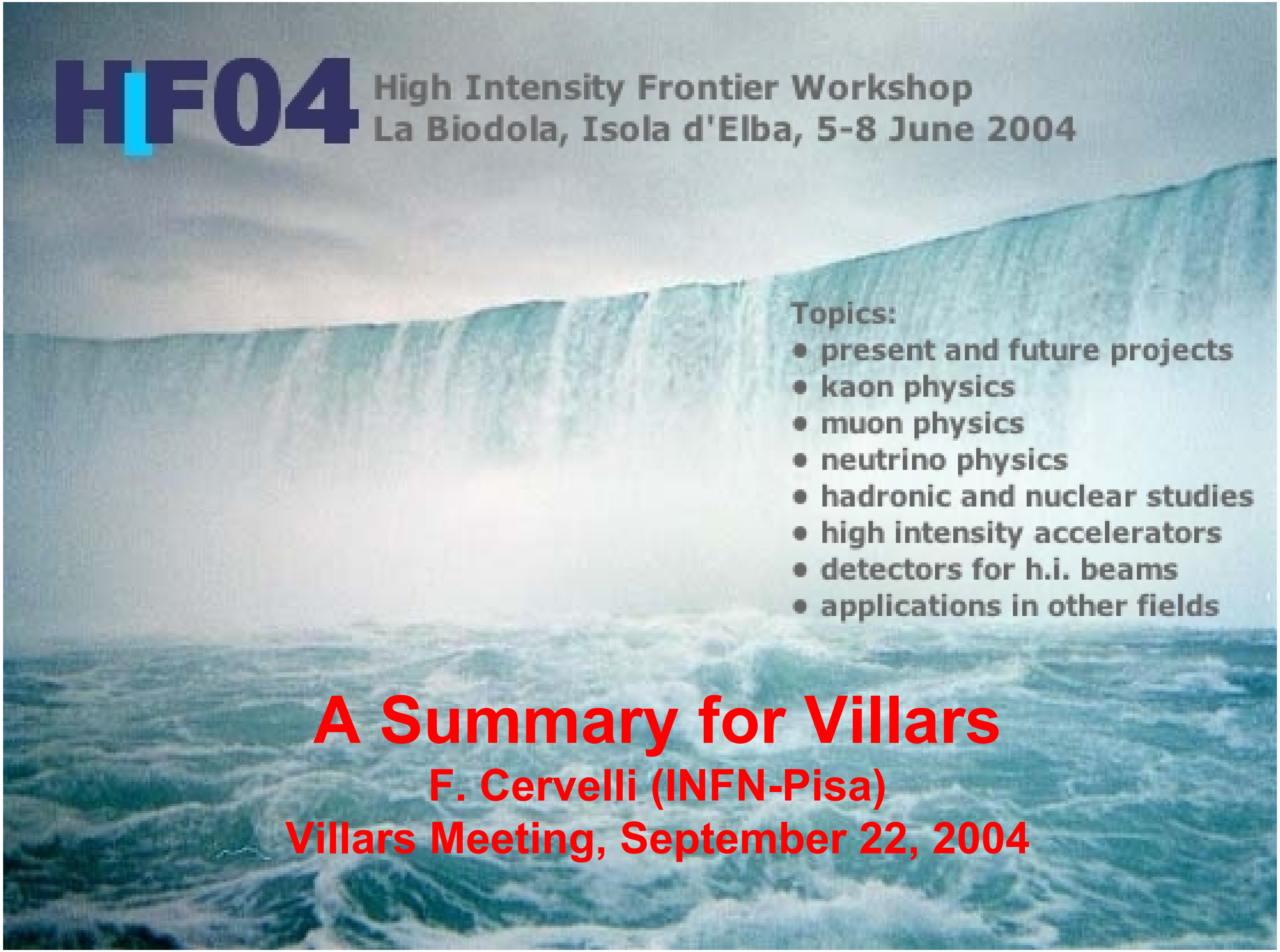


A Summary for Villars

F. Cervelli (INFN-Pisa)

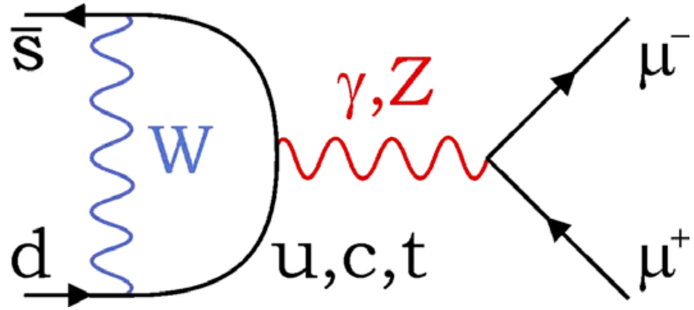
Villars Meeting, September 22, 2004

Why study Rare Kaon Decays

- Search for explicit violation of Standard Model
  - Lepton Flavour Violation
- Probe the flavour sector of the Standard Model
  - FCNC
- Test fundamental symmetries
  - CP,CPT
- Study the strong interactions at low energy
  - Chiral Perturbation Theory, kaon structure

- **I will give a review of recent experimental results**
  - **In addition to K_L and K^+, also K_S rare decays *($BR \leq 10^{-8}$)* start to be studied**
- **I will also briefly review the new initiatives that should lead to significant advance in the field by the end of this decade**

$K^0_L \rightarrow \pi^0 e^+ e^-$ and $K^0_L \rightarrow \pi^0 \mu^+ \mu^-$

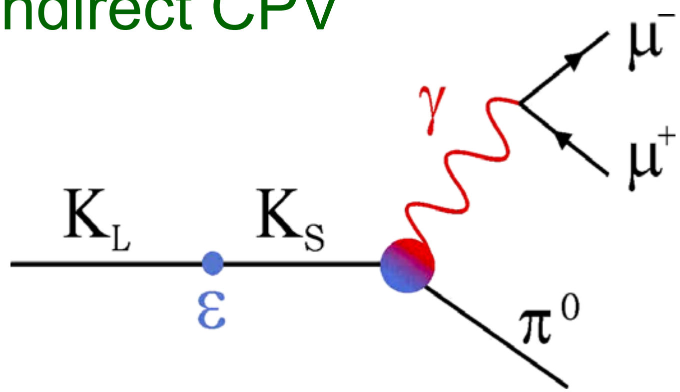


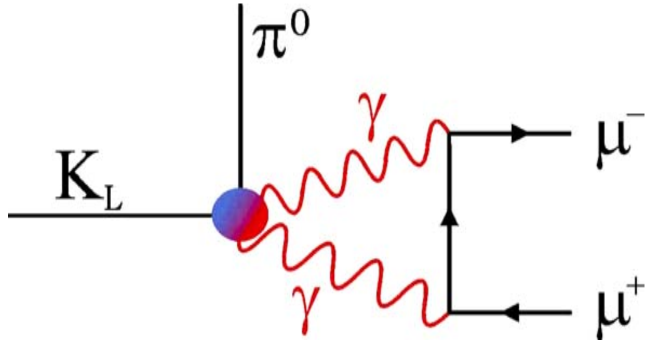
Direct CPV

Study Direct CP-Violation

- **Indirect CP-Violating Contribution has been measured (NA48/1, see next slide)**
- **Constructive Interference (theory)**
- **CP-Conserving Contributions are negligible**

Indirect CPV





CPC

0^{++}, 2^{++}

$K^0_L \to \pi^0 ee$ ($\mu\mu$): Sensitivity to New Physics

Isidori, Unterdorfer,Smith:

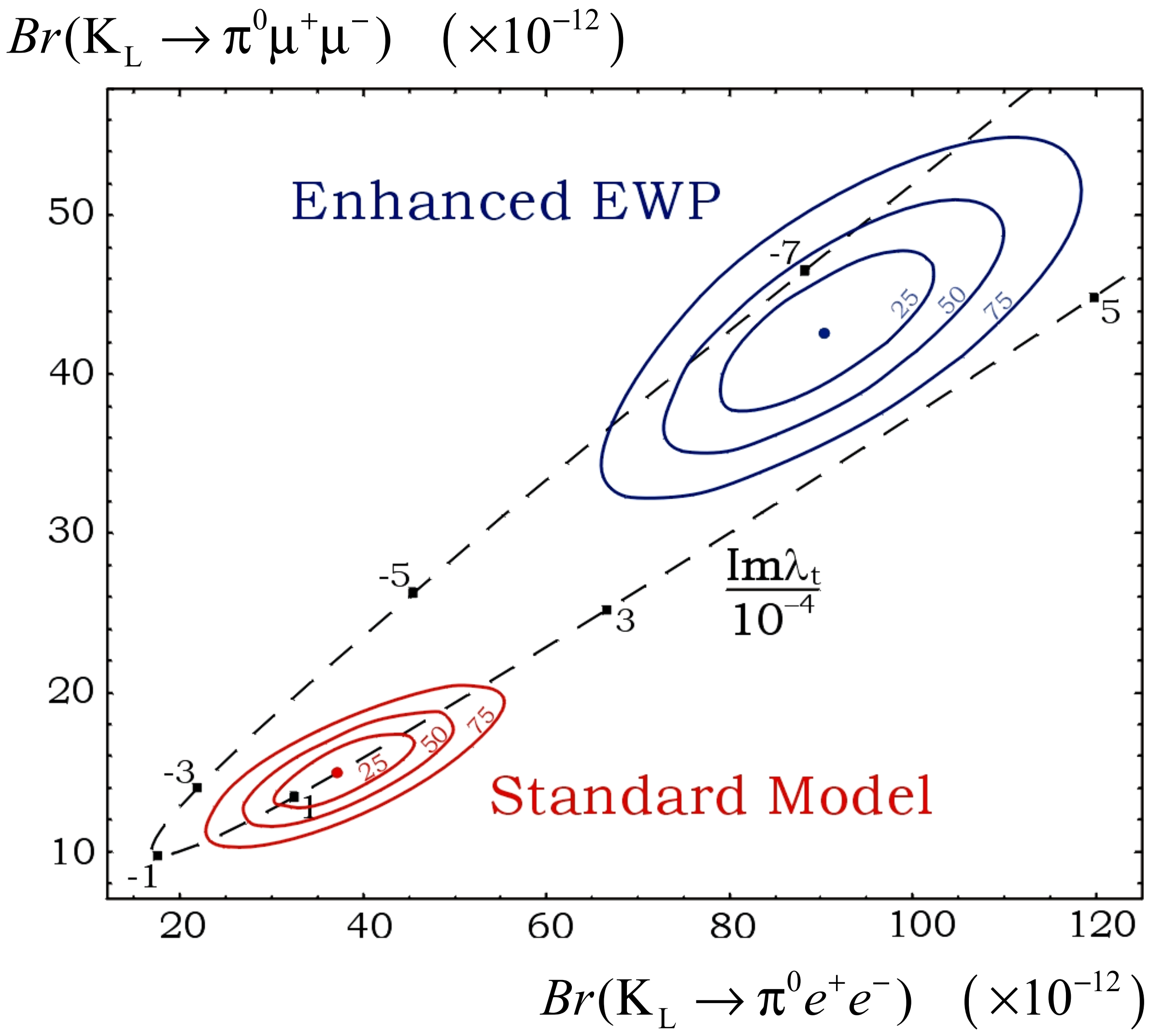
Fleisher et al:

Ratios of B → Kπ modes could be explained by enhanced electroweak penguins

and enhance the BR's:

$$B^{NP}_{e^+e^-} = 9.0^{+1.6}_{-1.6} \times 10^{-11}$$

$$B^{NP}_{\mu^+\mu^-} = 4.3^{+0.7}_{-0.7} \times 10^{-11}$$



* A. J. Buras, R. Fleischer, S. Recksiegel, F. Schwab, hep-ph/0402112

$K^0_L \to \pi^0 \nu \nu$

- Purely theoretical error ~2%: SM 3 10^{-11}
  - Purely CP-Violating (Littenberg, 1989)
  - Totally dominated from t-quark
  - Computed to NLO in QCD (Buchalla, Buras, 1999)
  - No long distance contribution SM~3 × 10^{-11}

- Experimentally: 2/3 invisible final state !!
- Best limit from KTeV using $\pi^0 \to ee\gamma$ decay

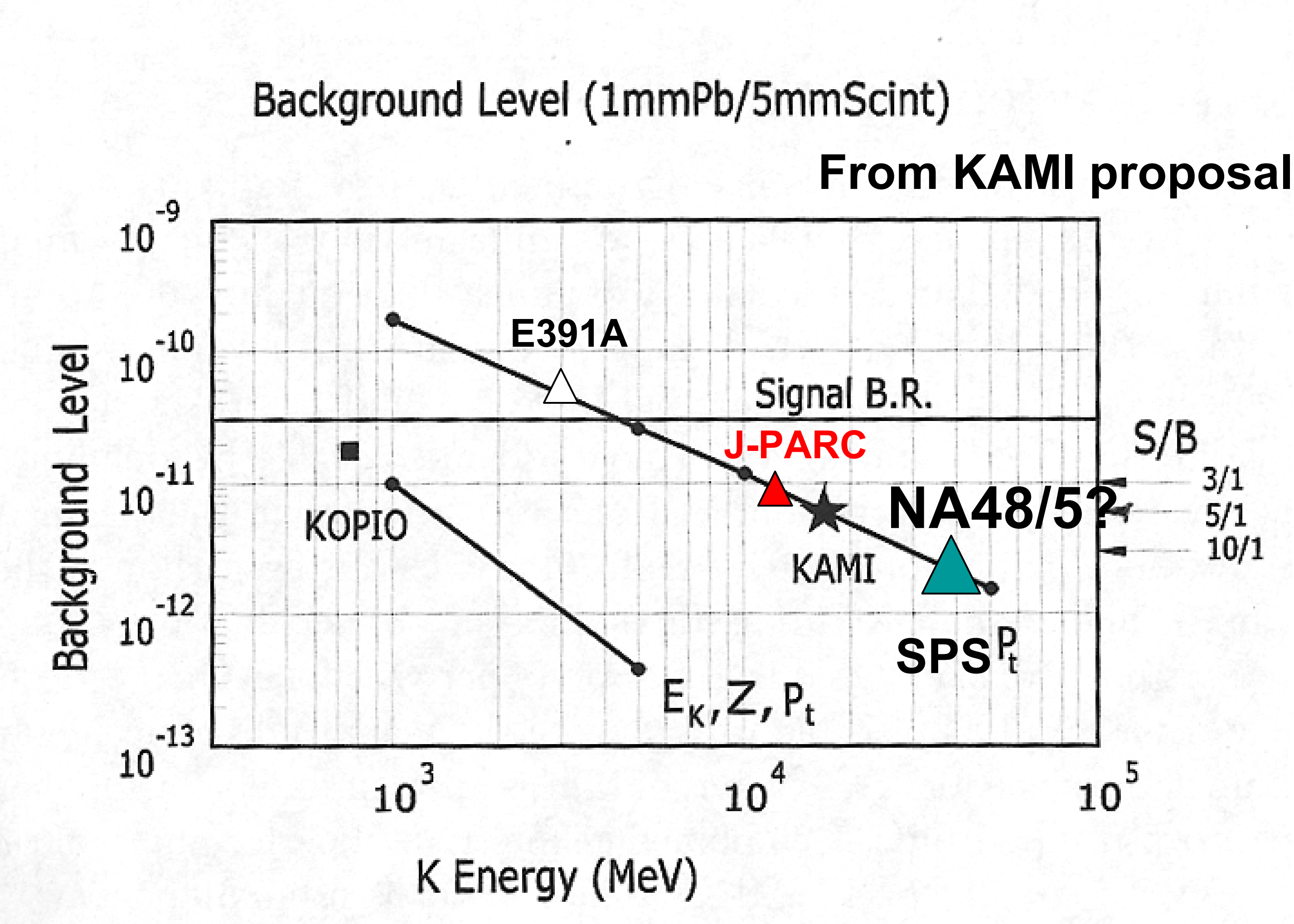
$BR(K^0 \to \pi^0 \nu\nu) < 5.9 \times 10^{-7}$ 90% CL

Still far from the model independent limit:

$BR(K^0 \to \pi^0 \nu\nu) < 4.4 \times BR(K^+ \to \pi^+ \nu\nu) \sim 1.4 \times 10^{-9}$

Grossman & Nir, PL B407 (1997)

$K_L \to \pi^0 \nu\nu$ @CERN?



Conclusions

- A competitive programme could take place in the near future for charged kaons

- For a very competitive neutral kaon decay experiment, ~ 10^{13} p/s slowly extracted, high energy protons would be needed

Beyond the Standard Model: the clue from Hadron studies ...

- **Precision study of hadrons ….**

  deviations in expected behaviour of

  light and c quarks → evidence for new physics +

  will elucidate new physics if found elsewhere

  - Rare decays
  - Mixing & CPV

Jin

Multi-quark states, glueballs and hybrids have been searched for experimentally for a very long time, but none is established.

However, during the past one year, a lot of surprising experimental evidences showed the existence of hadrons that cannot (easily) be explained in the conventional quark model.

The Renaissance in Hadron Spectroscopy

Quite a number of new narrow states just in the last two years!

η'_c from Belle, CLEO, BaBar

Narrow DsJ BaBar, CLEO, Belle

X(3872) from Belle, CDF, D0, BaBar

$\Theta^+(1540)$ ......a confused experimental scenario

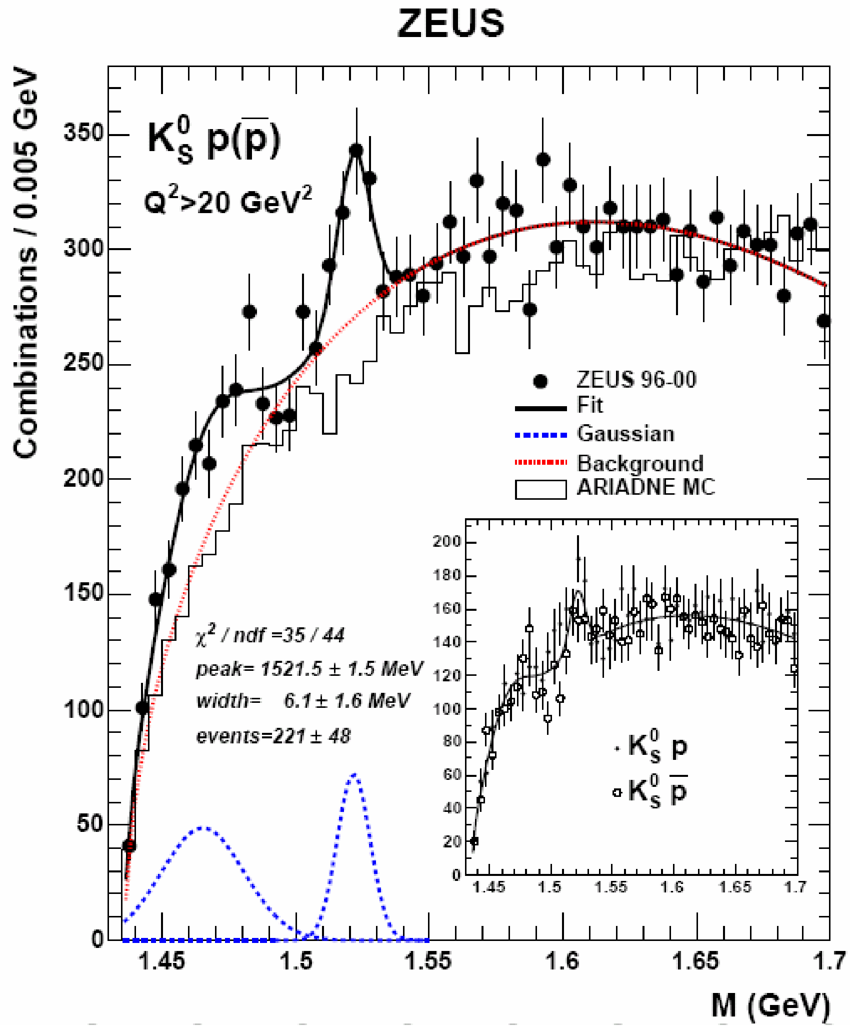
Evidence not confirmed

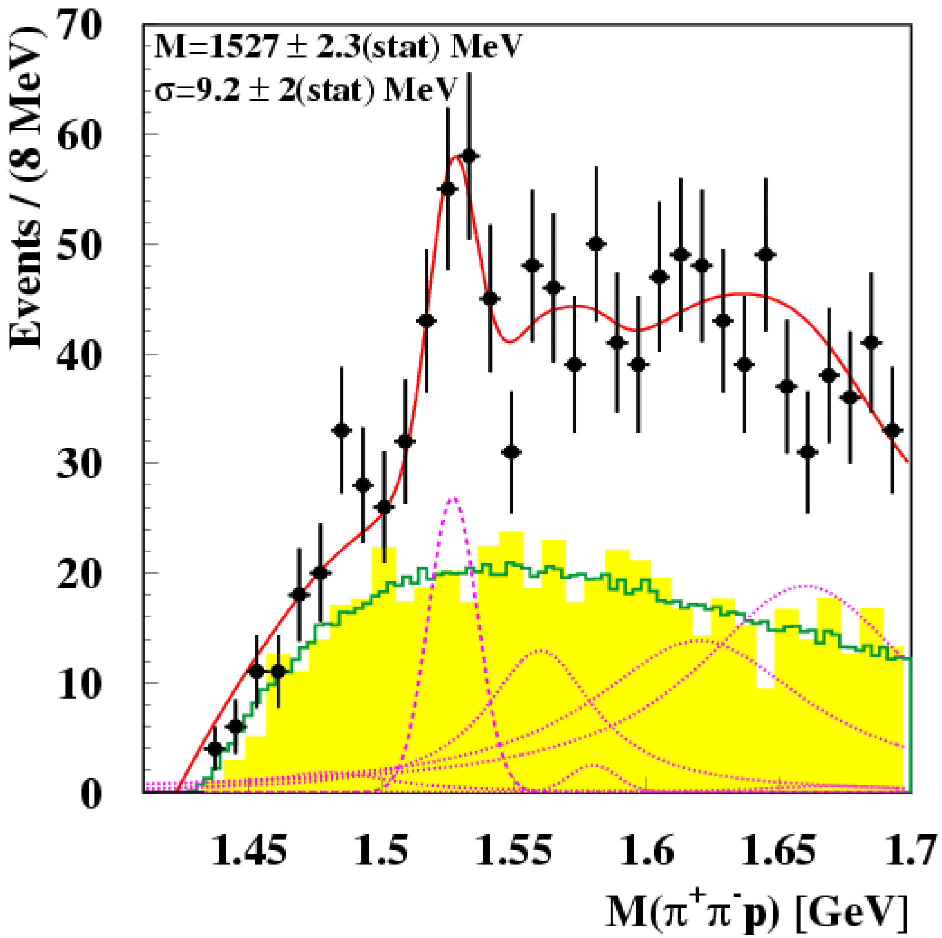
Ξ^+_{cc} Selex

$D^+_{SJ}(2632)$ Selex

Jin

Some Sightings of the $\theta^+(1530)$ …





… but many negative searches

Ellis

Questions on Hadron Spectroscopy

- Do (which) pentaquarks exist?
- Do other exotic hadrons exist?
- What are the quark descriptions of the $D_{sJ}(2317)$ and $D_{sJ}(2460)$?
- Does the $D_{sJ}(2632)$ exist (SELEX)?
- What is the quark description of the X(3872)?
- Interpretation of threshold reported states?
- Fate of 12% rule in ψ' decay (BES)?

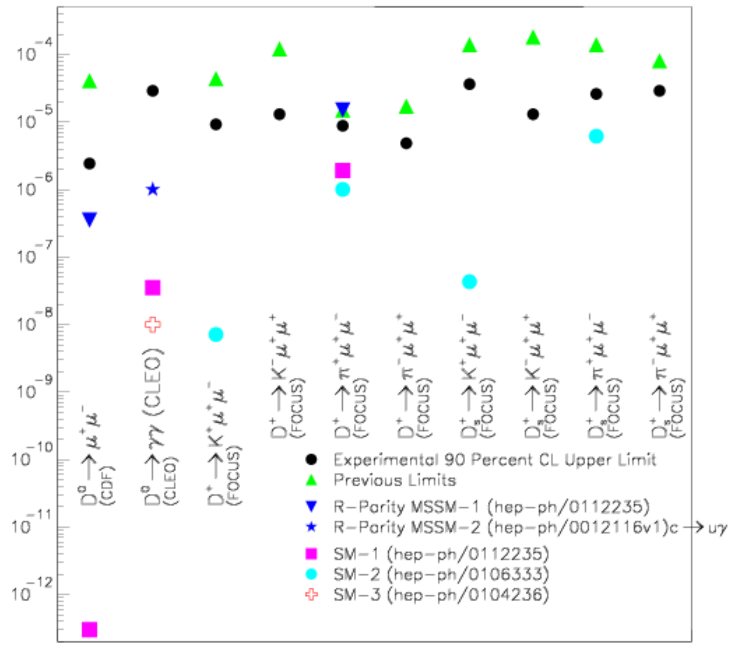
Rare and forbidden decays

Motivation: lepton number violation study
investigation of long range effects and SM extension

$$D^+, D_s^+ \rightarrow h^\pm \mu^\mp \mu^+$$

$$(h = \pi, K)$$

FOCUS improved results by a factor of 1.7 –14: approaching theoretical predictions for some of the modes but still far for the majority



CDF $Br(D^0 \rightarrow \mu^+\mu^-) < 2.4 \times 10^{-6}$ @ 90% C.L. ($65\ pb^{-1}$ data)

Hera –B $Br(D^0 \rightarrow \mu^+\mu^-) < 2 \times 10^{-6}$ @ 90% C.L

CDF and D0 can trigger on dimuons →promising

Next future: CLEO-c sensitivity 10^6

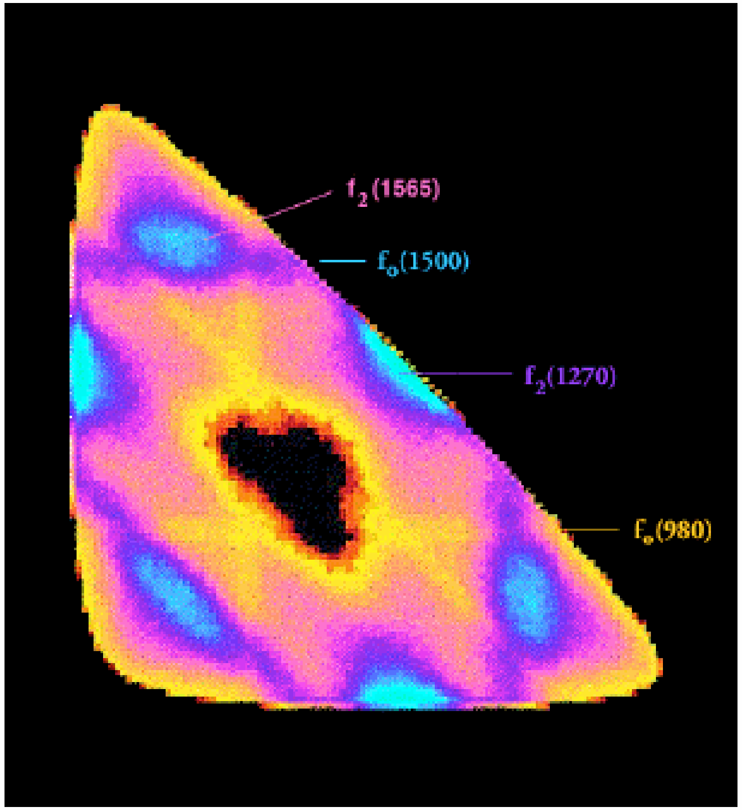
Next to Next future BTeV

Statistics is relevant!

Although statistics might
be a not sufficient condition,
it is certainly necessary!

PS	10^{13} p/sec @ 26 GeV/c
NEW PS	$6x10^{14}$ p/sec @ 30 GeV/c
SIS100/200 (GSI)	10^{13} p/sec @29GeV/c

$p\bar{p} \rightarrow \pi^0\pi^0\pi^0$ Dalitz plot



700000 events = 6×700000 entries

From Crystal Barrel

Future Muon Dipole Moment Measurements

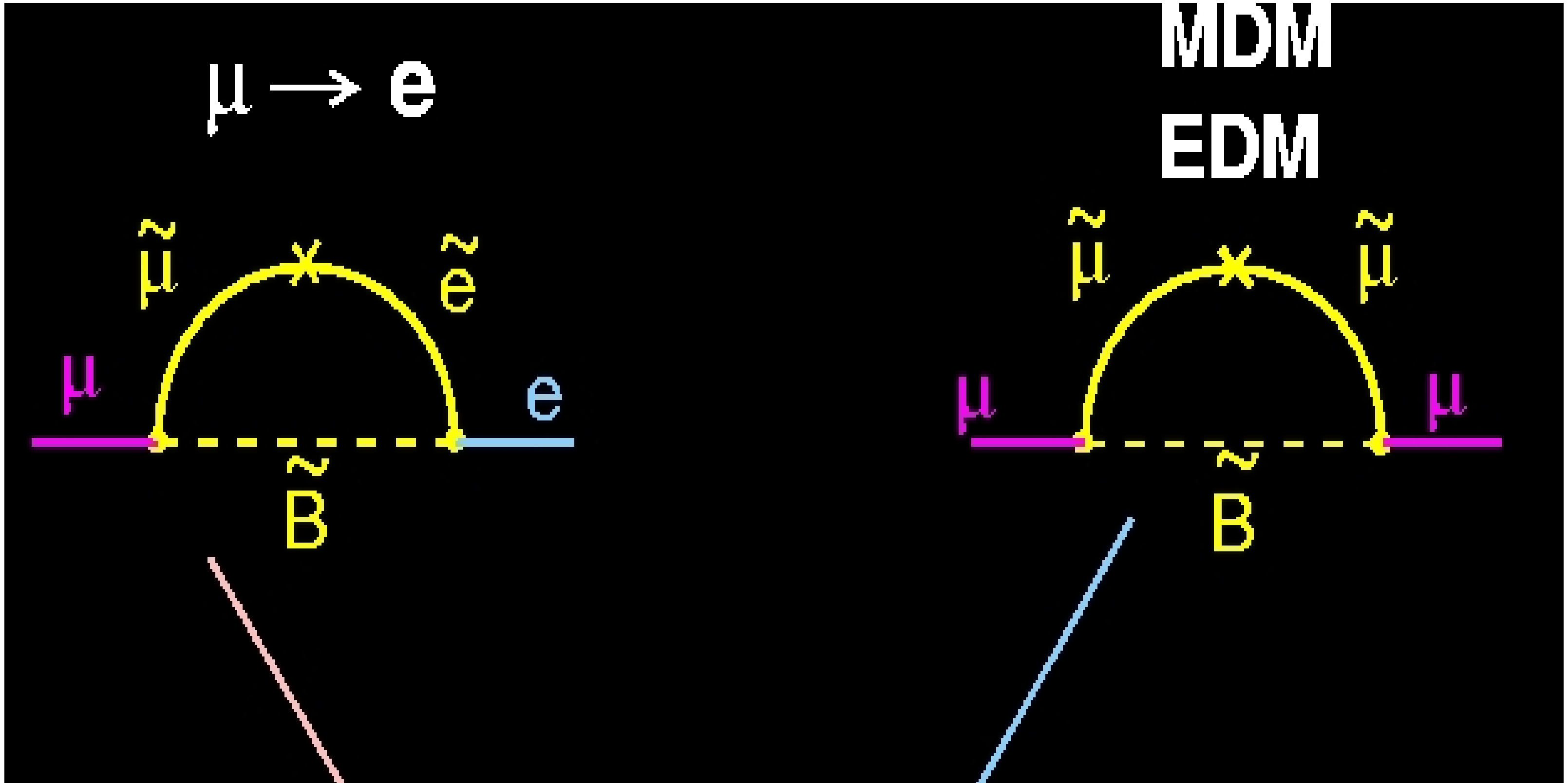
- at a high intensity muon source

A Precision Path to the Frontier

B. Lee Roberts
Department of Physics
Boston University

roberts@bu.edu http://physics.bu.edu/roberts.html

SUSY connection between D_μ, $\mu \rightarrow e$



$$\begin{pmatrix} m^2_{\tilde{e}\tilde{e}} & \Delta m^2_{\tilde{e}\tilde{\mu}} & \Delta m^2_{\tilde{e}\tilde{\tau}} \\ \Delta m^2_{\tilde{\mu}\tilde{e}} & m^2_{\tilde{\mu}\tilde{\mu}} & \Delta m^2_{\tilde{\mu}\tilde{\tau}} \\ \Delta m^2_{\tilde{\tau}\tilde{e}} & \Delta m^2_{\tilde{\tau}\tilde{\mu}} & m^2_{\tilde{\tau}\tilde{\tau}} \end{pmatrix}$$

Present EDM Limits

Particle	*Present EDM limit* (e-cm)	*SM value* (e-cm)
n	6.3×10^{-26}	10^{-31}
e^{-}	$\sim 1.6 \times 10^{-27}$	10^{-38}
μ	$< 10^{-18}$ (CERN) $\sim 10^{-19}$ * (E821)	10^{-35}
future μ exp	10^{-24} to 10^{-25}	

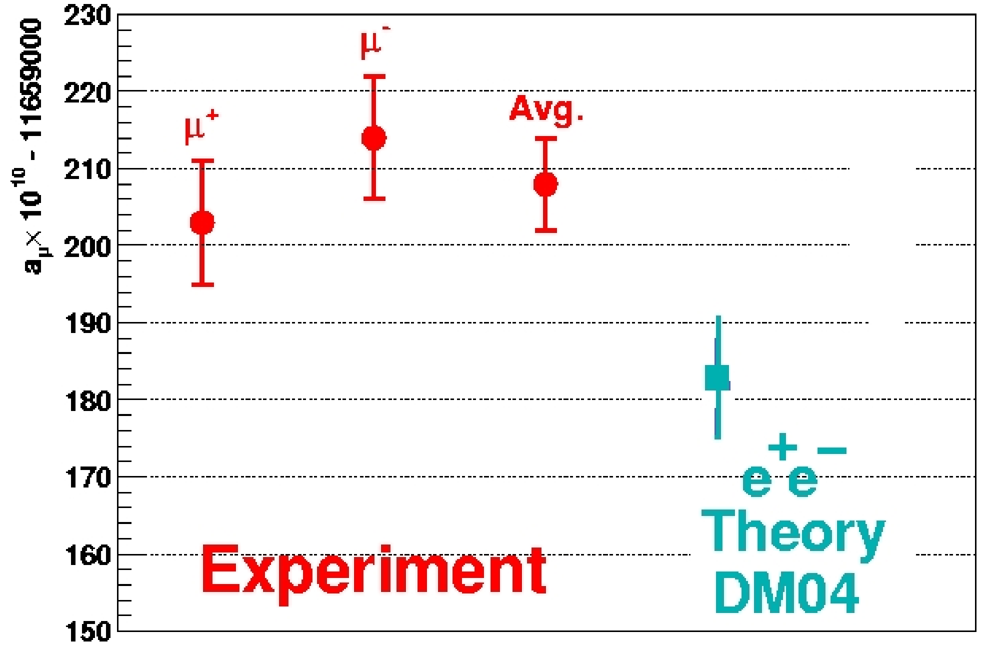
*projected

Unlike the EDM, a_μ is well measured.

$$a_{\mu^-} = 11\,659\,214(8)(3) \times 10^{-10} \quad (\pm 0.7\,\text{ppm})$$

$$a_{\mu^+}(\text{exp}) = 11\,659\,203(8) \times 10^{-10} \quad (\pm 0.7\,\text{ppm})$$

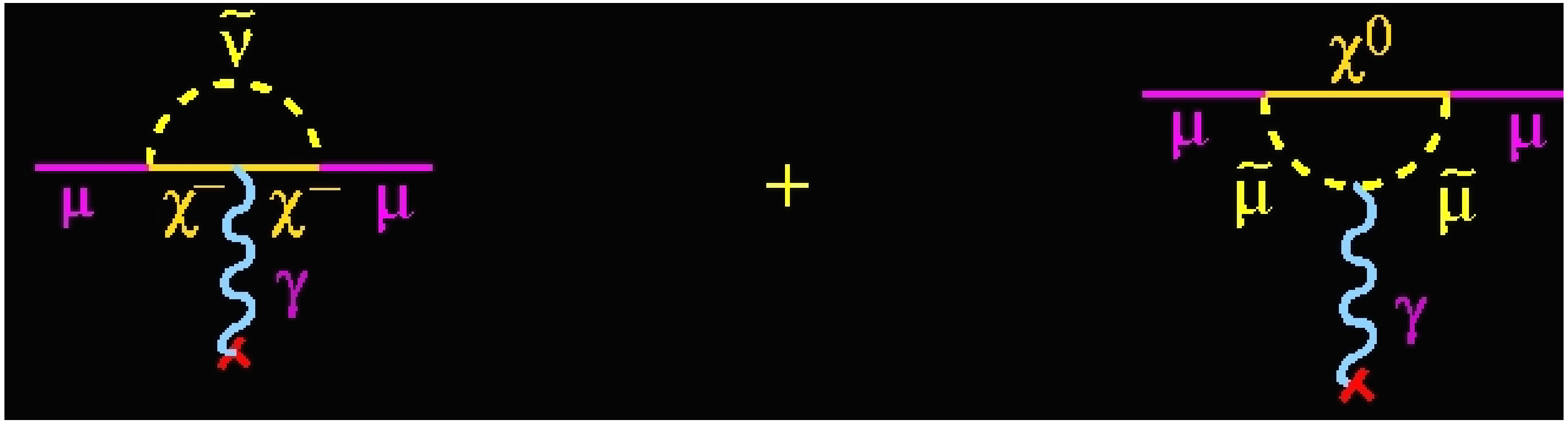
Comparing with e^+e^- - data shows a discrepancy with the standard model of 2.4σ



the combined value is

$$a_\mu(\text{exp}) = 11\,659\,208(6) \times 10^{-10} \quad (\pm 0.5\,ppm)$$

a_μ is sensitive to **all** virtual particles which couple to the muon, e.g. SUSY



a toy model with equal susy masses gives:

$$a_\mu(\text{SUSY}) \sim 1.3 \ \text{ppm} \quad \tan\beta \left(\frac{100 \ \text{GeV}}{\tilde{m}}\right)^2$$

If SUSY is discovered at LHC, then (g-2) will give a 20% determination of tan β

Required μ Fluxes

Experiment	N_μ	p_μ(MeV)	$\Delta p_\mu / p_\mu (\%)$	sensitivity	I_{off}/I_{on}, δT, ΔT
$\mu^+ \to e^+e^-e^+$	10^{17}	< 30	< 10	BR=10^{-15}	DC beam
$\mu^+ \to e^+\gamma$	10^{17}	< 30	< 10	BR=10^{-15}	DC beam
$\mu^- - e^-$ pulsed	10^{21}	< 80	< 5	BR=10^{-19}	10^{-10}, < 100ns, $> 1\mu$s
$\mu^- - e^-$ continuos	10^{20}	< 80	< 5	BR=10^{-19}	DC beam
μEDM	$10^{16}/P^2$	$300 - 500$	< 5	$10^{-24}\,e\,cm$	pulsed beam
$g - 2$	10^{16}	3100	< 2	< 0.1ppm	pulsed beam

Summary on muons

- Both g-2 and μEDM are sensitive to new physics *behind the corner*
- Unique opportunity of studying *phases of mixing matrix* for SUSY particles
- Historically, limits on d_E have been strong tests for new physics models
- μEDM would be the first tight limit on d_E from a second generation particle
- The experiments are hard but, in particular the μEDM, not impossible
- A large muon polarized flux of energy 3GeV (g-2) or 0.5GeV (μEDM) is required

ν Physics

ν oscillations are the most important discovery in hep of the last 15 years.

They measure fundamental parameters of the standard model. Mixing angles, neutrino masses and the CP phase δ_{CP} are fundamental constants of the standard model.

They are a probe of the GUT scales . The smallness of neutrino masses is connected to the GUT scale through the see-saw mechanism.

They are directly linked to many fields in astrophysics and cosmology : baryogenesis, leptogenesis, galaxies formation, dynamic of supernovae explosion, power spectrum of energy anisotropies, etc.

They open the perspective of the measure of **leptonic CP violation.**

Most of the parameters are waiting to be measured

δm^2_{12} ✔ — SOLARS+KAMLAND: $\delta m^2_{12} = (7 \pm 1)\ 10^{-5}\ eV^2$

θ_{12} ✔ — SOLARS+KAMLAND: $0.2 < \sin^2(\theta_{12}) < 0.5$

Addressed by a SuperBeam/Nufact experiment

δm^2_{23} ✔ — ATMOSPHERICS: $\delta m^2_{23} = (2.0 \pm 0.4)\ 10^{-3}\ eV^2$

θ_{23} ✔ — ATMOSPHERICS: $0.9 < \sin^2 2(\theta_{23}) < 1$

θ_{13} ☐ — CHOOZ LIMIT: $\theta_{13} < 14^0$

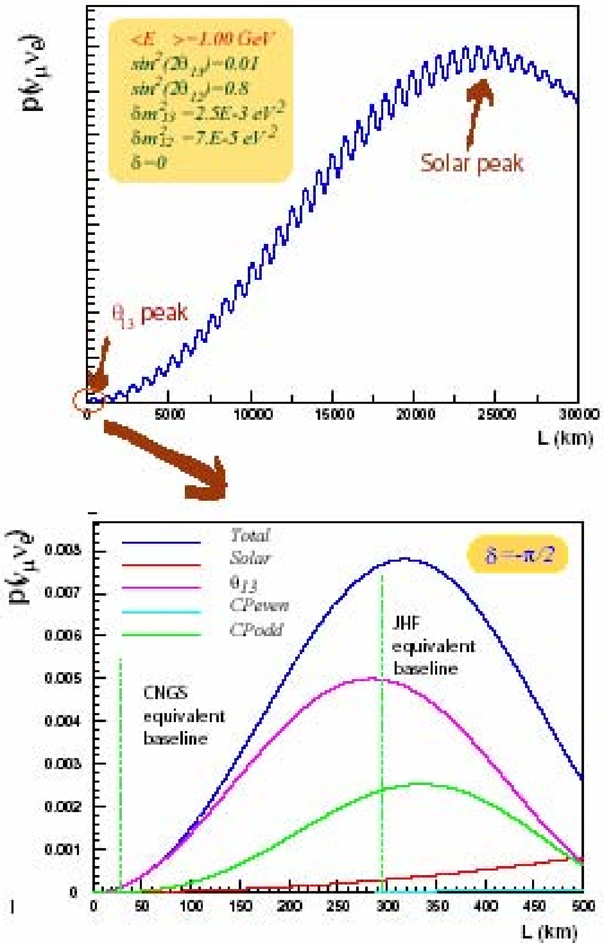
δ_{CP} ☐

Mass hierarchy ☐

Σm_ν ☐ — BETA DECAY END POINT: $\Sigma m_\nu < 6.6\ eV$

Dirac/Majorana ☐

Sub leading $\nu_\mu - \nu_e$ oscillations



$p(\nu_\mu \rightarrow \nu_e)$ developed at the first order of matter effects

$$p(\nu_\mu \rightarrow \nu_e) = 4c_{13}^2 s_{13}^2 s_{23}^2 \sin^2 \frac{\Delta m_{13}^2 L}{4E} \qquad \theta_{13}\text{ driven}$$

$$+ 8c_{13}^2 s_{12} s_{13} s_{23} (c_{12} c_{23} cos\delta - s_{12} s_{13} s_{23}) \cos \frac{\Delta m_{23}^2 L}{4E} \sin \frac{\Delta m_{13}^2 L}{4E} \sin \frac{\Delta m_{12}^2 L}{4E} \text{CPeven}$$

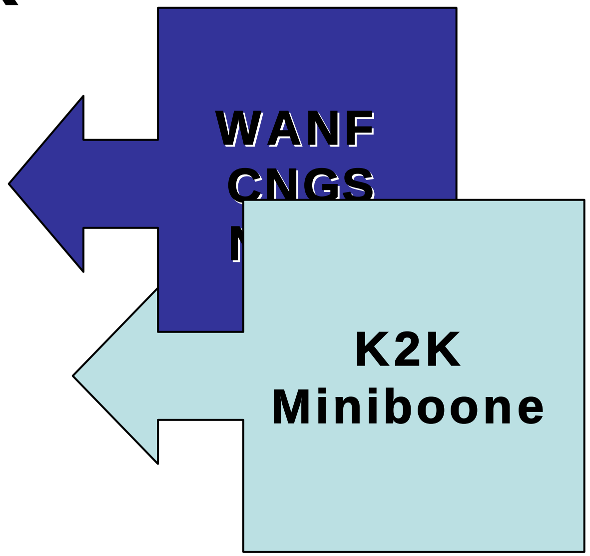
$$- 8c_{13}^2 c_{12} c_{23} s_{12} s_{13} s_{23} \sin\delta \sin \frac{\Delta m_{23}^2 L}{4E} \sin \frac{\Delta m_{13}^2 L}{4E} \sin \frac{\Delta m_{12}^2 L}{4E} \qquad \text{CPodd}$$

$$+ 4s_{12}^2 c_{13}^2 \{c_{13}^2 c_{23}^2 + s_{12}^2 s_{23}^2 s_{13}^2 - 2c_{12} c_{23} s_{12} s_{23} s_{13} cos\delta\} \sin \frac{\Delta m_{12}^2 L}{4E} \qquad \text{solar driven}$$

$$- 8c_{12}^2 s_{13}^2 s_{23}^2 \cos \frac{\Delta m_{23}^2 L}{4E} \sin \frac{\Delta m_{13}^2 L}{4E} \frac{aL}{4E} (1 - 2s_{13}^2) \qquad \text{matter effect (CP odd)}$$

where $a = \pm 2\sqrt{2} G_F n_e E_\nu = 7.6 \cdot 10^{-5} \rho [g/cm^3] E_\nu [GeV] \quad [eV^2]$

Outlook



- “Traditional” Neutrino Beams

  $(\pi^{\pm}, \kappa^{\pm} \rightarrow \upsilon_{\mu}\ \upsilon_{e})$

  – Narrow beams (NNB)

  – Wide Band (WNB)

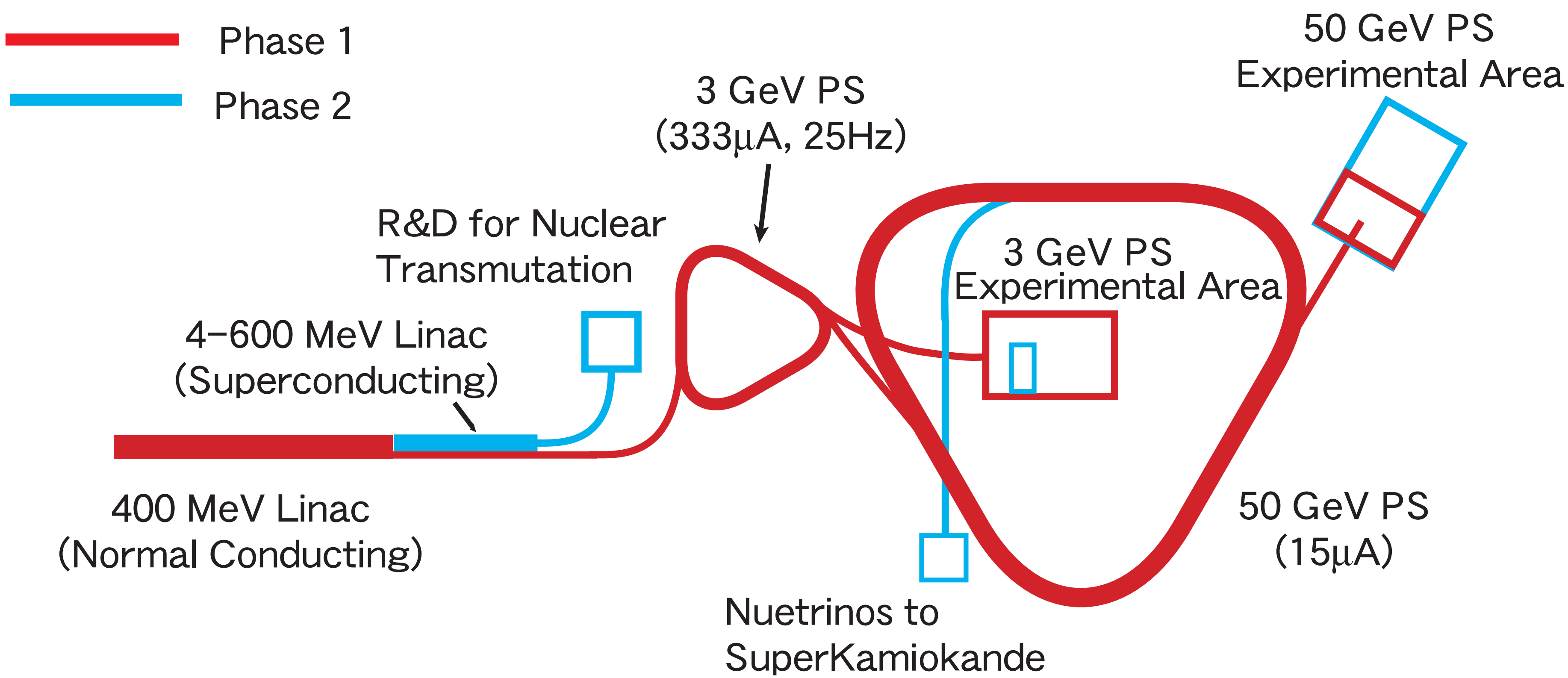
- Super Beams
  – Off-Axis
- Neutrino –Factories ($\mu^{\pm}$ -> $\upsilon_{\mu}\ \upsilon_{e}$)
- Beta Beams

Super Beams

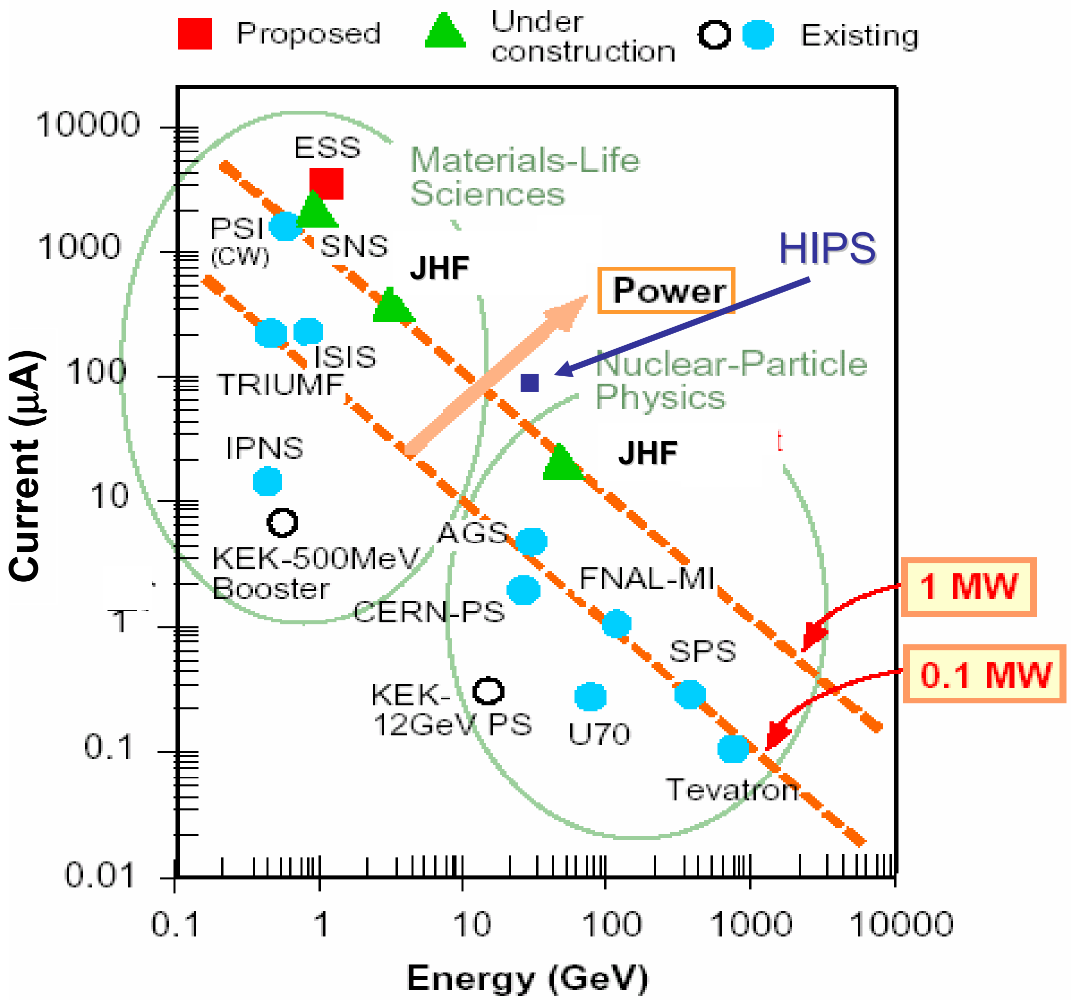
Standard Beams but with High Intensity

- Higher power machine, i.e. an higher number of proton on target;
- Large and tunable L/E_ν
- Better defined $E_\nu \sim 1\text{–}2$ GeV
- Less ν_e/ν_μ contamination, i.e. suppressing the K^0 and K^+ production

JHF Complex

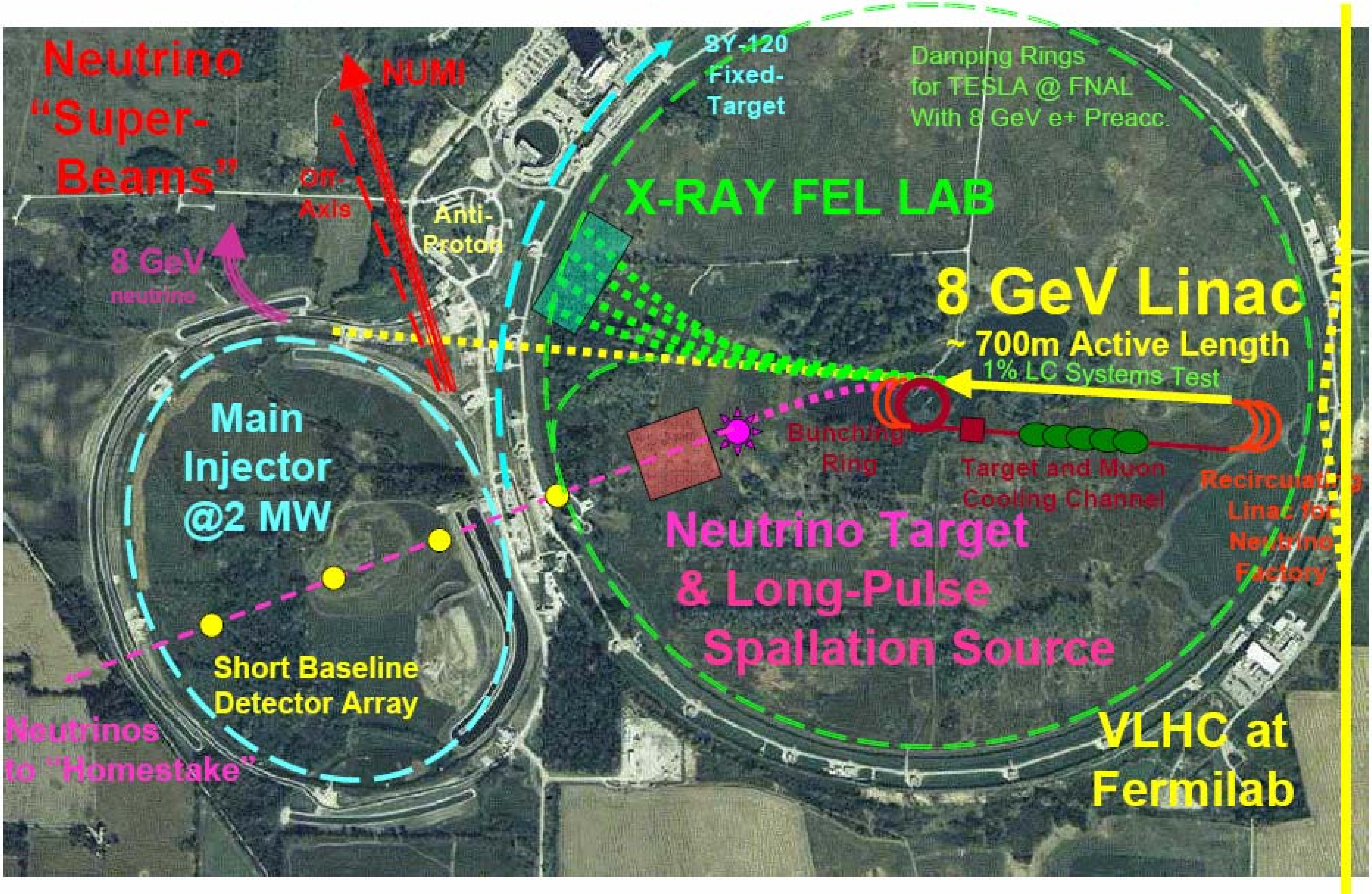

Phase 1
Phase 2
50 GeV PS
Experimental Area
3 GeV PS
(333μA, 25Hz)
R&D for Nuclear
Transmutation
3 GeV PS
Experimental Area
4–600 MeV Linac
(Superconducting)
400 MeV Linac
(Normal Conducting)
50 GeV PS
(15μA)
Nuetrinos to
SuperKamiokande

BEAM ENERGY, BEAM CURENT, AND BEAM POWER OF WORLD'S PROTON MACHINES

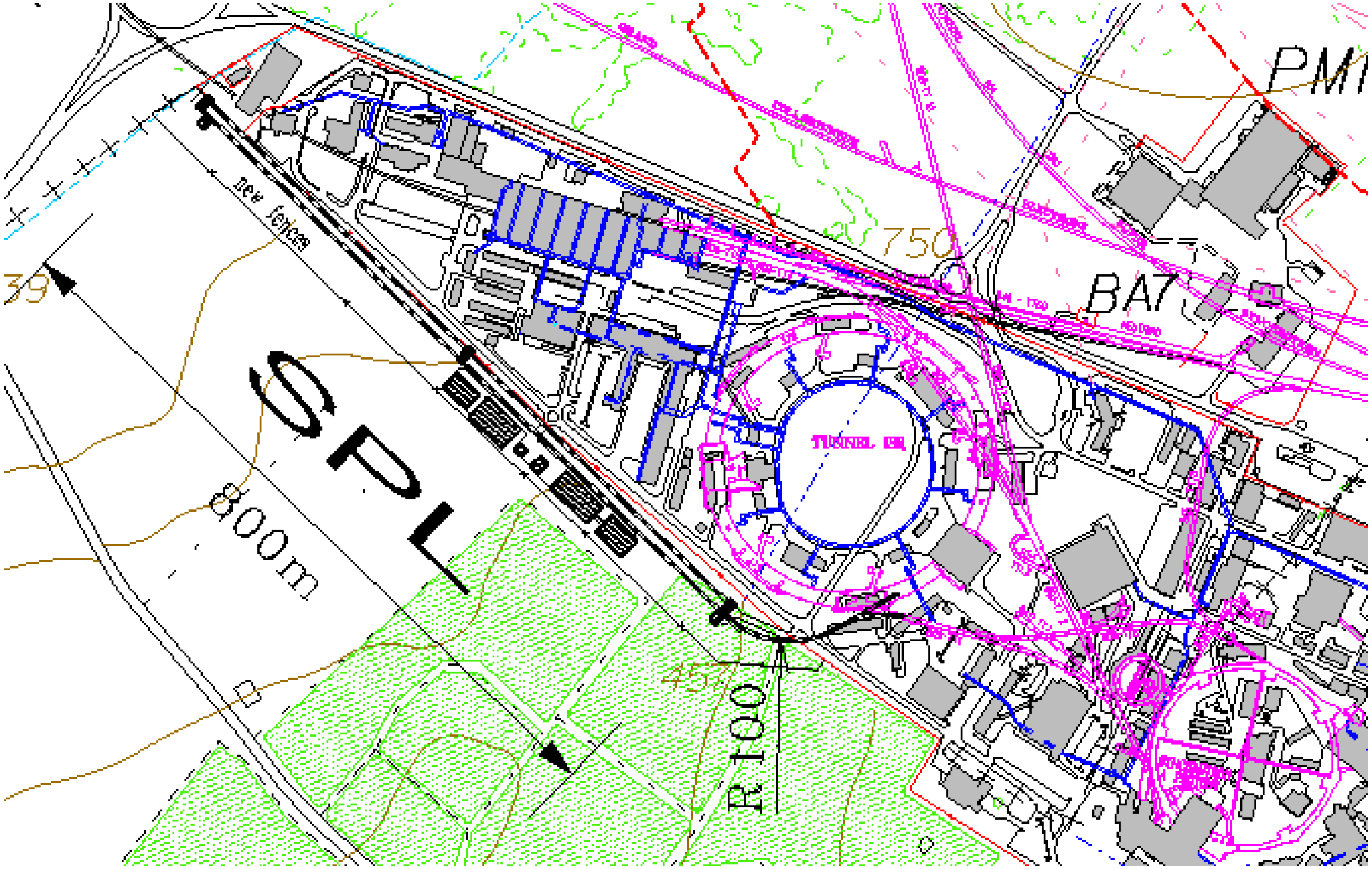


8 GeV Superconducting Linac

With X-Ray FEL, 8 GeV Neutrino & Spallation Sources, LC and Neutrino Factory



Layout (CDR 1)



Benefits of the SPL

Replacement of the (40 years old !) 1.4 GeV PSB by a 2.2 GeV SPL

⇓

☺ Radio-active ion beams: EURISOL is feasible

(direct use of 5-100 % of the SPL nominal beam)

☺ Neutrino super-beam: ideal with a large detector at Frejus

(using an accumulator and 100 % of the SPL nominal beam)

☺ Neutrino beta-beam: ideal + synergy with EURISOL

(direct use of 5 % of the SPL nominal beam)

☺ LHC: - potential for substantial increase of brightness/intensity from the PS beyond the ultimate (space charge limit is raised to 4 10^{11} ppb)*

- large flexibility for # bunch spacings (replacing RF systems…)
- simplified operation / increased reliability

😐 PS: - limited benefit on peak intensity (~ 6 10^{13} ppp)

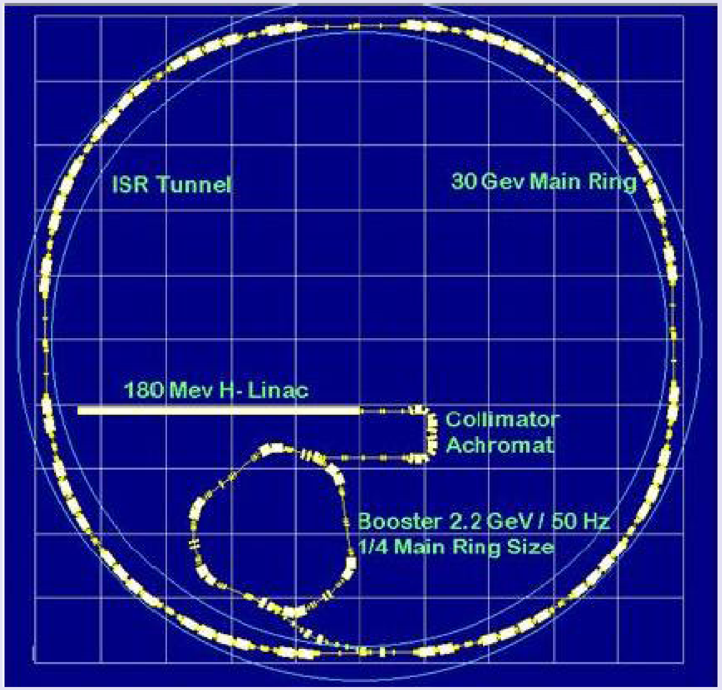
- large potential for higher beam brightness (x 2)
- large flexibility in number of bunches, emittances and intensities

😐 CNGS: limited benefit (target capability is fully used with 7 10^{13} ppp)

* More work is needed to analyse the other limitations

Typical 30 GeV RCS

A 30 GeV, 8 Hz Synchrotron as Possible Replacement for CERN PS



- 180 MeV H^- Linac with 2.5 MeV fast beam chopper
- Achromatic arc with high normalised dispersion
- Momentum ramping for injection painting
- bunch compression

Consequences (2)

- Potential of 4 MW - 30 GeV RCS:
  - Driver for kaon physics
  - Driver for ν physics

  } If sharing the same target !

  - Upgraded proton injector for LHC
  - Upgraded proton injector for a higher energy synchrotron (SPS or super-SPS)

  } With adequate choice of RF

- Limitation of 4 MW – 30 GeV RCS: lack of flexibility
  - Magnetic cycle is fixed (likely, but to be confirmed)

    ⤷ Slow ejection ?
    Acceleration of heavy ions for LHC ?

  - RF has a limited frequency range (4.5 %)

    ⤷ Acceleration of heavy ions for LHC ?
    Beam gymnastics ?

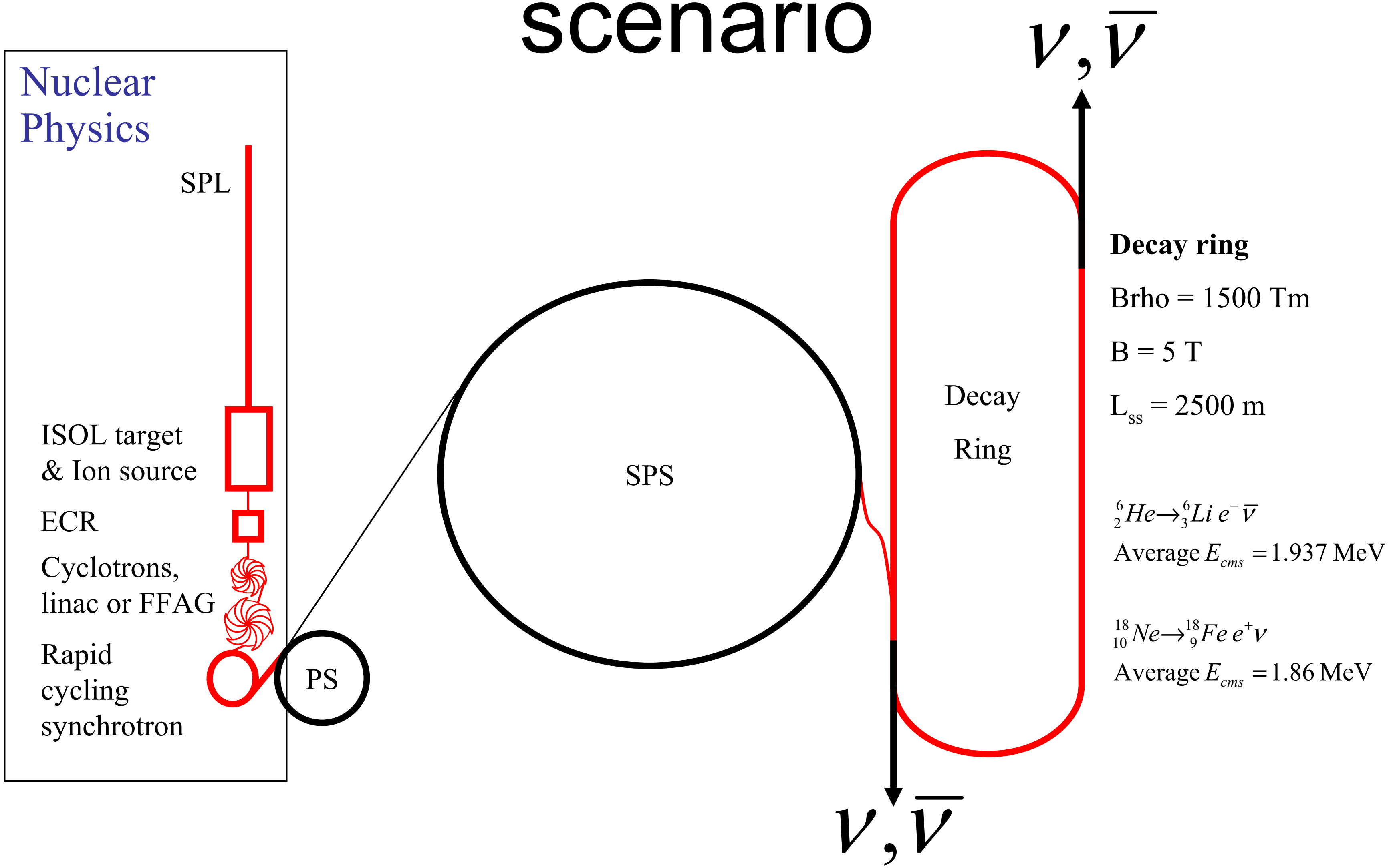
Long term: preliminary comparison

	INTEREST FOR			
	LHC upgrade	**Neutrino physics beyond CNGS**	**Radioactive ion beams (EURISOL)**	**Others ****
SPL * (>2 GeV – 50 Hz)	**Valuable**	**Very interesting for super-beam + beta-beam**	**Ideal**	**Spare flux ⇒ possibility to serve more users**
RCS (30 GeV – 8 Hz)	**Valuable**	**Very interesting for neutrino factory**	**No**	**Valuable**
New PS (30 GeV)	**Valuable**	**No**	**No**	**Valuable**
New LHC injector (1 TeV)	**Very interesting for doubling the LHC energy**	**No**	**No**	**Potential interest for kaon physics**

* Comparison should also be made with an RCS of similar characteristics.

** Input expected from the present workshop !

CERN: β-beam baseline scenario



ν beams parameters

Main parameters for present and future long base-line neutrino oscillation experiments at accelerators with conventional ν_μ beams.

Neutrino facility	Proton momentum (GeV/c)	L (km)	$E_\nu(GeV)$	p.o.t./year (10^{19})
KEK PS	12	250	1.5	2
FNAL NUMI	120	735	3	36
CERN CNGS	400	732	17.4	4.5
CERN SPL	2.2	130	0.27	10000
JHF-OA	50	295	0.76	100
NUMI-OA	120	820	2.0	40

Sensitivity to θ_{13}

The expected 90% C.L. sensitivity on θ_{13} measurements for the long-baseline experiments for $\Delta m^2_{23} \sim 2.5 \cdot 10^{-3}$ eV ($\delta = 0$).

Experiment	fid mass (Kt)	θ_{13}
MINOS	5.0	7.1^0
ICARUS + OPERA	2.4 + 1.8	5^0
ICARUS - L.E.$\times$1.5	2.4	3.5^0
β-Beam	440	0.8^0
CERN SPL	440	1.2^0
T2K	22.5	2.3^0
NOνA	50	1.8^0
Neutrino Factory	40	$< 0.1^0$

Machines comparison

		T2K	J-Park 2	PS++	SPL	βB
power p-driver	(MW)	0.75	4	4	4	0.4
p-beam energy	(GeV)	50	50	20	2.2	1-2.2
E_{ν_μ}	(GeV)	0.7	0.7	1.6	0.27	0.3
L	(Km)	295	295	732	130	130
Off-Axis		2^0	2^0	-	-	-
ν_μCC/Kt/year		100	500	450	45	38
ν_eCC/ν_μCC	%	0.4	0.4	1.2 - no opt.	0.7	0

- A huge work has been done in the last years in order to figure out which is the best facility for the neutrino sector but so far no full convergence obtained yet.

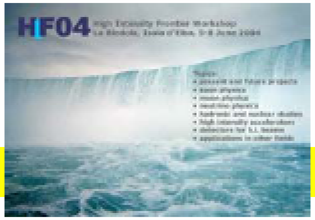
  (Each solution has O(1 G€) toll....)

- **We should converge towards a solution that fits the neutrino physics needs AND the hadron and nuclear communities**

- We should also try to exploit at the maximum EXISTING FACILITIES AND LABORATORIES; consider also sinergies with other labs

- WE MUST CONVERGE QUICKLY otherwise the physics program seen these days can be performed outside CERN (USA?)

- National interests cannot be neglected (..)

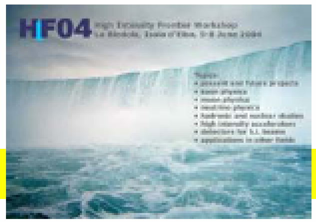


General landscape:

- Japan: rich (in all senses) program at JPARC in the near future; we have to take into account this competition in any new facility

- USA: task force at FNAL working to sort out what is needed; well advanced and organized. Name of the game: **flexibility** On similar lines is moving BNL

- Europe: build and exploit LHC
  GSI experimentation
  HERA shall (should) close in 2007
  try to figure out road map in neutrino sector
  try to figure out where to host nuclear physics facility



Machines comparison

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p-beam energy	(GeV)	50	50	20	2.2
E_{ν_μ}	(GeV)	0.7	0.7	1.6	0.27
L	(Km)	295	295	732	130
Off-Axis		2^0	2^0	-	-
ν_μCC/Kt/year		100	500	450	45
ν_eCC/ν_μCC	%	0.4	0.4	1.2 - no opt.	0.7

Kaons: Longer term (i.e. More Protons Needed!)

- $K^0_L \rightarrow \pi^0 e^+ e^-$ and $K^0_L \rightarrow \pi^0 \mu^+ \mu^-$ (NA48/4)
- $K^0_L \rightarrow \pi^0 \nu \nu$ (NA48/5)

QCD and strong interactions II

- Parton distribution functions (structure of nucleon) : a grand project of QDC over the last decades!
  - Complex enterprise involving theoretical and experimental errors, statistical and systematic.
  - Validation of QCD input parameters (PDF, α_s) in view of the early stage of LHC
- LHC itself will then provide a new frontier for QCD

The boundary between QCD for its own sake, and QCD as a servant for new physics is thin...QCD is anyhow challenging!!

Beyond the Standard Model (not LHC)

- Beauty studies are widely uncovered with dedicated facilities.
- Only more recently charm has attracted interest as clue for New Physics
  - this is due to the excellent statistics and quality of the data!
  - Investigation of rare (or unexpected) measurements
  - fixed target experiments have been competitive!

$\rightarrow$Mixing

Future proton beams at CERN

- **EURISOL community is interested in CERN**

  - Improved injector complex (replacement of Linac2 + PSB)

  should CERN host EURISOL ?

- **Large consensus for a multi-MW proton source**

  Must look for synergies

Already established:

- EURISOL

  ν super-beam + β-beam → Frejus experiment

To be worked upon:

- LHC upgrade
- Fixed target physics (kaons etc.)

Direct signatures for new physics in charm decays

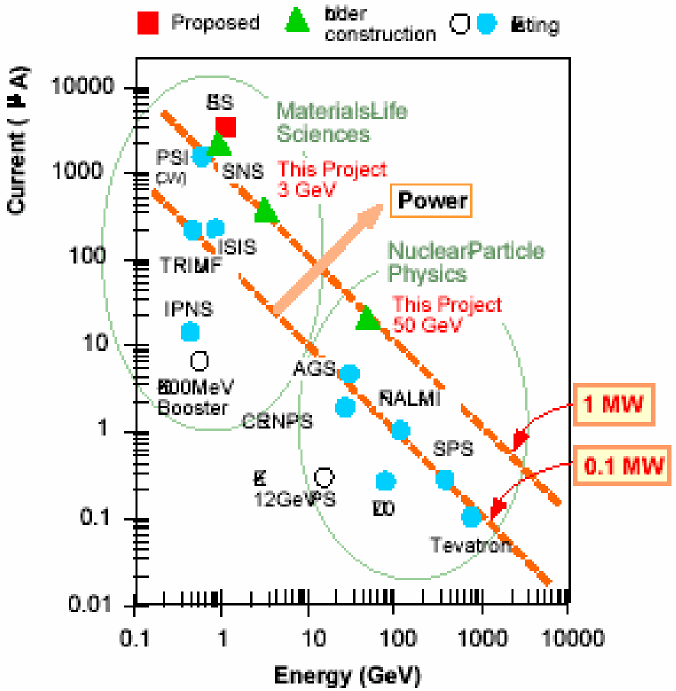
Bigi-Sanda hep-ph/9909479

"A priori it is quite conceivable that qualitatively different forces drive the decays of up-type and down-type quarks .
More specifically, non-Standard-Model forces might exhibit a very different pattern for the two classes of quarks".

Charm decays are the only up-type quarks that allow to probe this physics:non-strange light flavour hadrons do not allow for oscillations and top-flavoured hadrons do not even form in a practical way

After T2K, in the standard scenario

- θ_{13}, discovery or precision measure
- Mass hierarchy
- **Leptonic CP violation**



Any major improvement of T2K will be extremely expensive:

- The proton driver is a next generation machine
- The detector is 10 times bigger of the second biggest: Minos.
- The designed close detectors system is very ambitious.

THE θ_{13} DILEMMA

The knowledge of θ_{13} is necessary to guarantee the conditions to measure δ and to optimize the facility.

Waiting for the T2K results (or Numi Off-Axis or Reactors) implies a 10 years delay.

If we wait and θ_{13} remains undetected we should consequently stop any further neutrino oscillation initiative (because of the cost).

Any future initiative should have enough physics potential besides neutrino oscillations to justify the risk of starting the Leptonic CP violation searches without any guarantee.

BEAM FLUXES: ORDERS OF MAGNITUDE

momentum range (GeV/c)	length (m)	flux per sec	beam purity
0.4 to 0.8	17.5	K^+ 10^6 K^- $5\cdot10^5$	$\pi/_K \gtrsim 1$
0.4 to 0.8	14.5	K^+ $5\cdot10^6$ K^- 2.5×10^6	$\pi/_K \gtrsim 1$
0.7 to 1.5	26.5	K^+ $6\cdot10^6$ K^- $3\cdot10^6$	$\pi/_K \sim 2$
1.2 to 2.5	32	K^+ 10^7 K^- $5\cdot10^6$	$\pi/_K \sim 1$
4 to 13	750	μ^+ $5\cdot10^8$	$\pi/_\mu$ 10^{-6}
1 to 6	750	$\bar{p}$ $2\cdot10^6$ $\bar{p}$ $3\cdot10^8$ $\bar{p}$ $2\cdot10^8$	10^{-3} $\pi^-/_{\bar{p}}$ 3 20
2.5 to 7.5	90	K^+ $8\cdot10^7$ K^- $3\cdot10^7$	$\pi/_K \sim 3(4)$
K_L^0 (0°)	50	K_L^0 10^7	(3.5m C abs) $K_L^0/n \sim 1$

PHYTHIA: E = 30 GeV, I = 80 μA

Conclusions

- The measured value of a_μ differs from the SM value by ~2.4 to 3 σ, and a_μ will remain an important quantity. If SUSY is found, → tan β
- We propose to improve the precision of a_μ .
- The muon EDM experiment can only be done at a high intensity muon source.
- We believe that a precision of $10^{-24} – 10^{-25}$ e-cm could be reached at a high intensity muon source.
- EDMs are an excellent opportunity to search for non-standard-model *CP* violation.

Basic parameters

Input (?)

	Request	Typical choice
Particles	Protons	
Energy	> 15 GeV	30 GeV
Beam power	Multi-MW	4 MW
Type of accelerator		Synchrotron
Beam intensity (Energy/pulse)		~ 10^{14} p/p (480 kJ/p)
Cycling rate		~ 8.3 Hz
Type of magnets		Normal conducting
Circumference		~ 2π 100 m

Close

Interpretations of $\theta^+(1530)$ – **if it exists**

- Naïve non-relativistic quark model would need epicycles:
  di/triquarks, P-wave ground state
- Predicted in chiral soliton model:
  fits data, predicts other exotic states
- Existence requires confirmation:
  a high-statistics, -significance experiment
- If it exists, θ^+ spin & parity distinguish models

← Based on idea that quarks weigh << Λ_{QCD}

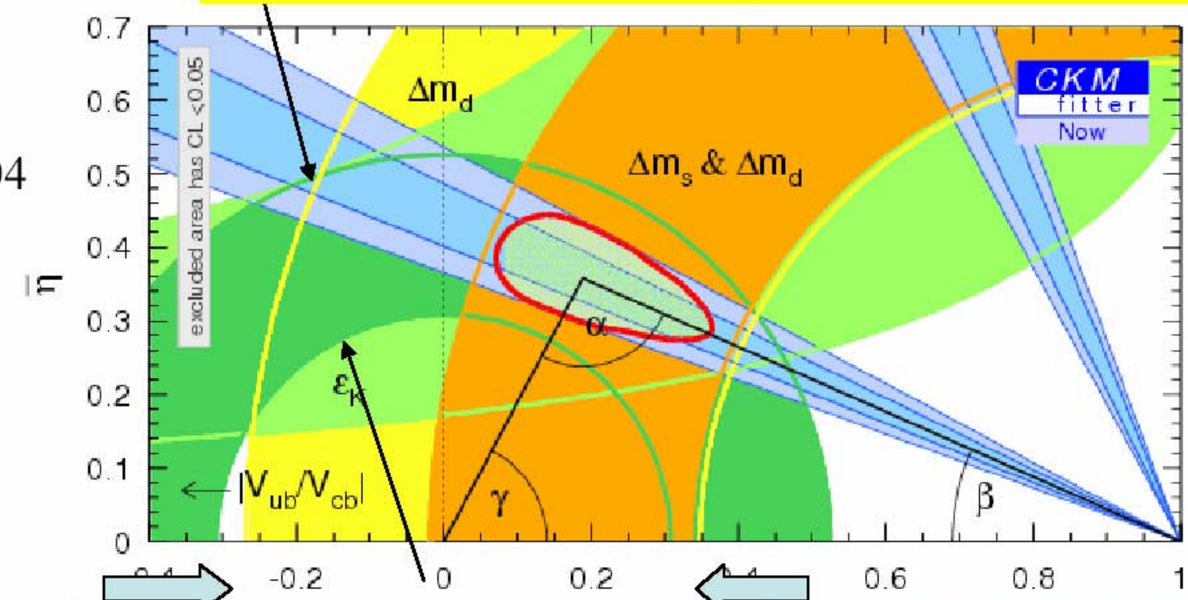
The stakes are high:

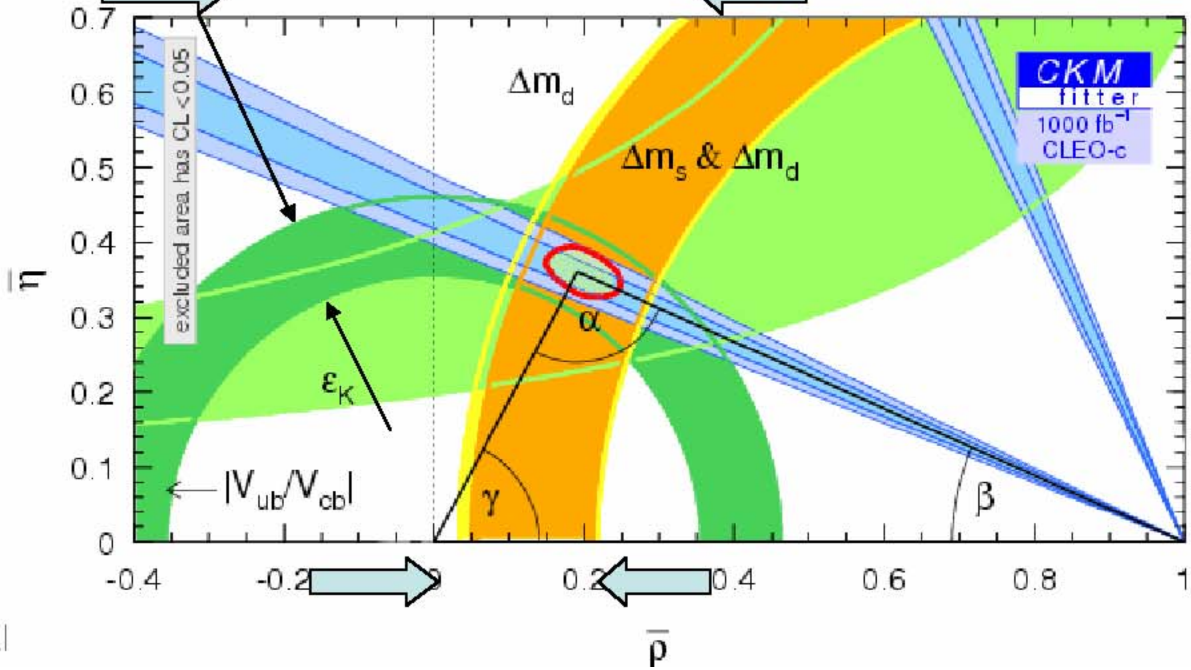
the θ^+ may take us beyond the naïve quark model

Precision theory + charm = large impact

Shipsey

2004



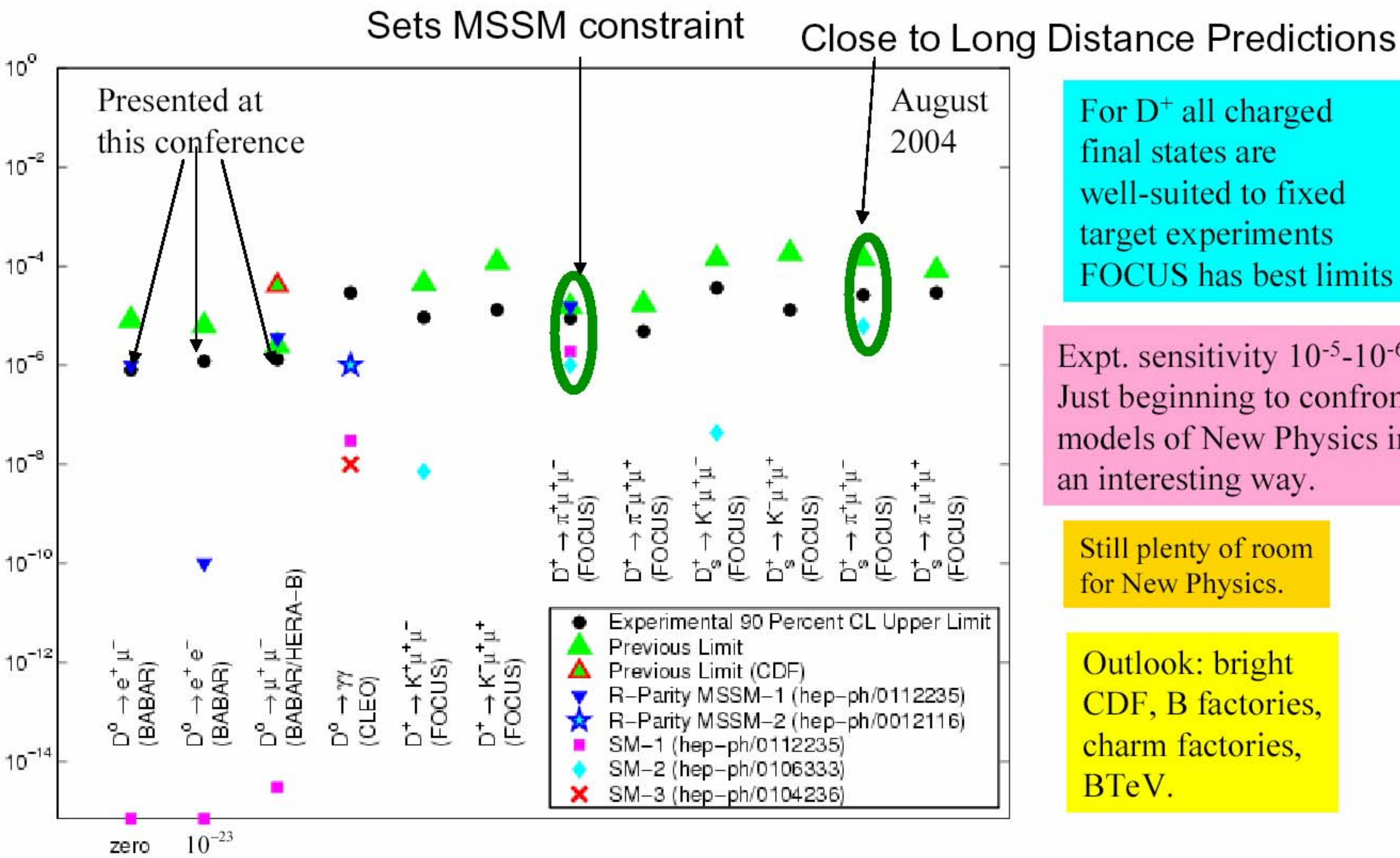


precision QCD calculations tested with *precision* charm data
➔theory errors of a few % on B system decay constants & semileptonic form factors

+

500 fb-1 @ BABAR/Belle

Rare Decay Summary



For D^+ all charged final states are well-suited to fixed target experiments FOCUS has best limits

Expt. sensitivity 10^{-5}-10^{-6} Just beginning to confront models of New Physics in an interesting way.

Still plenty of room for New Physics.

Outlook: bright CDF, B factories, charm factories, BTeV.

HIF04
High Intensity Frontier Workshop
La Biodola, Isola d'Elba, 5-8 June 2004

The workshop deals with medium and long term opportunities for particle and nuclear physics, offered by high intensity proton sources.

Discussions will focus on particle and accelerator physics to investigate new High Intensity Frontiers.

Many areas can benefit from high current beams:

- experiments with kaons and muons

  (CP violation, Lepton Flavour violation, g-2 and muon EDM measurements)
- neutrino beams (superbeams, beta-beams and factories)
- hadron studies (spectroscopy, DIS, structure functions, antiprotons)
- nuclear physics

Present projects for new accelerators will be reported and promising ideas for future proposals will be brought forward.

INFN

Kaons at CERN

- The effort is centered around the activities of the NA48 Experiment
  - Focus on Rare Kaon Decays as the next logical step

- Short to medium term scenario (2004-2010):
- Identify a compelling physics case that can be addressed with the existing CERN Accelerator Complex (e.g. SPS, 400 GeV) …and:
- Is compatible with the current approved programme (LHC + CNGS+ COMPASS)
  - SPS as injector of the LHC ~15% of time
  - SPS to deliver ~4.5 $\times$ 10^{19} POT/YEAR To Gran Sasso
- Builds on the existing NA48 infrastructure
  - ECN3 underground area, vacuum tank, LKr Calorimeter, Collaboration

- Longer term scenario (>2011):
- Assume a new PS and/or SPS capable of higher intensity/energy as ultimate injectors for LHC

- General Considerations:
- High Energy protons are needed to make kaons!
- The kaon experiments need slow proton extraction!

QCD and strong interactions I

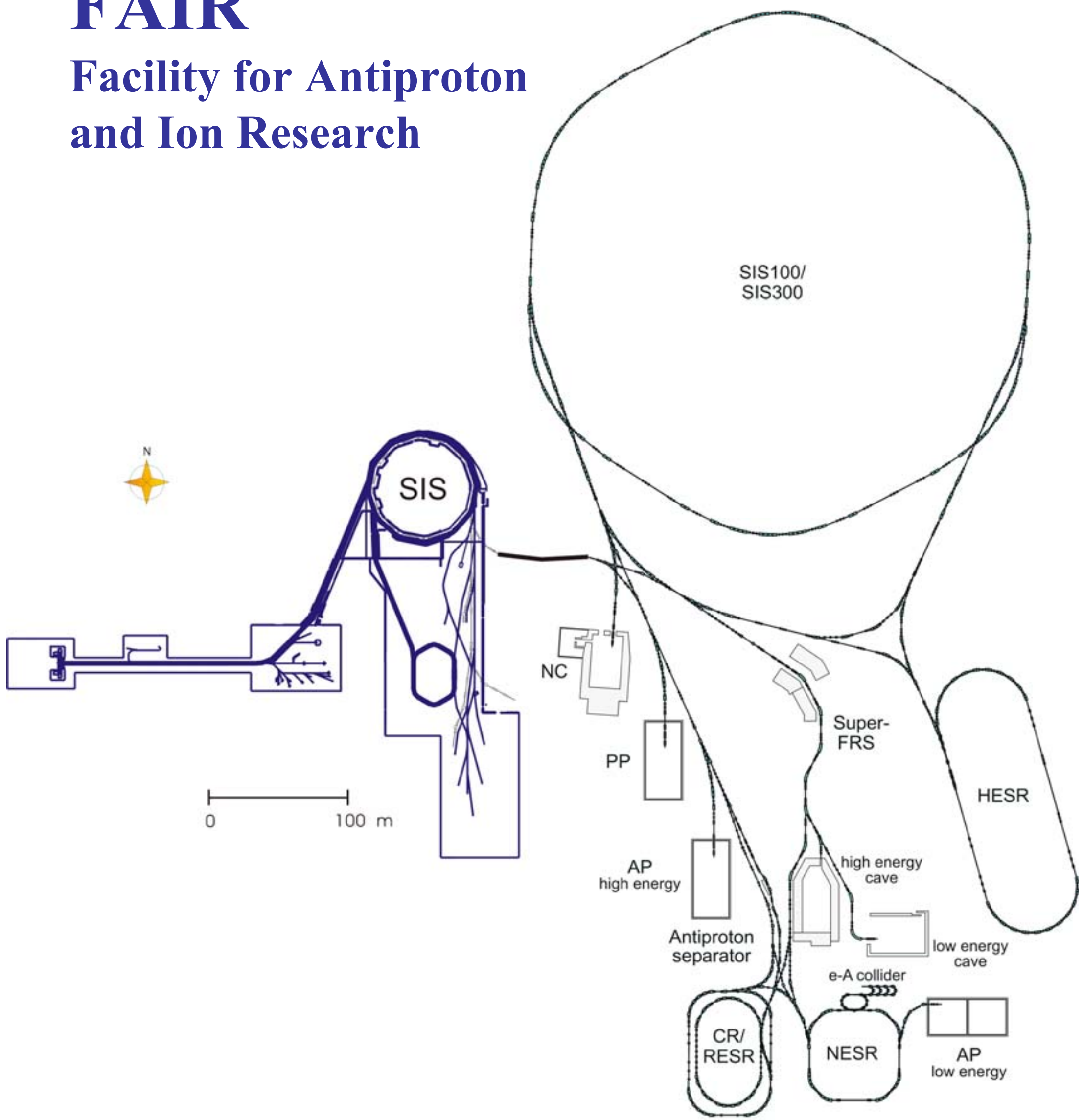
- Strong interaction studies will play a crucial role: QCD is ubiquitous in high energy physics!

  Once new particles are discovered at LHC, it will be mandatory to explore parameters, mixing patterns, i.e , we need an unprecedented ability to interpret the strong interaction structure of final states

  Synergy: Kaon system, Heavy Flavour, Hadron spectroscopy—
- Many intellectual puzzles still open in QCD!
  - Confinement, chiral symmetry breaking, vacumm structure (glueballs etc) light particle classifications, multi-quark states...

FAIR

Facility for Antiproton and Ion Research



research areas:

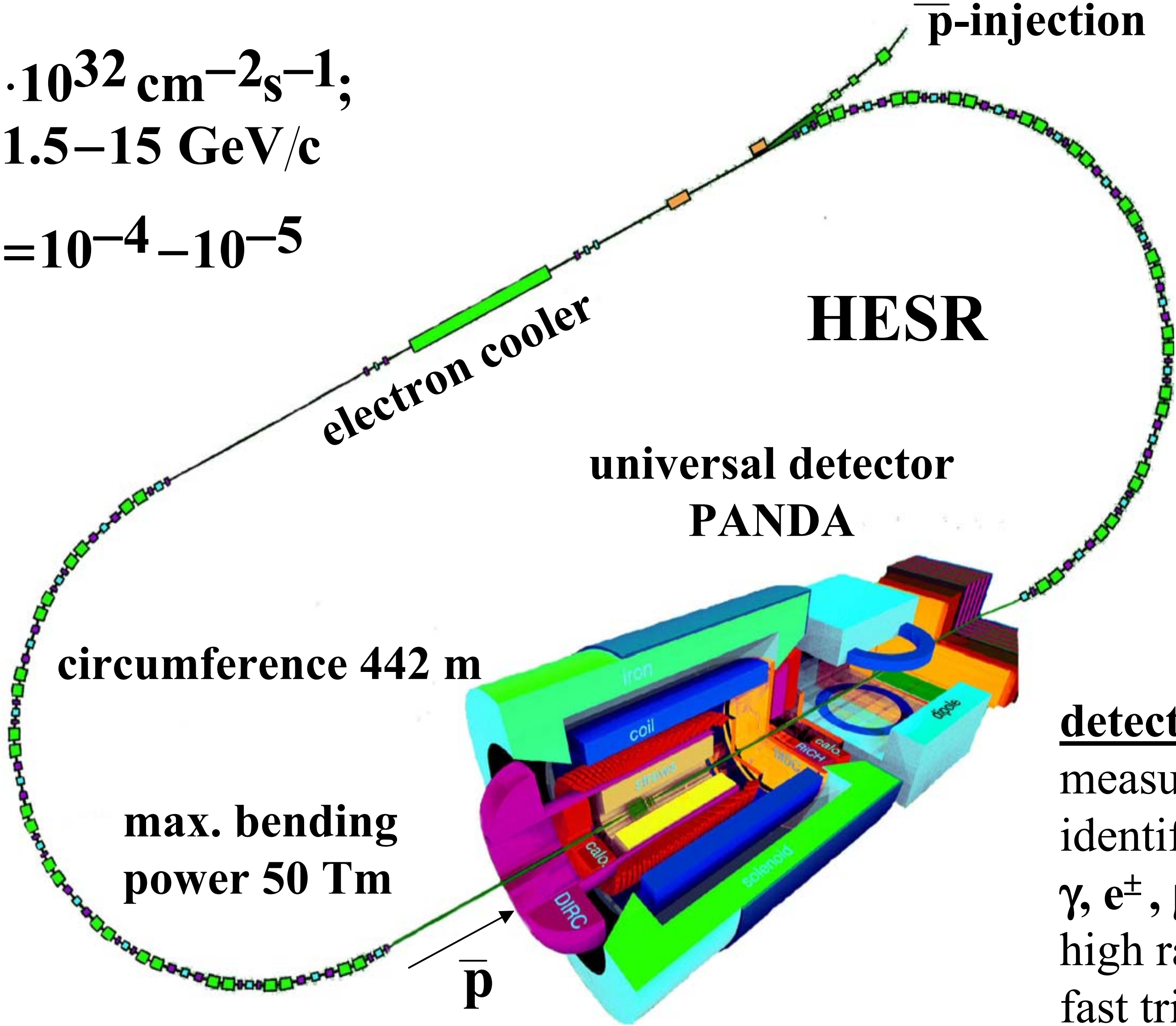
- **Nuclear Structure Physics and Nuclear Astrophysics with Radioactive Ion-Beams**
- **Hadron Physics with $\bar{p}$ - Beams**
- **Physics of Nuclear Matter with Relativistic Nuclear Collisions**
- **Plasma Physics with highly bunched Laser- and Ion-Beams**
- **Atomic Physics and Applied Science**
- **Accelerator Physics**

High Energy Storage Ring (HESR) and Detector Concept

$L = 2 \cdot 10^{32}\, cm^{-2} s^{-1}$;

$p_{\bar{p}} = 1.5 - 15$ GeV/c

$\delta p / p = 10^{-4} - 10^{-5}$



detector features:

measurement and identification of

γ, $e^{\pm}$, $\mu^{\pm}$, $\pi^{\pm}$, $K^{\pm}$, $\bar{p}$, p

high rate capability

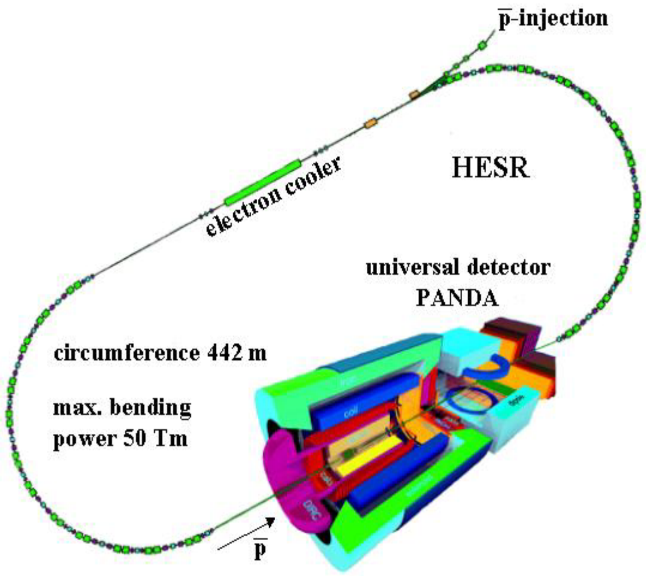
fast trigger scheme

Physics program at the High Energy Storage Ring (HESR)

glueballs (ggg)
hybrids ($c\bar{c}g$)

J/ψ spectroscopy
confinement

hidden and open
charm in nuclei



strange and
charmed baryons
in nuclear field

fundamental
symmetries:
$\bar{p}$ in traps
(FLAIR)

inverted deeply virtual
Compton scattering

CP-violation
(D/Λ - sector)

The world situation

- **There is (unprecedented?) world-wide agreement, now in existence or ~ 2 years, that the next step for accelerator-based particle physics should be the construction, in a timely manner, of a linear e^+-e^- collider with an energy of at least around 500 GeV.**
- **ECFA report:**

  "…the realisation, in as timely a fashion as possible, of a world-wide collaboration to construct a high-luminosity e^+e^- linear collider with an energy range up to at least 400 GeV as the next accelerator project in particle physics; decisions concerning the chosen technology and the construction site for such a machine should be made soon;"
- **HEPAP report:**

  "We recommend that the highest priority of the U.S. program be a high-energy, high-luminosity, electron-positron linear collider, wherever it is built in the world…. We recommend that the United States prepare to bid to host the linear collider, in a facility that is international from the inception."
- **ACFA:**

  "ACFA urges the Japanese Government to arrange a preparatory budget for KEK to pursue an engineering design of the collider, to study site and civil engineering, as well as to investigate the process for the globalization."

High intensity machines - ν factory

- ECFA report explicitly mentions this in the Executive summary recommendations:
  "a co-ordinated collaborative R&D effort to determine the feasibility and practical design of a neutrino factory based on a high-intensity muon storage ring"
- ECFA report also explicitly recognises the importance and promise of the ν factory and supports the increase in resources and manpower in the field of accelerator physics necessary to build it:
  "A neutrino factory complex, beginning with its proton driver, allows a number of unique experiments in a fundamental domain: neutrino masses and mixing, CP violation, and lepton number violation. The realisation of this important programme requires a substantial international programme of R&D."

Other high-intensity machines

- As the programme for this conference demonstrates, there are many other opportunities to push accelerators to higher intensity to exploit particular areas of physics. Just because these may not appear on high-level roadmaps does not mean that they are not very important. Indeed, the continuing concentration of particle physics into a smaller and smaller number of very large projects is a concern which can be alleviated by carefully targeted and well motivated specialised experiments.
- Opportunities include many areas of K physics, including CP studies & the Frascati upgrade programme for DAPHNE; rare kaon decay searches in several labs world-wide, DIS in particular kinematic regimes, precision experiments, beta beams etc., etc. I will briefly mention some of these with reference to the European situation.

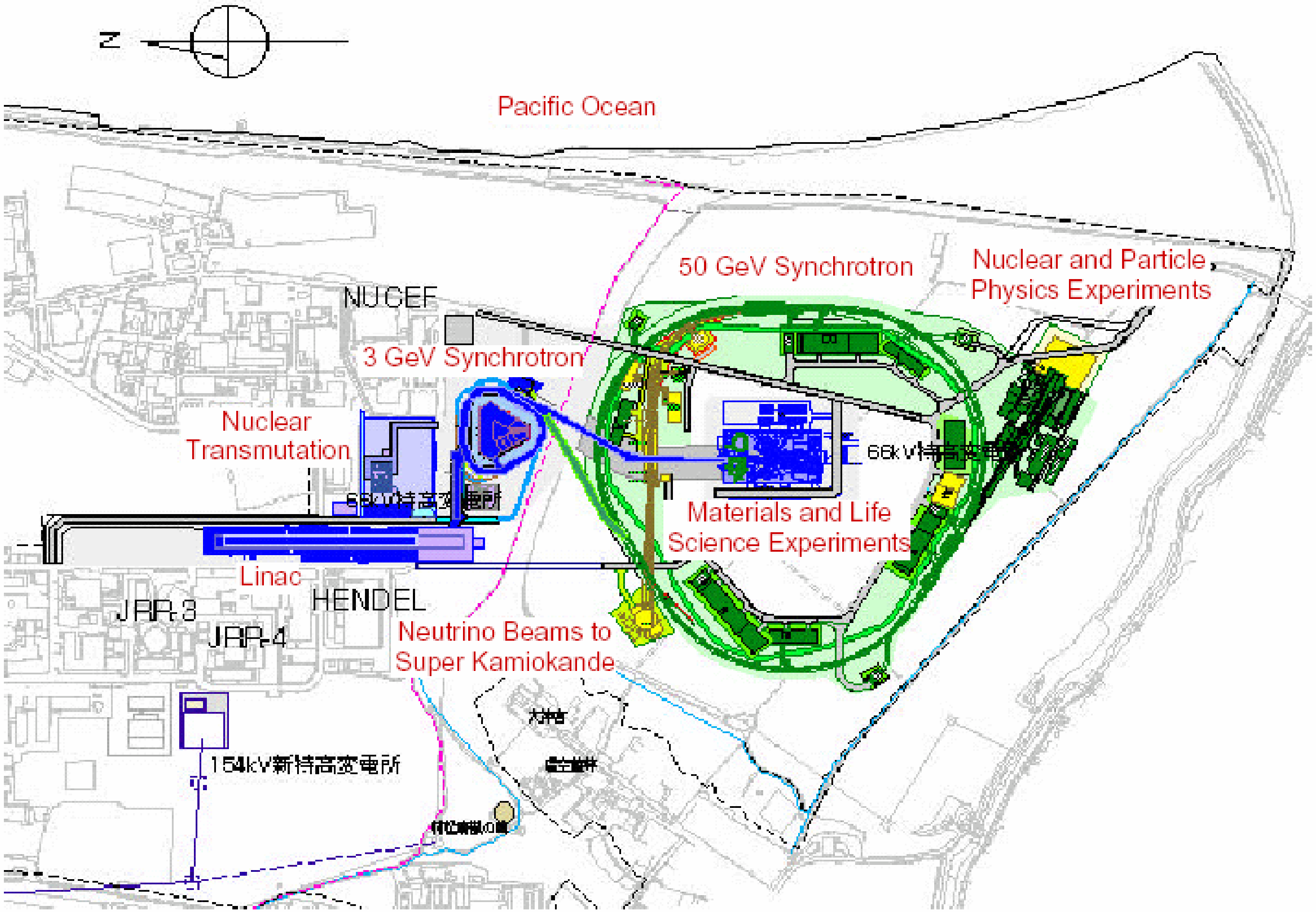
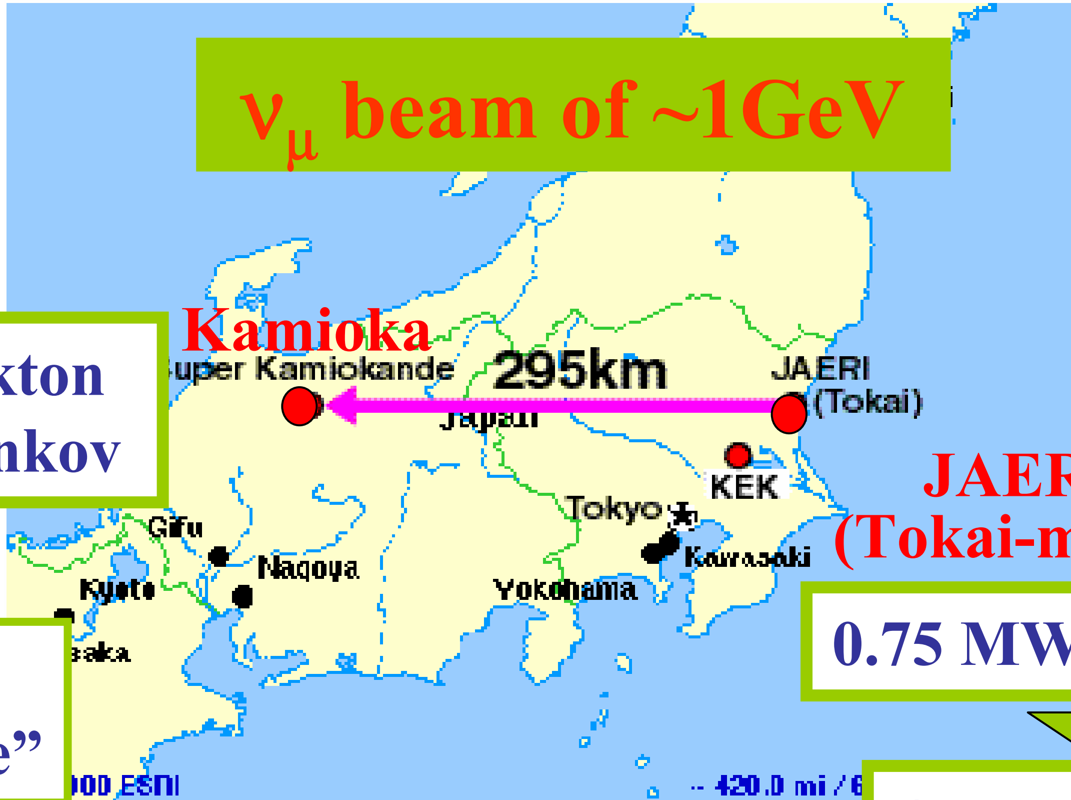


FIG. 1.5: Plan view of the facility

JHF Overview

ν_μ beam of ~1GeV



Super-K: 50 kton
Water Cherenkov

~Mt "Hyper
Kamiokande"

JAERI
(Tokai-mura)

0.75 MW 50 GeV PS

4MW 50GeV PS

1st Phase

- $\nu_\mu \rightarrow \nu_x$ disappearance
- $\nu_\mu \rightarrow \nu_e$ appearance
- NC measurement

2nd Phase

- CPV
- proton decay

Role of CERN

- Everyone agrees that CERN's first priority has to be to construct LHC, to deliver first beams in the summer of 2007, and to plan and deliver suitable LHC upgrades both to the machine and the experiments so that the unique capabilities of and the major investment in LHC can be optimally utilised.

- The very tough conditions under which LHC was approved means that CERN is under extreme financial and personnel pressure until well beyond the completion of the machine. The financial debt that the organisation has taken on to cope with the cash flow requirements of LHC will not be cleared until 2011, which greatly limits the possibilities of new initiatives before then.

The way forward

- We have to be selective, to make hard choices, but we have also to be ambitious! LHC and LC are not enough. There are major physics questions to be answered with the NF and the steps on the way to it, including the high-intensity sources. No one thinks twice that the astronomers request facilities simultaneously in several different EM wavelngths and in space, because the science drives this. It does in our case too and we have to continue to make the case.
- In this regard, the coming Villars SPSC meeting is crucial for the future of this field in Europe. The community must take a view as to what its priorities in this area of physics are and then see what resources are required. The good news is that, on the scale of LHC and LC, these are small.

Jin

Interesting states

- **Multi-quark candidates:**
  - Pentaquarks
  - X(3872)
  - $D_{sJ}(2632)$
  - Resonant structures near mass thresholds and $\omega J/\psi$ mass thresholds. $p\bar{p}$, $p\bar{\Lambda}$, $\bar{p}\Lambda_C$, $K\Lambda$
- **Light scalar mesons:**
  - σ, κ, $f_0(980)$, $f_0(1370)$, $f_0(1500)$, $f_0(1710)$, $f_0(1790)$
- **Other interesting results from BES and CLEO-c**

Challenging problems in non-perturbative QCD

- **Why are quarks confined within hadrons?**
- **How are hadrons constructed from their constituents?**
- **What is the relation of parton degrees of freedom and the low energy structure of hadrons?**
- **What is the origin of hadron masses?**
- **How are hadrons modified when embedded in nuclei?**
- **Do glueballs (ggg) and hybrids (qqg) exist?**

$\Rightarrow$ New experimental approach: antiproton beams up to 15 GeV/c