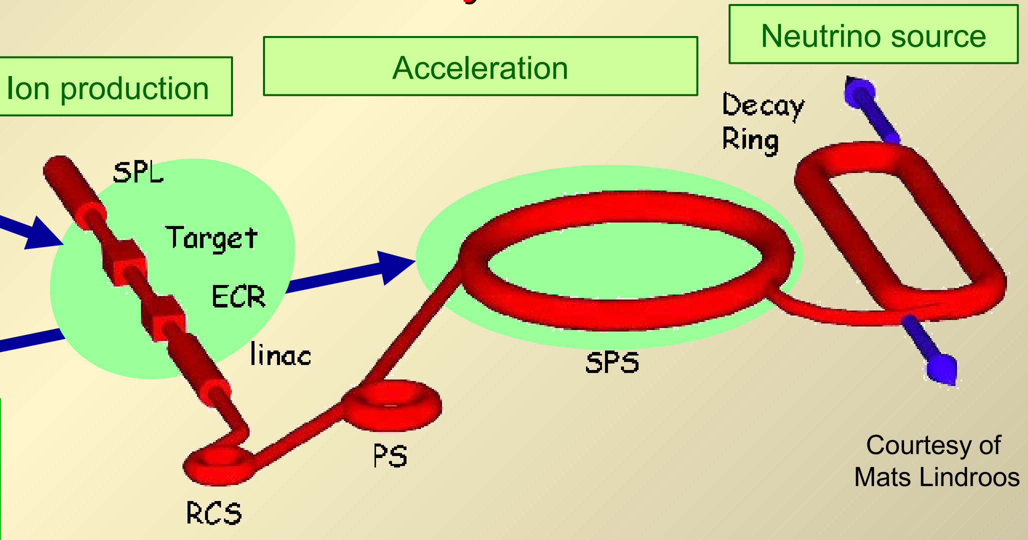
$^{6}_{2}He^{++} \rightarrow {}^{6}_{3}Li^{+++}\,\bar{\nu}_e\, e^-$ $\quad$ $^{18}_{10}Ne \rightarrow {}^{18}_{9}F\,\nu_e\, e^+$

ongoing R&D for ion production

EURISOL design study

missing feasibility study

CERN layout



Courtesy of
Mats Lindroos

New ideas:

- *Monocromatic beam: Burget et Al.*
- *Efficient ion production: C. Rubbia*

- Performance increases with beam energy if L/E is kept at oscillation max:
  - Higher flux and cross section. Better energy binning (no Fermi motion)
  - Smaller systematics from cross section and detector efficiency

(Burget et al.)

Performance

High γ	LHC	γ~1500	7 GeV	3000 Km	0.1 MT TC	CERN-Canarias
	Tevatron or S-SPS	γ~350	1.5 GeV	730 Km	1 MT WČ	CERN-GS/Canfranc
Low γ	SPS (max energy)	γ~150	0.6 GeV	300 Km	1 MT WČ	?
	SPS	γ~100	0.35 GeV	130 Km	1 MT WČ	CERN-Frejus

Neutrino factory

- 50% $\bar{\nu}_\mu$ 50% ν_e ➡ small beam systematics … but charge required
- High energy beam ➡ small cross section systematics
- A wide variety of studies are possible:

unitarity $\nu_e \rightarrow \nu_\tau$ **silver**

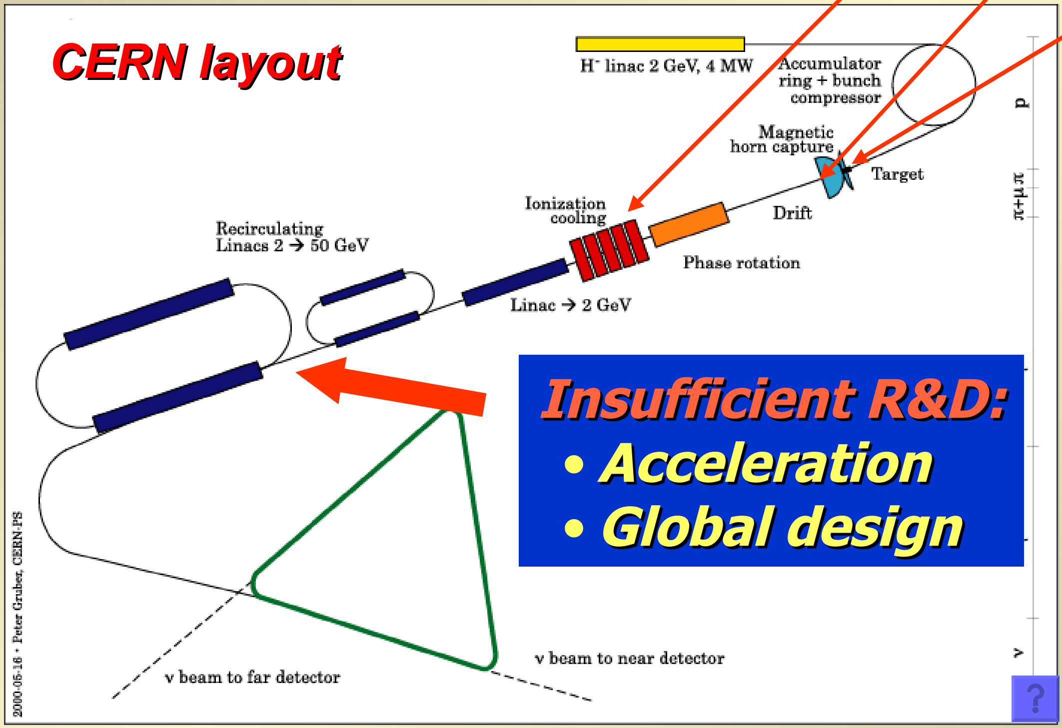
CP violation $\nu_e \rightarrow \nu_\mu$ **golden**

T, CPT $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ **bronze**

and also: $\bar{\nu}_\mu \rightarrow \bar{\nu}_\mu$ $\bar{\nu}_\mu \rightarrow \bar{\nu}_\tau$

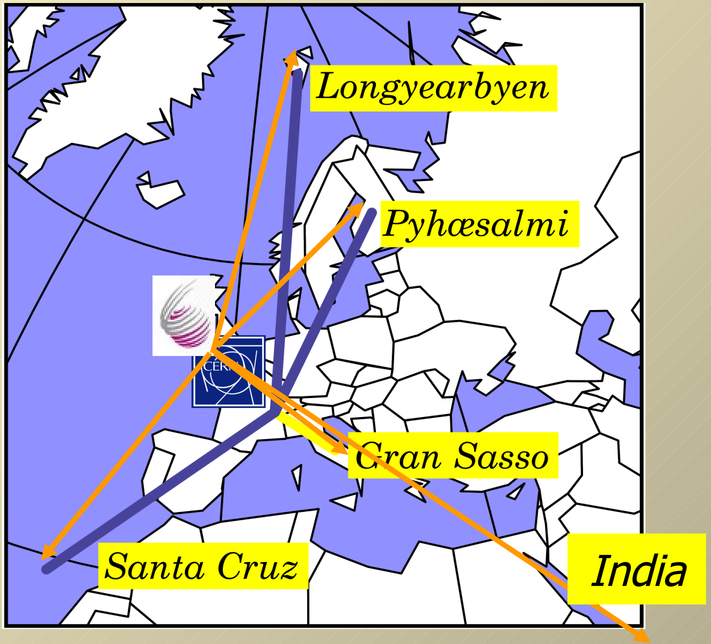
Atmospheric osc.

- Challenging ➡ Ongoing R&D: *MICE, HARP, MERIT*



Insufficient R&D:

- ***Acceleration***
- ***Global design***



Detectors

Neutrino Energy

High energy beams only: Nufact or high γ β-beam

Hybrid emulsion (4 KT)

- Experience from OPERA
- Silver channel

$$\nu_e \rightarrow \nu_\tau$$

Interesting to solve degeneracies

CP asymmetry has opposite sign

- Golden and bronze also

Tracking Calorimeters (100 KT)

- Fully active with liquid scintillator: ~NOvA
- Or sampling iron calorimeter: ~MINOS
- Muon charge is crucial: B field !!!
- Golden channel

$$\nu_e \rightarrow \nu_\mu$$

Both

Liquid Argon TPC (100 KT)

- 3D active detector:
  Imaging, calorimetry, Čerenkov
- Challenging: ongoing R&D strategy

- GLACIER conceptual design
- … also with magnetic field
- Could explore all channels

Low energy beam only:

- γ<350 β-beam
- Super-beam

And also:

- *Proton decay*
- *Supernovae neutrinos*

Water Čerenkov (0.5-1 MT)

- Well known technique from Super-K
- Interesting for e/μ separation

$$\nu_\mu \rightarrow \nu_e$$

super-beam

$$\nu_e \rightarrow \nu_\mu$$

β-beam

Outlook

Physics

- The CP violating phase and the mass hierarchy are crucial elements for the understanding of the leptonic sector
- Next generation neutrino facilities are required to assess these issues

Low γ β-beam +
Super-Beam +
Megaton detectors

High γ β-beam

Neutrino Factory

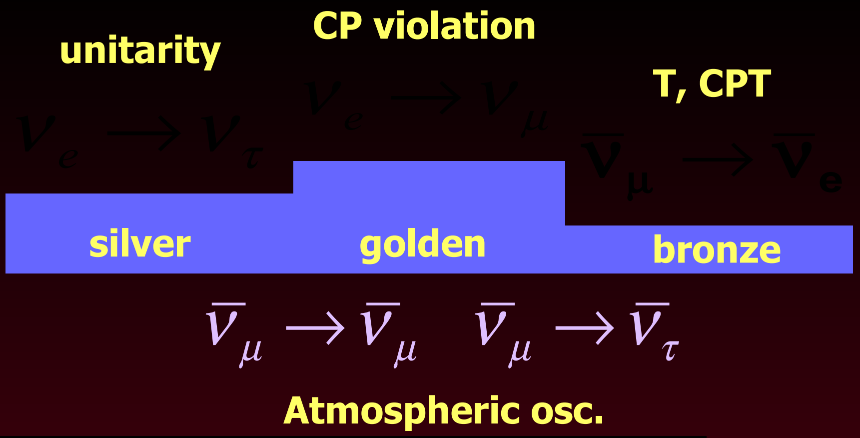
Time scale

- We should enter the precision era in the second half of the next decade
- Meanwhile **priority is to perform an "International Design Study"**
  - Conceptual design and realistic cost estimate
  - Hardware R&D on accelerator and detectors

~ G€

- … in order to be able to compare cost, feasibility and performance
- … to make the best choice by ~2011

« precision era »



➔ CP,T, CPT violation, universality, solving ambiguities, matter resonance and precision measurements.

several options are proposed

-- extension of conventional beam facilities (T2KK, S-NOvA)
-- low energy superbeam+beta-beam
-- high energy beta-beam
-- neutrino factory

THE QUESTION

What is the best realistic scenario one could build in a reasonable time scale (10-15 years) to address CP violation and mass hierarchy ?

Many new ideas are still coming and welcome:

e

In Neutrino Factory new ideas for finer grained detectors (combination of NOvA and MINOS) should improve high theta13 sensitivity……
synergy with LENA?

Precision Measurements

Gerco Onderwater, KVI Groningen

Two complementary approaches in experimental particle physics

(to deepen our understanding and to search for new physics)

Precision measurements of quantities well calculable within the Standard Model

often in the domain of low energies

atomic parity violation,
EDMs, electron/muon g-2,
Z^0-mass, EW parameters,
rare decays
.....

Direct observations of (new) particles and processes

typically at high energies

Higgs search, top-quark,
P/CP violation, Z^0-existence,
QCD, axions, ...

Nature of Fermions

* direct ν_e-mass measurement: KATRIN

- unique European position
- tritium β-decay; goal 0.2 eV
- strongly support it *(i.e. get it funded and running!)*

…… next step: requires a technology breakthrough

* ν-nature Dirac ↔ Majorana: 0νββ-decay

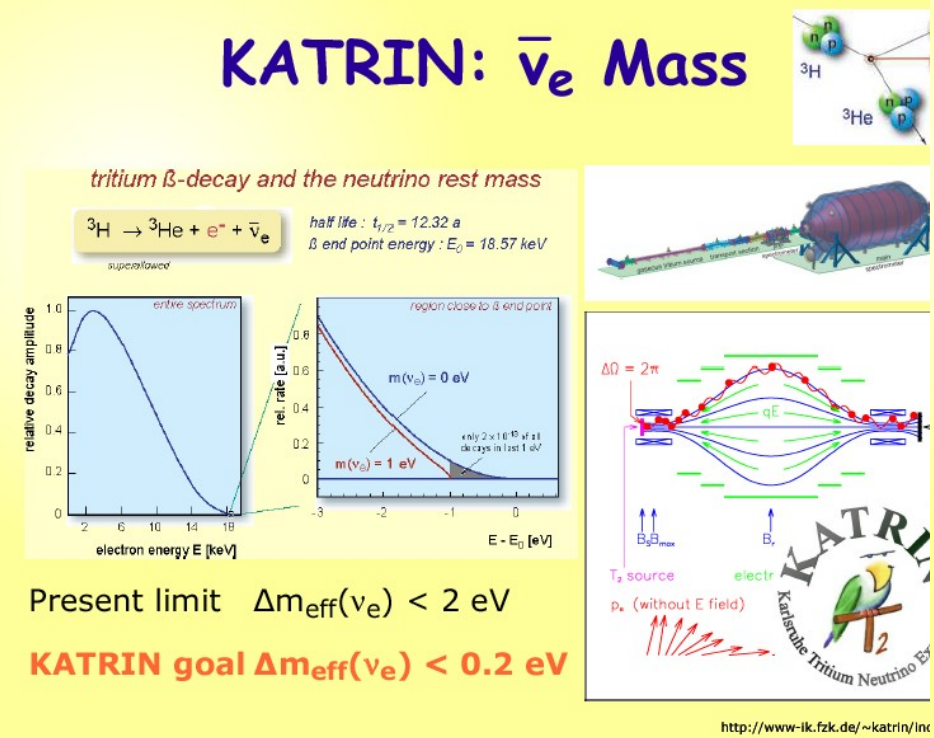
if observed beyond doubt: revolutionary!

→ measurements on several isotopes

→ ν-mass determination: nucl. Matrix el. ** use existing facilities while still in operation **

→new experiments: European/global coordination

→(Sudbury underground lab, looking for



KATRIN: $\bar{\nu}_e$ Mass

tritium ß-decay and the neutrino rest mass

$^3H \rightarrow {}^3He + e^- + \bar{\nu}_e$

superallowed

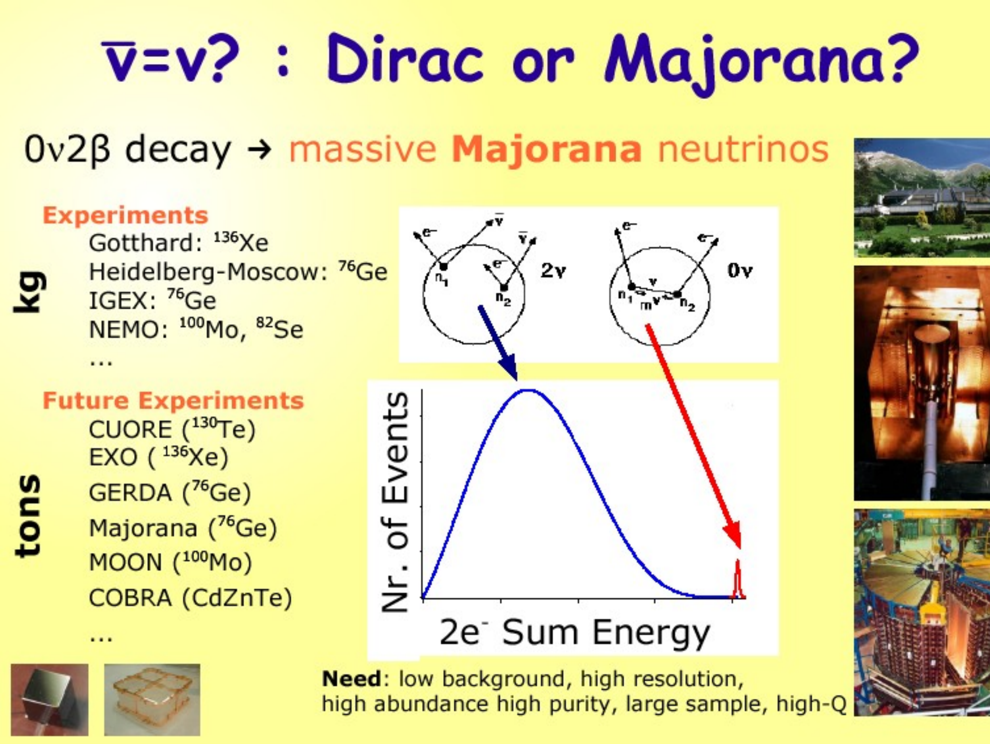
half life : $t_{1/2}$ = 12.32 a

ß end point energy : E_0 = 18.57 keV

Present limit $\Delta m_{eff}(\nu_e) < 2$ eV

KATRIN goal $\Delta m_{eff}(\nu_e) < 0.2$ eV

http://www-ik.fzk.de/~katrin/inc



$\bar{\nu}=\nu$? : Dirac or Majorana?

0ν2β decay → massive **Majorana** neutrinos

Experiments

Gotthard: ^{136}Xe

Heidelberg-Moscow: ^{76}Ge

IGEX: ^{76}Ge

NEMO: ^{100}Mo, ^{82}Se

…

Future Experiments

CUORE (^{130}Te)

EXO (^{136}Xe)

GERDA (^{76}Ge)

Majorana (^{76}Ge)

MOON (^{100}Mo)

COBRA (CdZnTe)

…

Need: low background, high resolution, high abundance high purity, large sample, high-Q

Nature of Interactions

- muon g-2 measurement, what next?
  - Brookhaven funding? J-PARC >2015? ···
  - better precision required on the hadronic corrections
    → via radiative returns at (low energy) e^+e^- colliders
    → interplay theory ↔ experiment

  * *novel idea: 'Farley concept' (>γ ⇒ more precision)* *

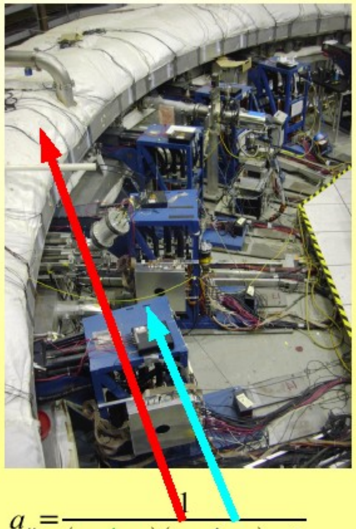
  * *need more muons → accelerator infrastructure* *
- muon lifetime i.e. G_F:

  * *need more muons → accelerator infrastructure* *
- neutron experiments ⇒ e.g. gravity @ nm scale

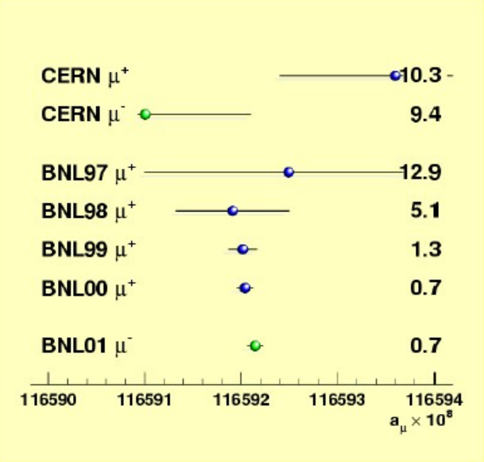
  * *need more neutrons → accelerator infrastructure* *

common theme: more particles/accelerator infrastructure

a_μ : adding STRONG & WEAK



$$a_\mu = \frac{1}{(\mu_\mu/\mu_p)(\omega_p/\omega_a) - 1}$$



$a_\mu(\mathrm{exp}) = 11\ 659\ 208.0\ (5.4)(3.3) \times 10^{-10}$

G.W. Bennett et al., Phys.Rev.Lett.92:161802,2004

Sensitivities

$$a_\mu = a_\mu^{QED} + a_\mu^{strong} + a_\mu^{weak} + \epsilon_\mu^{exotic}$$

QED error very small, using α(a_e)

Hadronic relies on data (e^+e^-, τ)
hadronic light-by-light problematic

Weak upto second order; OK

New Physics
40,000 more sensitive than electron

$$\Delta a_{exotic} \propto \left(\frac{m_\mu}{m_{new}}\right)^2$$

$[a_\mu \times 10^{-10}]$

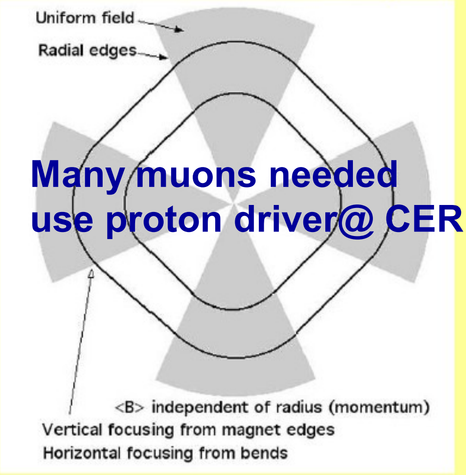
QED	11 658 471.94	±0.14	
STRONG	694 – 702	±6	!
WEAK	15.2	±0.3	
SM	11 659 181 – 9	±6	
EXPT	11 659 208	±6	
Δa_μ	19 – 27	±8.4	

Future Efforts

BNL E821	completed; **statistics limited**	0.5 ppm
BNL E969	Scientific approval; @ P5 US HEP panel	0.2 ppm
J-PARC LOI	encouraged; J-PARC μ's not before 2015	0.03 ppm
Farley's idea	NMR in-flight, $\gamma > \gamma_{magic}$	0.03 ppm
Theory	hinges on hadronic contributions	0.2 ppm?
New Physics	competitive sensitivity	
If LSP found	measurement of tanβ	

Benchmark for SM
***and* anything beyond it**

Francis Farley's New Concept



**Many muons needed
use proton driver@ CERN?**

Revolutionary Technique

ω_a more precise due to higher γ, rather than magic γ_{magic}

ω_p from transversely polarized protons, rather than NMR

Most of all, it needs μ's!

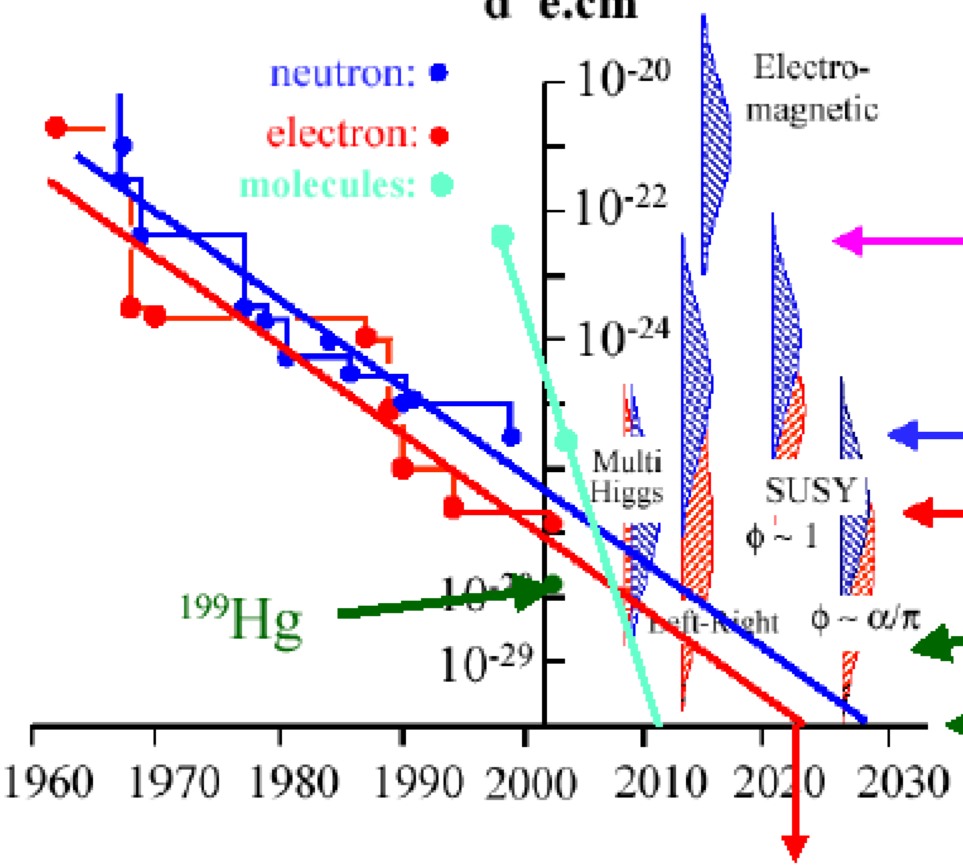
Also, need $\lambda = \mu_\mu/\mu_p$ to better precision (from muonium spectroscopy; presently ~0.14ppm)

$$a_\mu = \frac{1}{(\mu_\mu/\mu_p)(\omega_p/\omega_a) - 1}$$

Novel Ideas Necessary for Progress

EDM Experiments Compared

New 2004 from muon g-2:
d (muon) < 2.8 ×10^{-19}



d(proton) < 6×10^{-23}

d(neutron) < 6×10^{-26}

d(electron) < 1.6×10^{-27}

Deuteron potential

Radium potential

d_e (SM) < 10^{-37}

New techniques: radioactive atoms, cryoEDM, liqXe, GGG, storage ring, ….

Summary

Precision measurements are complimentary to direct observations and have robust potential to test the SM and its extensions

To make full use of possibilities, experiments should be pushed to their systematic and/or theoretical uncertainty limit

Room should be provided to explore novel experimental techniques

An increase in particle flux, from *e.g.* a multi-MW proton driver, is indispensable for significant progress in many areas of the field

Uncertainties in calculating hadronic phenomena (matrix elements, form factors, radiative corrections,...) are worrisome

Key experiments addressing fundamental issues, such as ν-mass matrix, ν-nature and the origin of CP violation (EDM search, correlation experiments, ...), should receive full support

Non-accelerator particle and astroparticle physics

- Nathalie Palanque-Delabrouille (*DAPNIA, Saclay*)

- - Dark matter

- - Proton decay

- - Particle Astrophysics
-     Ultra high energy cosmic rays
-     Gamma rays
-     Neutrinos

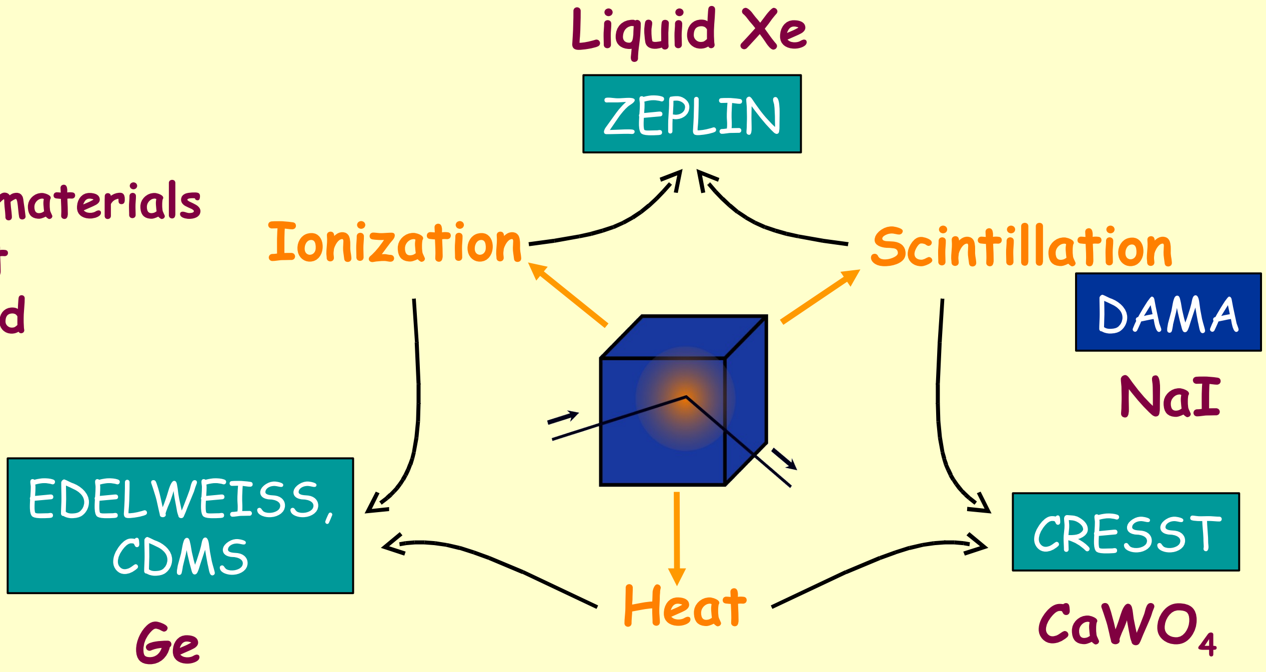
- - Dark energy

Detection challenge

WIMP: elastic scattering on detector nucleus

<< 1evt / kg / day ⇒

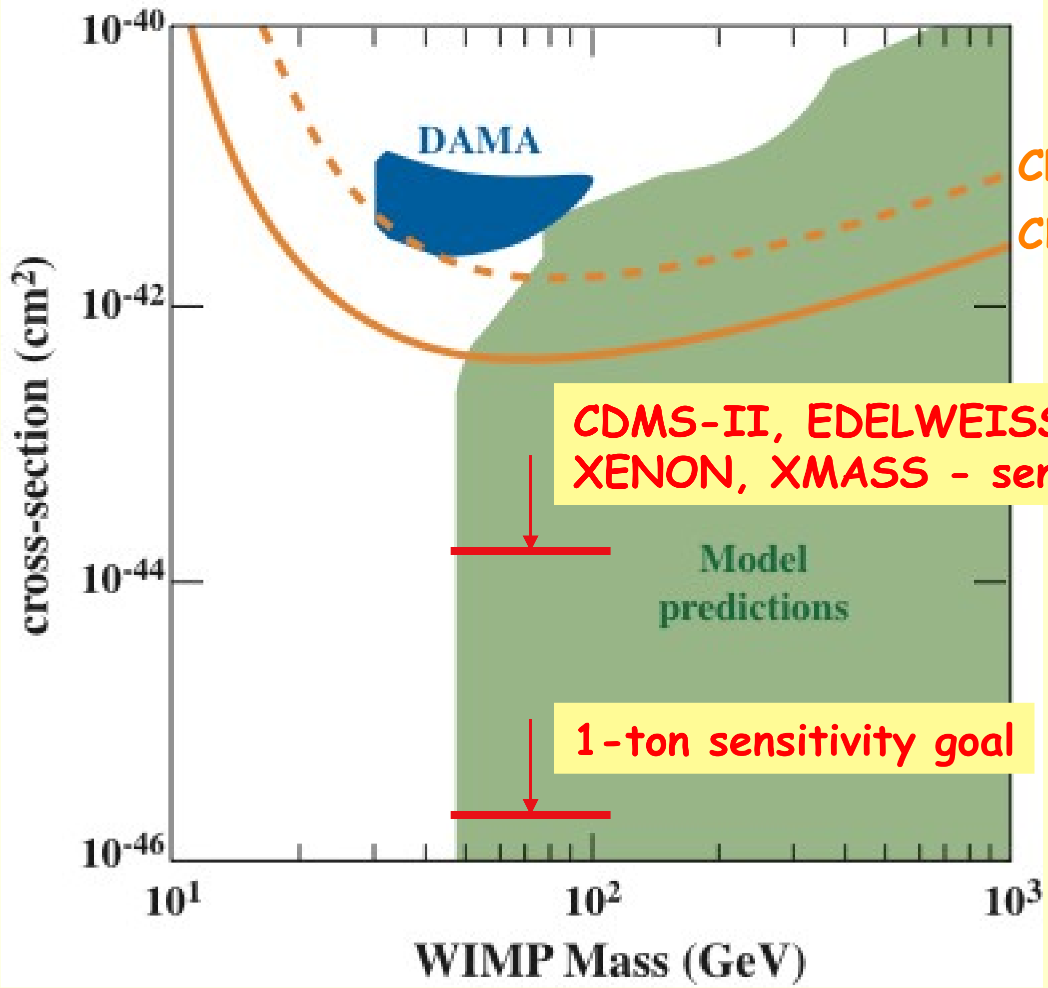
- Deep underground
- Low radioactivity of materials
- Discrimination against radioactive background



Nuclear (vs. electronic) recoil discrimination: event by event or statistical


WIMP signal
Radioactive background

Current limits on WIMP



Testing most SUSY param. space (MSSM) requires 3 orders of magnitude beyond present best performances

Future 1-ton projects

EURECA (Europe)

EDELWEISS + CRESST collaborations + CERN + …
First studies: cryogeny, electronics, shielding
Multi target approach: Ge (phonon ionization)
CaWO$_4$ (phonon scintillation)
Detector R&D ongoing

Super-CDMS Ge, Si (US)

XENON (US), **XMASS** (Japan)

Liquid Xenon (an easier target than a crystal)
XENON: 10 kg proto at Gran Sasso

ArDM, WARP (Europe)

Liquid Argon
OK on the paper, feasibility study (calibration w/ source)

Proton decay : future initiatives

UNO (Underground Nucleon decay and neutrino Observatory)
Mine in US 440 kT

MEMPHYS (MEgaton Mass PHYSics)
Fréjus 440 kT

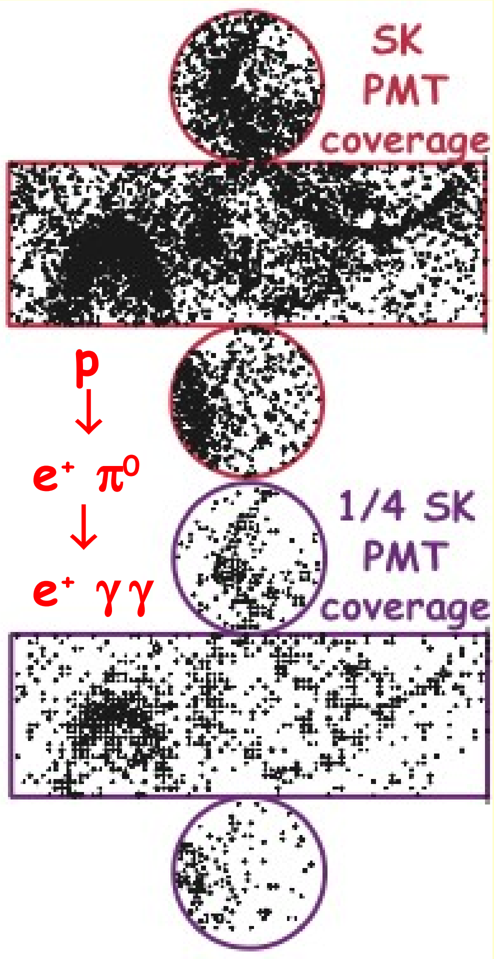
HyperK
Japan 550 kT

Liquid Argon TPCs (FLARE (US), GLACIER (Europe))
? 100 kT

Complementarity liquid argon vs. water Cerenkov

$p \to K^+ \nu$
(higher detection eff.)

$p \to e^+ \pi^0$
(larger mass)



Particle astrophysics

or the use of multi-messengers

The high energy Universe as seen with

Cosmic rays

Charged (⇒ do not point except at UHE)

Highest energies observed

Gamma rays

Traditional messenger yet unexplained phenomena (GRBs…)

Neutrinos

Most challenging to detect, but no GZK

Status & future of ν astronomy

ANTARES, AMANDA: 0,1 km2 arrays
Allow assessment of under-ice, under-water ν telescopes
Possible observation of diffuse neutrino fluxes (from AGN)
(current limits from AMANDA reaching predictions from some models)
No point sources so far

Actual ν astronomy (point sources) requires **1 km^3**

IceCube: 80 1-km long strings over ~1 km^2
January 2006: 6 lines deployed

KM3: design study in FP6 through network KM3Net
Joint study from ANTARES, NESTOR, NEMO

Revolutions in cosmology

Great achievements in past decade with observations of

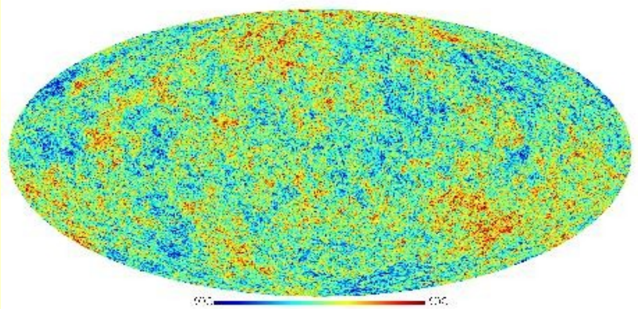
Cosmic Microwave Background

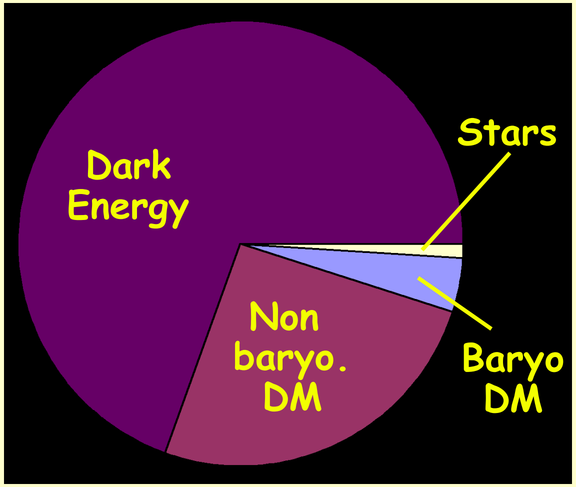
3K black body (COBE)
⇒ expansion of Universe

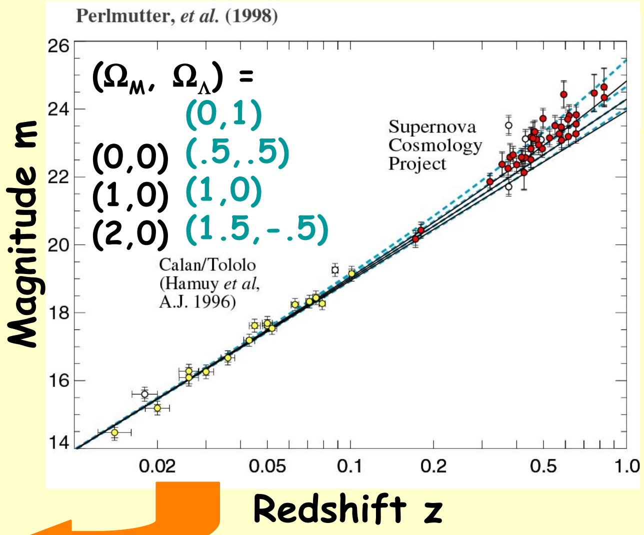
Anisotropies (balloons, WMAP)
⇒ composition of Universe
+ seeds for structure formation

Type Ia Supernovae

Hubble diagram of SNIa
(flux vs. redshift)
⇒ accelerated expansion







Questions as conclusions…

Do nucleons decay?
What physics is there at 10^{16} GeV?
How large can detectors become?

Dark energy:
Quantum field?
New laws of gravity?

Dark matter:
WIMPS? axions?
What knowledge will come from
accelerators (LHC, ILC or CLIC)?
direct detection (sensitive enough)?
sky (gamma rays or UHECR)?

Messages from the sky:
Nature of most energetic phenomena
(AGN, GRBs…)?
Origin of cosmic rays?
Acceleration processes?

QCD i ciężkie jony

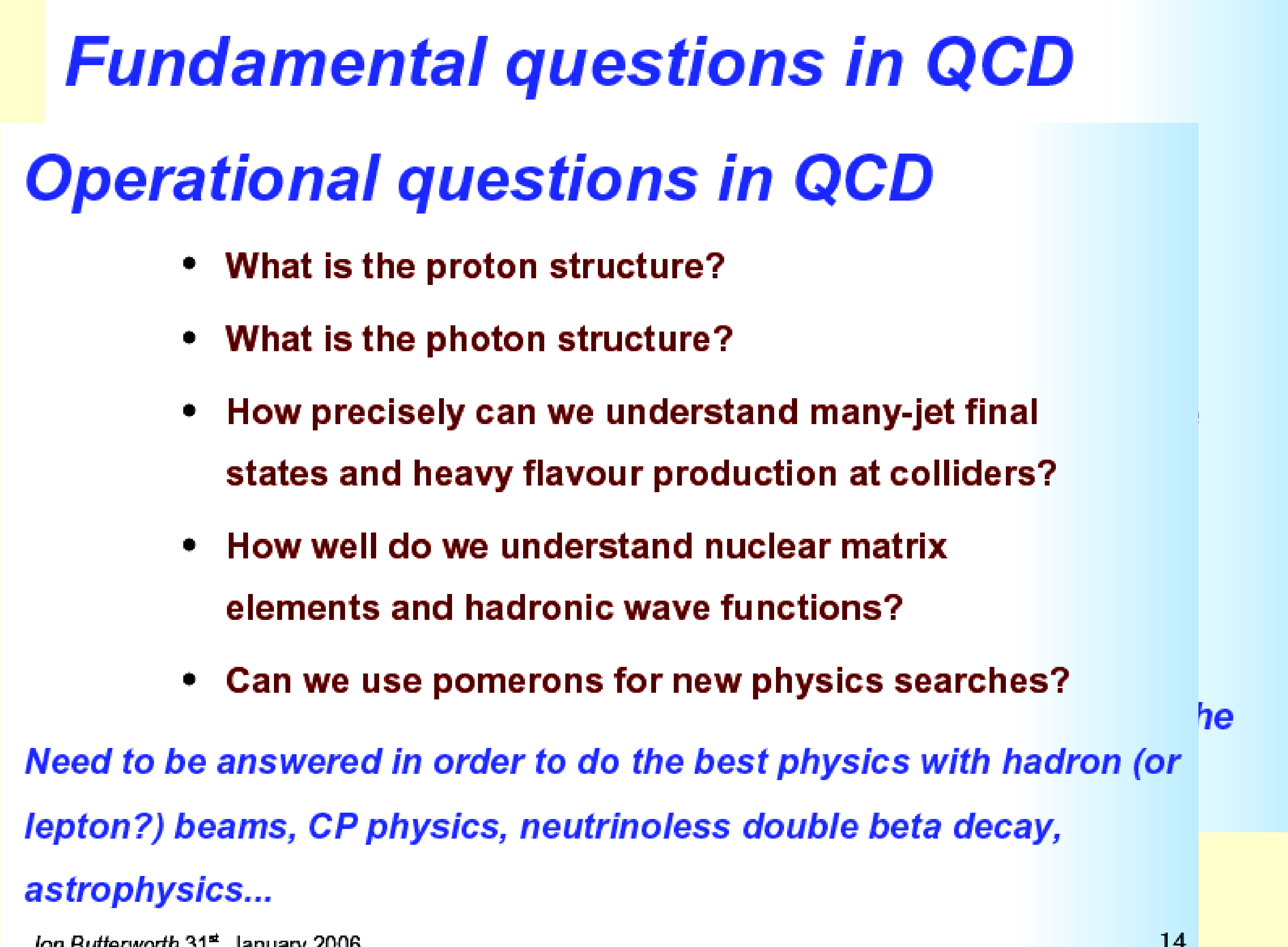
J. Butterworth,
UCLondyn

- Struktura hadronów
  dla małych Q2
- Studia DIS
- Procesy przy dużych Q2
- (spektroskopia hadronowa)
- Często podkreślana rola eksperymentów mierzących „input dla hadronowych coliderów”

Jean-Yves Ollitrault,
Saclay

- Czego dotyczą badania ciężkich jonów?
- Krótka historia badań
- Co się dzieje w zderzeniach?
- Jakie są najważniejsze „observable”?
- Jakie stosujemy podejścia teoretyczne?
- Czego nauczyliśmy się dotychczas?
- Czego oczekujemy w zderzeniach ciężkich jonów w LHC?
- Czego jeszcze oczekujemy od eksperymentów na stacjonarnej tarczy?

QCD



Fundamental questions in QCD

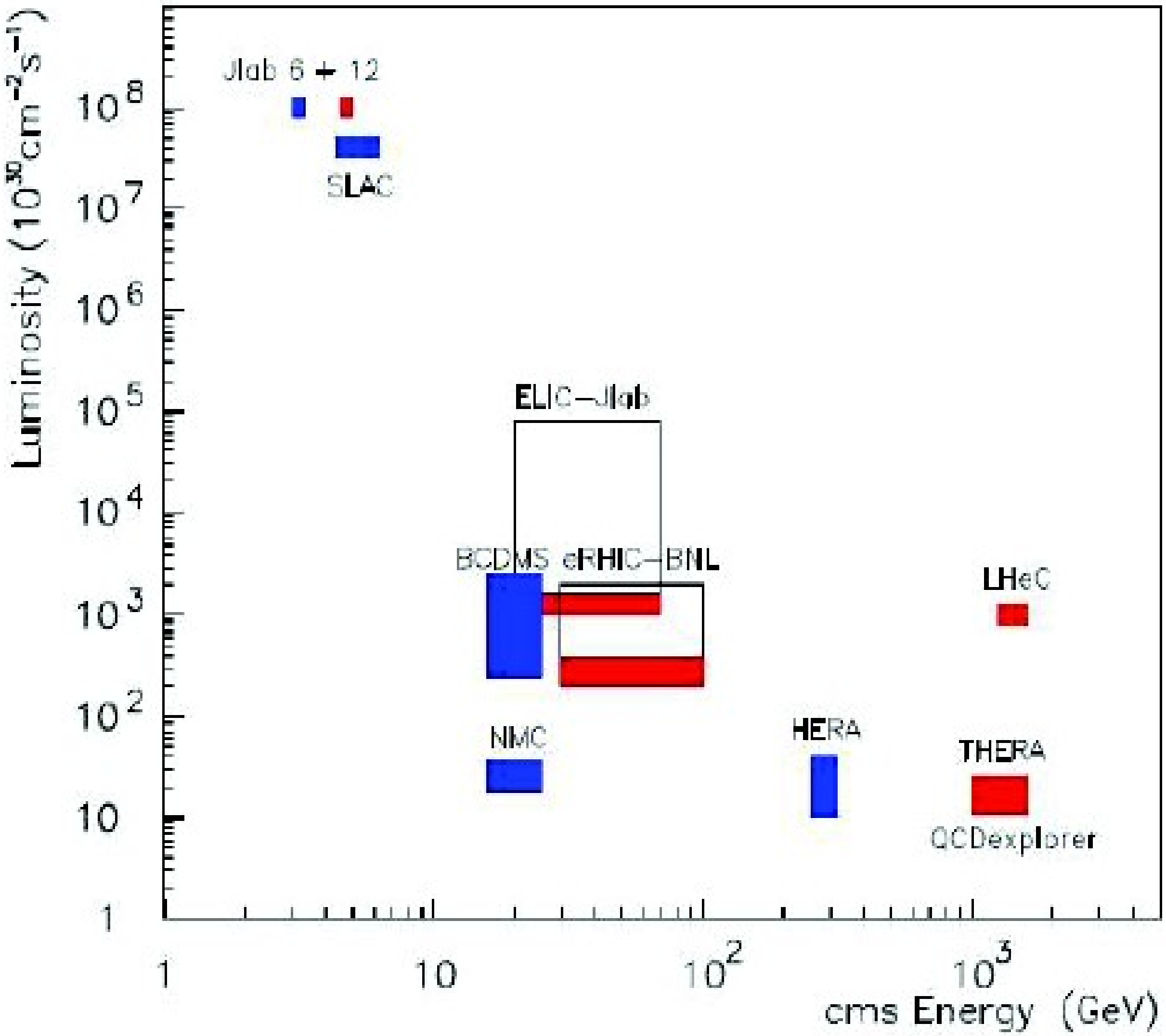
Operational questions in QCD

- What is the proton structure?
- What is the photon structure?
- How precisely can we understand many-jet final states and heavy flavour production at colliders?
- How well do we understand nuclear matrix elements and hadronic wave functions?
- Can we use pomerons for new physics searches?

Need to be answered in order to do the best physics with hadron (or lepton?) beams, CP physics, neutrinoless double beta decay, astrophysics...

Jon Butterworth 31st January 2006 14

Facilities for Deep Inelastic Scattering



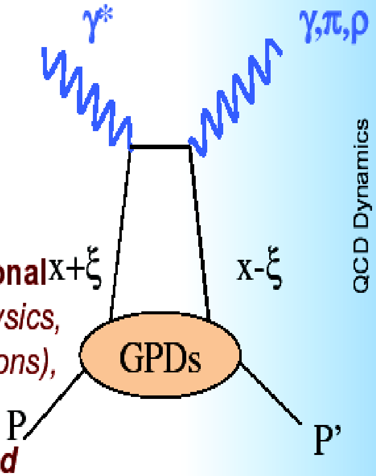
How does confinement work?

- **Hadron spectroscopy**
  - **COMPASS, e.g. double charmed baryons "molecule-like" excitation spectrum**
  - **Glueball spectrum, 1.5-2.5 GeV, and hybrid mesons.**
  - **A busy past few years with new states coming (and in some cases going) at *CLEO, BES, Belle, Babar, Daphne, HERA…*** (see talk by A. Hocker)
  - **Important area for validating lattice calculations.**

What happens at high quark and gluon density?

- **"Unintegrated" partons densities needed at low x**
  - $F(x,Q^2,k_T)$
  - **Correlated with transverse spin? With radial position in proton?**
- **Low x evolution – DGLAP not adequate?**
  - **CCFM, BFKL…**
  - **Affects high rapidity final state physics. HERA measurements indicate such effects are significant. (Dijet decorrelation, forward jets).**
- ***More from HERA II; also eRHIC and LHeC***

- **Generalised parton distributions (GPD)**
  - **Exclusive channels (deeply virtual compton scattering, vector meson production)**
  - **Pull a quark out and put it back…**
  - **Begin to really build up a 3D map of the partons in the proton - "parton tomography".**
  - **Also provides some answers to operational questions:** *Proton structure, diffractive physics, underlying events (multiple parton interactions), connected to total cross sections…*
  - ***COMPASS (intermediate x) H1, ZEUS and HERMES, FP420, LheC (low x), maybe MINERVA.***



QCD Dynamics

- **Also want to know where the spin of the proton comes from.**
- **Measurement of longitudinal spin functions, but little information on transverse degrees of freedom ("transversity" and k_T)**
- **Addressed at *HERMES, COMPASS, RHIC, eRHIC, LheC; JLAB, Drell-Yan processes at FAIR/GSI polarised p-pbar.***
- **NB Collins fragmentation function from Belle.**

Operational questions in QCD which have not been covered along the way

- **Photon structure – *HERA photoproduction, ILC / photon collider***
- **High x proton structure – *HERA II, DIS at neutrino beams***
  W, Z, pl
- **Testing**
  matrix e
  COMPA

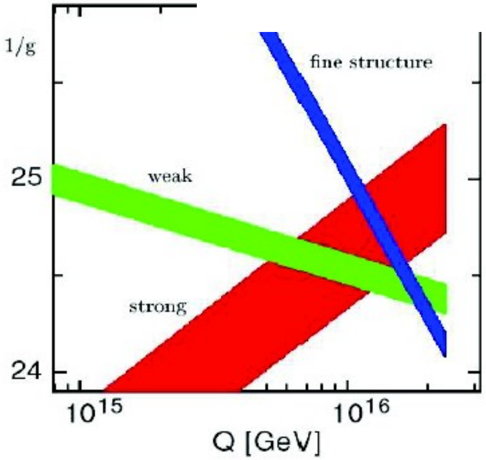
Why do high energy hadronic cross sections behave the way they do?

- **High energy pp cross section at LHC (TOTEM/FP420)**
- **Diffractive physics, vector**
  n, rapidity gaps
  eC., eRHIC...
  en perturbative
  tive QCD.
  HIC, neutrino

- **Much of our understanding of QCD final states (jets, charm, beauty....) at colliders is best encapsulated in Monte Carlo generators. *Need access to large data sets (LEP, HERA, Tevatron, SPS; eventually LHC and ILC) to validate these and improve the next generation of measurements and models (virtuous cycle).***

What, pre

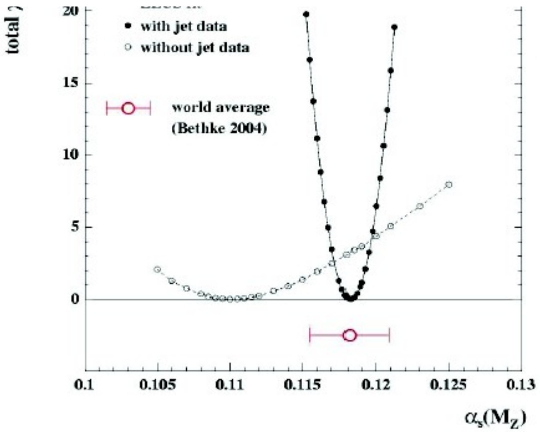
where do

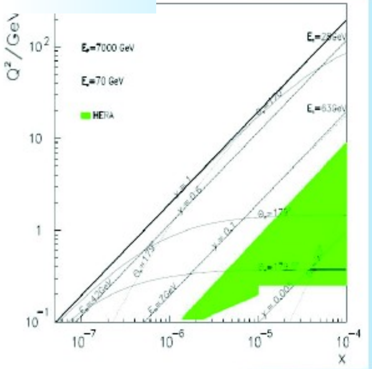


Compare to the EM, weak and gravitational (~10^{-9}, 10^{-5}, 10^{-3})

ant and

ts at LheC



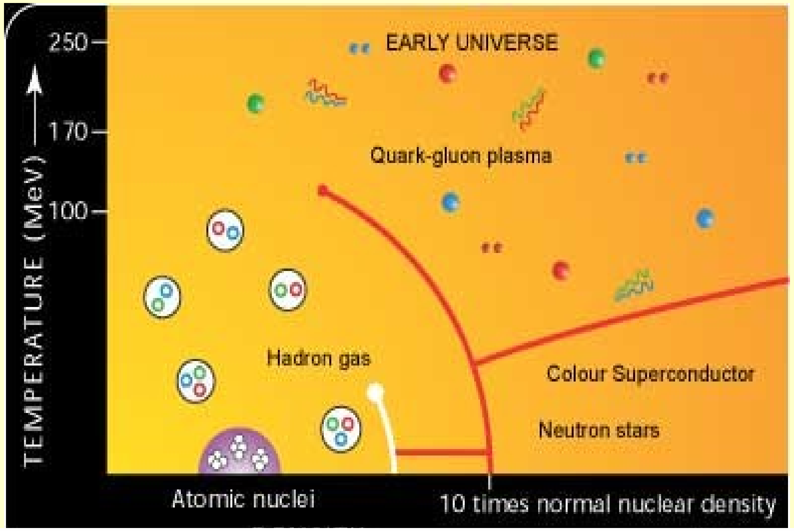


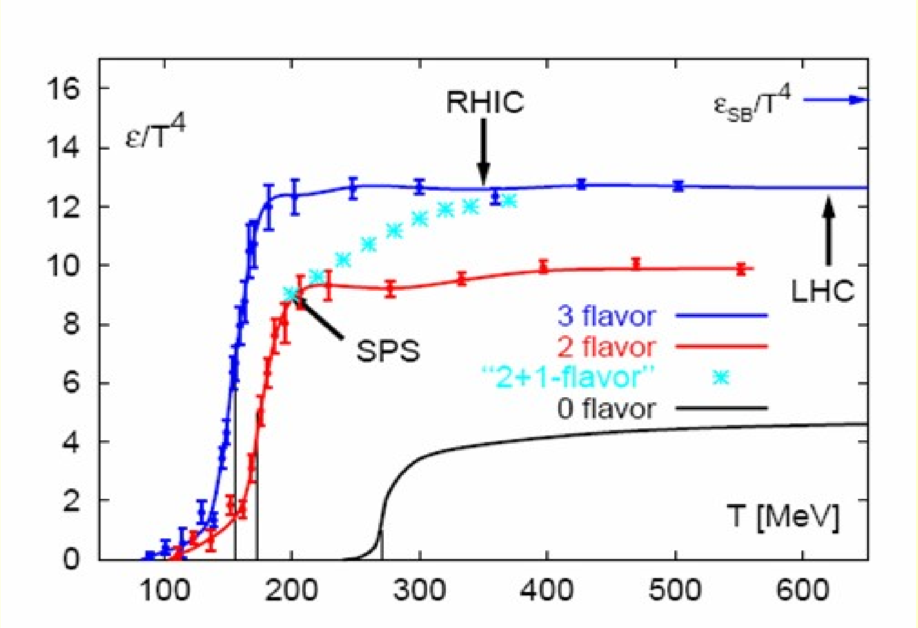
What are heavy ions about?

Heavy ion collisions create matter of extremely high density.

The initial goal was to probe experimentally the QCD phase diagram.

The scope is now wider: study various properties of the high-density phase





What are the theoretical approaches?

1. Lattice QCD

2. Analytical calculations at high T

3. high-energy QCD

Important progress made in perturbative calculations at high temperature, using improved resummations schemes. 3 examples:

- *Energy loss of a hard parton through a quark-gluon plasma (jet quenching) (Baier Dokshitzer Mueller Peigné Schiff hep-ph/9608322)*
- *Photon production by a quark-gluon plasma was computed to leading order only very recently (Arnold, Moore, Yaffe, hep-ph/0111107)*
- *Perturbative calculations of the eq. of state are in a… with lattice calculations down to a few Tc (Blaizot Iancu Re… ph/0…*

Exact calc… also a source of inspiration: v… N=4 supersymmetric QCD was computed using the AdS/CFT correspondence, *(Policastro Son Starinets hep-th/0104066)*

Important progress recently made in understanding quantum field theory out of equilibrium *(e.g. Aarts et al hep-ph/0201508)*

Lattice calculations go beyond the mere equation of state of QCD matter

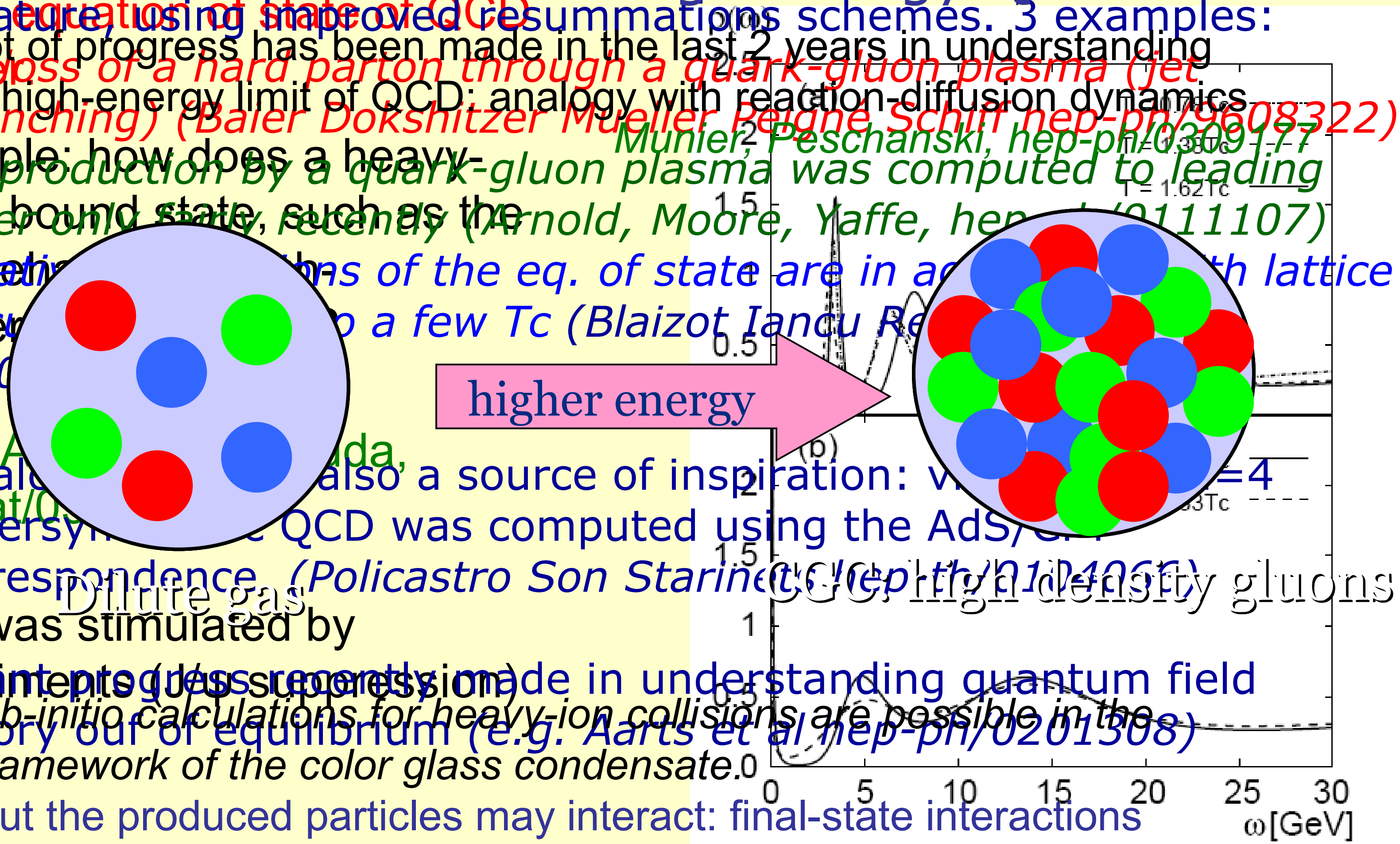
Example: how does a heavy-quark bound state, such as the J/ψ, behave in high-temper…

(from A… …da, hep-lat/0…

This was stimulated by experiments (J/ψ suppression)

A lot of progress has been made in the last 2 years in understanding the high-energy limit of QCD: analogy with reaction-diffusion dynamics

Munier, Peschanski, hep-ph/0309177



Ab-initio calculations for heavy-ion collisions are possible in the framework of the color glass condensate.

But the produced particles may interact: final-state interactions

What have we learnt from previous experiments?

1. Particle yields from the fireball
2. Elliptic flow
3. Jet quenching

Elliptic flow is NOT a small e
indication of collective (fluid-l
motion

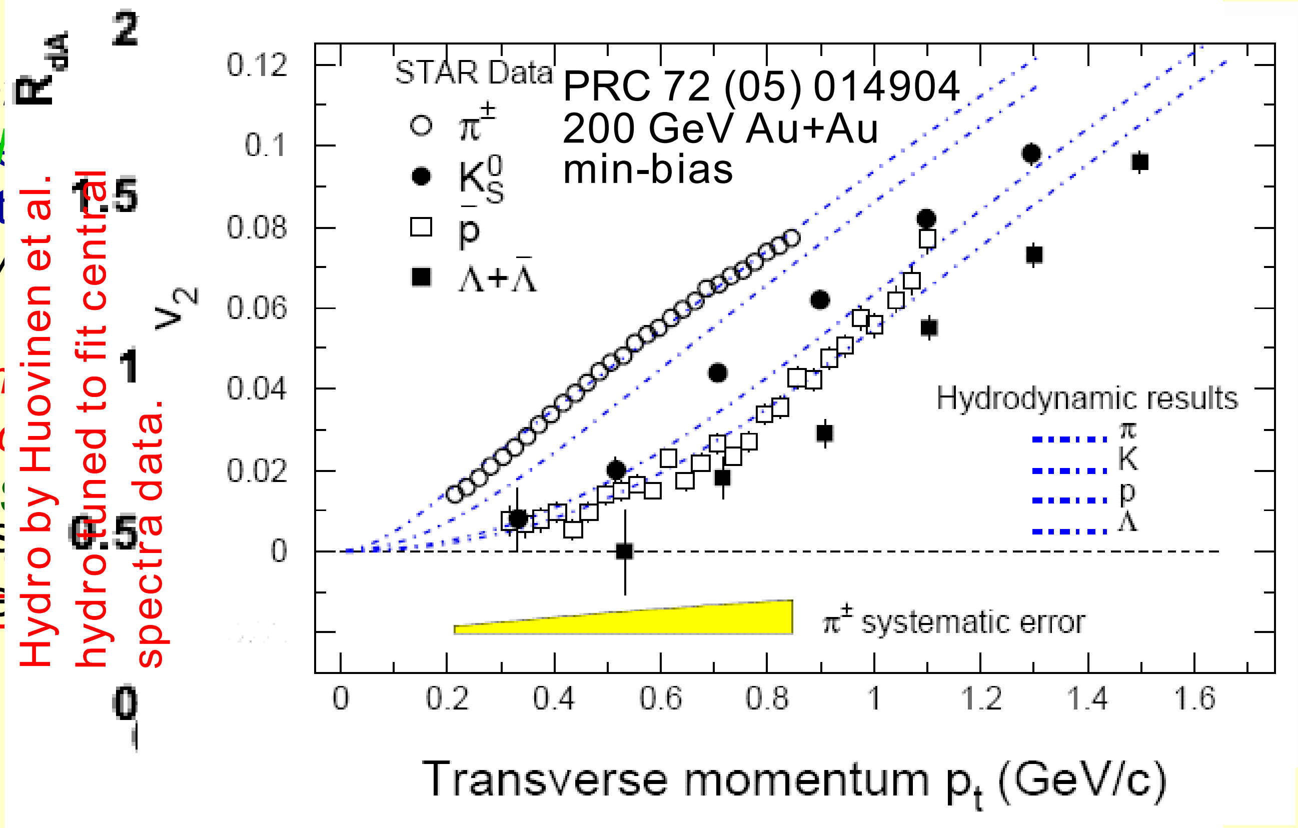
Clear mass-ordering: lower v
heavier particles at given pt

The only explanation of the m
ordering is that the fluid veloc
relativistic v~0.7 c

Hadron abundances are we
described by « thermal » fit
i.e., by Boltzmann factors
(2 parameters only)

The temperature seen at SPS
and RHIC = the deconfinem
temperature from lattice QC

One of the most striking results from RHIC:
Suppression of high-pt particles in central nucleus-nucleus collisions compared to the expectation from proton-proton collisions

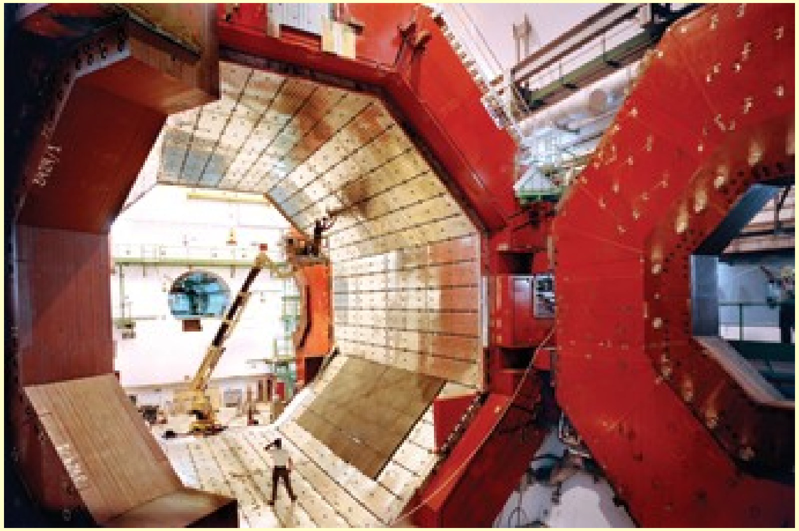


Hydro by Huovinen et al.
hydro tuned to fit central spectra data.

The heavy-ion program at LHC

From RHIC to LHC: colliding energy x30, particle density (expected) x2

A dedicated Heavy-Ion experiment: ALICE

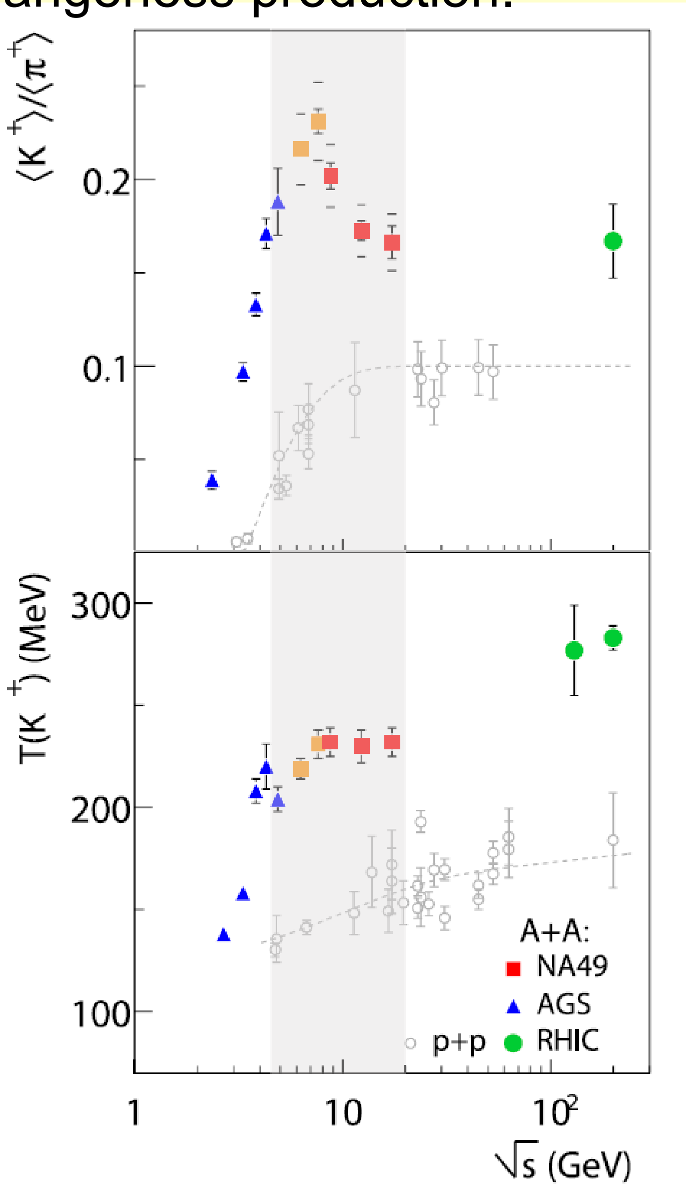


And also heavy ion studies in ATLAS and CMS

iATLAS

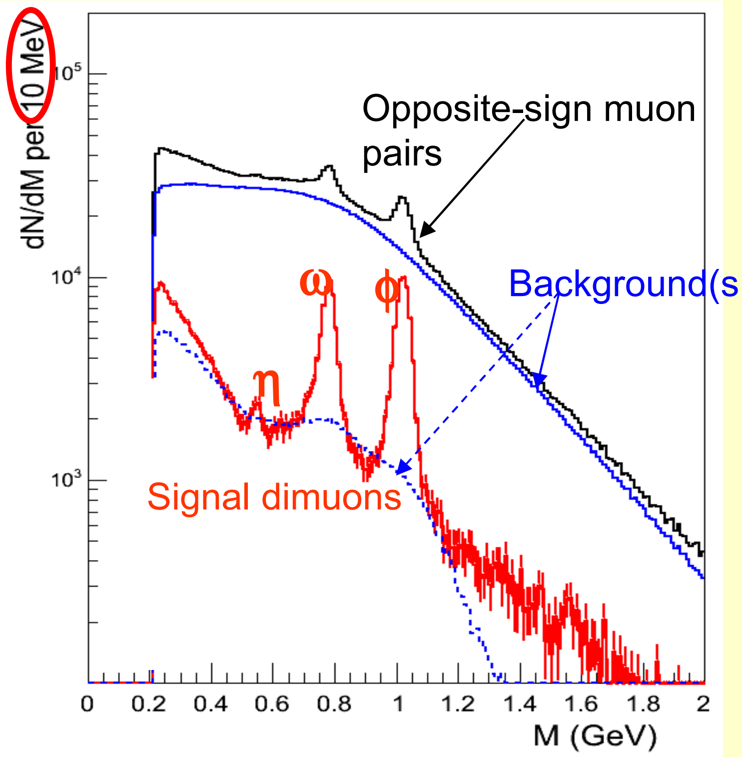
ATLAS Experiment Heavy Ion Physics Group

The future NA49 experiment will also investigate further the anomaly (sharp peak) in strangeness production.



The NA60 experiment at SPS

- **An upgrade of the famous SPS dimuon experiment using a technological breakthrough: radiation-hard silicon pixel detectors:**



In summary (QCD)

Continued need of detailed QCD studies to keep the pace of higher precision measurements.

Need to preserve/transmit all the information collected at Hera and the Tevatron

Low energy measurements of higher quality needed

In summary (Heavy Ions)

An exciting era is opening up with Alice.

Valuable informations are still coming from the SPS

A planning of the LHC operation is very much needed to minimize interference with the high luminosity program.

A reflection on the long term future of the field has started and should be encouraged.