B Factories

EPS Session during the 2009 Europhysics Conference
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ECFA

LPHE

Introduction (I)

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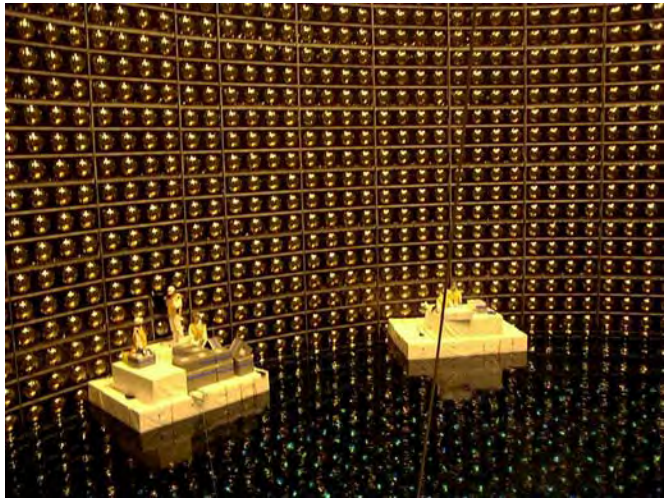
  Neutrino oscillations

S-KAMIOKANDE



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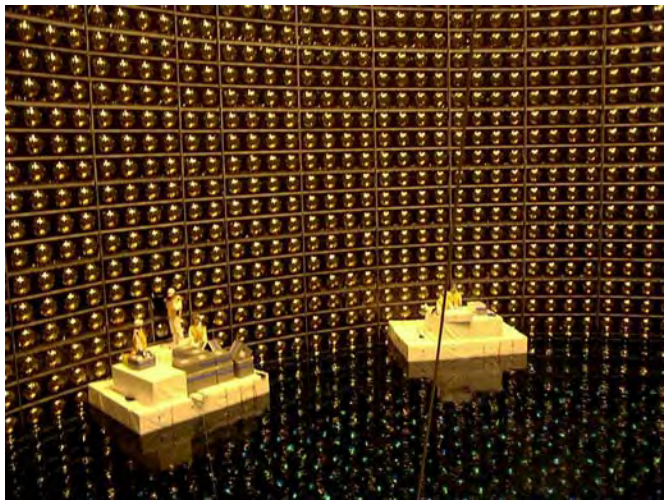

Bullet Galaxy Clusters

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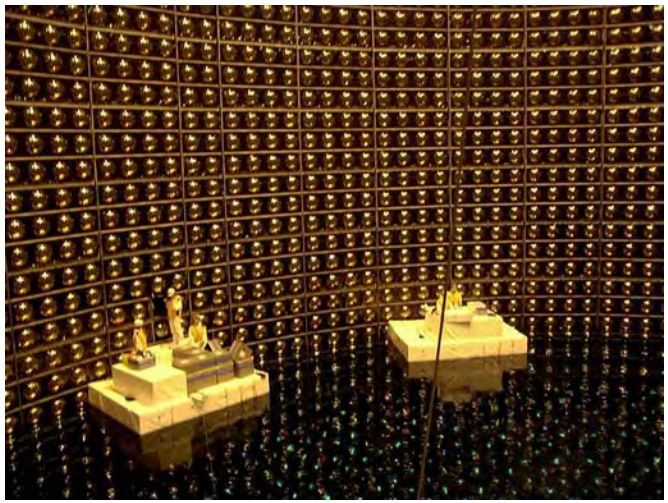
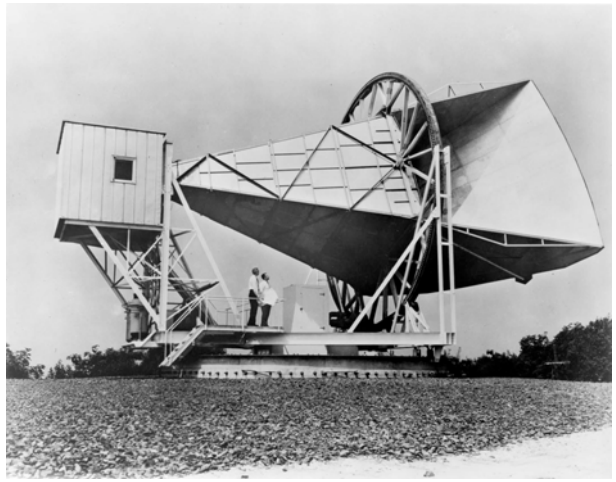


Bullet Galaxy Clusters

The Horn Antenna
Bell Telephone Laboratory



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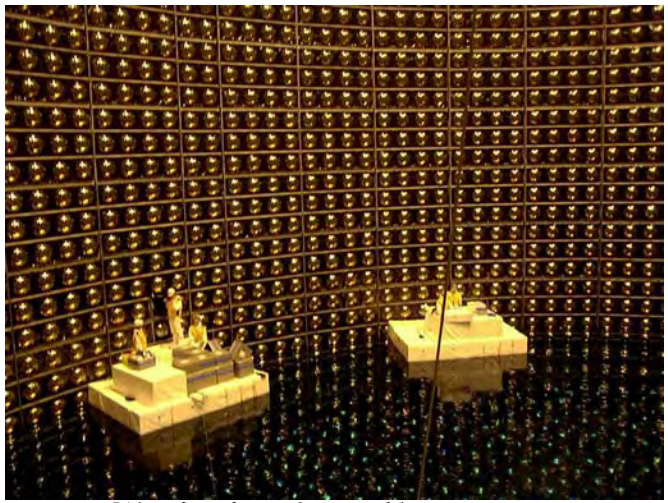

Christian's talk

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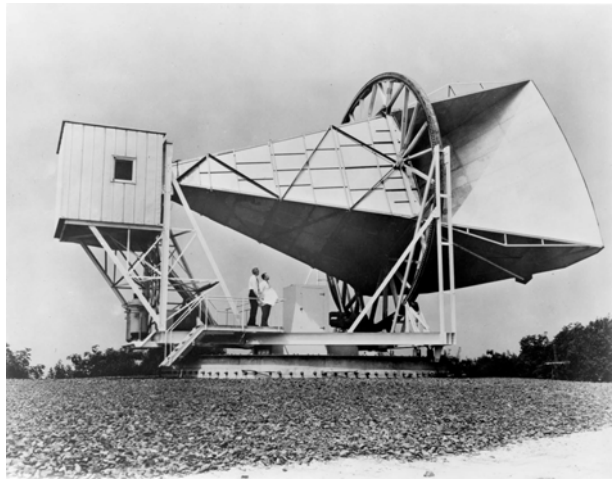

also more philosophical/theoretical/esthetical arguments…

Introduction (II)

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Discovering new particles at LHC, followed by more detailed studies by LC… ⇒ Rolf's talk

Introduction (III)

What is on the moon?

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Of course going there, 40 years ago

Introduction (III)

What is on the moon?

But it has been studied a lot before

Introduction (III)

What is on the moon?

And may be finding something new?

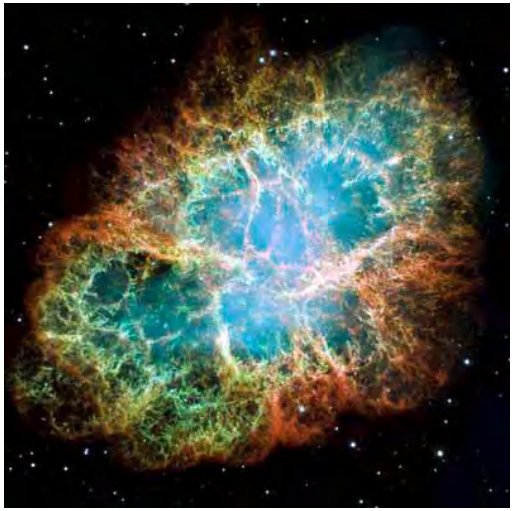
Introduction (III)

What is on the moon?

Instruments can be improved and

Introduction (III)

What is on the moon?



We see far beyond
the direct reach...

Introduction (IV)

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  Using the quantum fluctuations in the loop diagram

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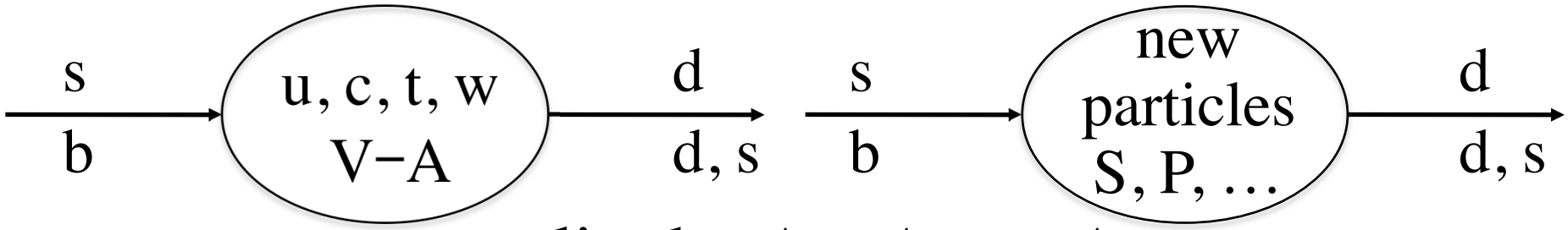

amplitude: $A = A_{SM} + A_{NP}$

$|A|$: rare decays, Δm

arg A: CP violation

Lorentz structure of A: "photon" polarization via
final state angular distribution or mixing-decay CP violation

(neutrino measurements are at the three level, Alain's talk)

Successful story at (4S)

- DORIS-II @ DESY ARGUS experiment
  and
  CESR @ Cornell CLEO experiment
  with notable discoveries
  observation of b → u+W decays: $V_{ub} \neq 0$
  B_d-$\overline{B}_d$ oscillations: $m_t > 50$ GeV/c^2

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- PEP-II @ SLAC BABAR experiment
  and
  KEKB @ KEK Belle experiment
  with a notable discovery
  CP in $B_d \rightarrow J/\psi K_S$ as expected from the CKM matrix:
  validation of the KM mechanism as the major source for
  ~~CP~~, followed by quantitative tests of the CKM scheme

PEP-II and KEKB (2006)

	PEP-II		KEKB	
	High E-beam	Low E-beam	High E-beam	Low E-beam
Energy [GeV]	9.0	3.1	8.0	3.5
Beam current [A]	**1.9**	**3.0**	1.3	1.7
Bunch current [mA]	1.1	1.7	1.0	1.2
ε_x [nm]	48	24	**24**	**18**
σ_x(IP)/σ_y(IP) [μm]	155 / 4.2		**110 / 1.9**	
beam-beam x	0.059	0.009	0.070	0.117
beam-beam y	0.074	0.058	0.056	0.110
Crossing angle [mr]	0		**±11**	
Peak L [10^{34}cm^{-2}s^{-1}]	1.2		**1.7**	

PEP-II = high current and head-on collision

KEKB = small beam and crossing angle collision: crossing scheme won

$\int L\,dt$ @ $\Upsilon(4S)$ is somewhat higher for KEKB: 720 fb^{-1} (800 M $B\bar{B}$)

Very comparable physics achievements by BELLE and BABAR

KEKB further evolution

- Crab crossing since 2008 and finally success in June 2009

	KEKB (2009)		KEKB (2006)	
	High E-beam	Low E-beam	High E-beam	Low E-beam
Beam current [A]	**1.1**	**1.6**	1.3	1.7
Bunch current [mA]	0.75	1.03	1.0	1.2
ε_x [nm]	24	18	24	18
σ_y(IP) [μm]	0.94		1.9	
beam-beam x	0.102	0.127	0.070	0.117
beam-beam y	0.090	0.129	0.056	0.105
Crossing angle [mr]	crab crossing		±11	
Peak L [10^{34}cm^{-2}s^{-1}]	**2.1**		1.7	

Crab crossing allowed to increase the beam-beam parameters

less currents and higher luminosity!!!

Now and it follows

- BABAR and PEP-II operation completed in 2008
  Belle and KEKB will complete in FY2009 (March 2010)
  with a total of ~1.2 ab^{-1} data, i.e. ~1.3×10^9 $B\overline{B}$!
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- CDF and D0 will improve their statistics in 2009 and 2010
  ~8 fb^{-1}/experiment,
  ~~CP~~ in $B_s\rightarrow J/\psi\phi$,: $\sigma_{2\beta_s} \approx 0.15$
  Br for $B_s\rightarrow\mu^+\mu^-$: < ~2×10^{-8} (90% CL)
  (and A_{FB} for $B_d\rightarrow K^{*0}\mu^+\mu^-$?)
- LHCb first "new" results toward the end of 2011
  $\sigma_{2\beta_s} < 0.15$, $Br(B_s\rightarrow\mu^+\mu^-) < 10^{-8}$, A_{BF} with ~1k $K^{*0}\mu^+\mu^-$

By ~2016

- From LHCb we will know

  $\sigma_{2\beta_s} < 0.02$

  ~20% accuracy measurement of SM $Br(B_s \rightarrow \mu^+\mu^-)$

  A_{BF} with 36k $K^{*0}\mu^+\mu^-$

  $\sigma_\gamma = 2\sim3°$

  ~~CP~~ in $B_s \rightarrow \phi\phi$ (0.05), $B_s \rightarrow \phi\gamma$ (0.1), $D \rightarrow K^+K^- \rightarrow \pi^+\pi^-$ ($<10^{-3}$)

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- However, still open fields for "super" B factories

  Final states with many neutrals

  e.g. Br for $B^+ \to \tau^+\nu$, CP in $B^0 \to \pi^0 K_S$, $B^0 \to K^{*0}(K_S\pi^0)\gamma$

  Lepton flavour violating tau decays, such as $\tau \to e\gamma$*

  and many others, e.g. QCD, spectroscopy, etc.

*beam polarization an important issue: taken up by the INFN SuperB

The next step

- A factor of 10 increase in statistics would be fine to clear-up ~3σ discrepancies or change “evidences” to “discoveries”, but not for producing new discoveries. At least 50 better 100 needed for a next generation B factory. But no guaranteed success unlike for the original B factories (we know too little about new physics)

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INFN Approach
Reducing the IP dimension (σ_y=38 nm, cf KEKB ~1 μm) using very small emittance beams. Maintain optimal collisions by crab waist
CDR in 2007

INFN SuperB and KEKB Upgrade

- INFN approach is a very attractive concept:
  $L = 10^{36}$ cm^{-2}s^{-1} with ~2.7 A/beam (PEP-II low-E beam 3A)
  low power cost, low background, …
  DAPHNE test @ Frascati (0.5 GeV/beam) shows that a large beam-beam parameter can be maintained with crab waist crossing at the required current.☺☺☺☺

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ECFA considered this approach promising and must be pursued to produce a TDR, as a base for an approval.

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- Preliminary design parameters emerged.

	INFN SuperB		New KEKB Upgrade	
	High E-beam	Low E-beam	High E-beam	Low E-beam
Energy [GeV]	7	4	8.0	3.5
Beam current [A]	2.7	2.7	2.21	3.84
ε_x(IP)/ε_y(IP) [nm]	1.6/4	2.8/7	2.0/3.6	2.8/2.07
σ_x(IP)/σ_y(IP) [μm]	5.7/0.038	9.9/0.038	7.07/0.097	7.06/0.073
beam-beam y	0.095	0.094	0.079	0.079
Crossing angle [mr]	±30		±30	
Peak L [10^{36}cm^{-2}s^{-1}]	1.2		0.8	

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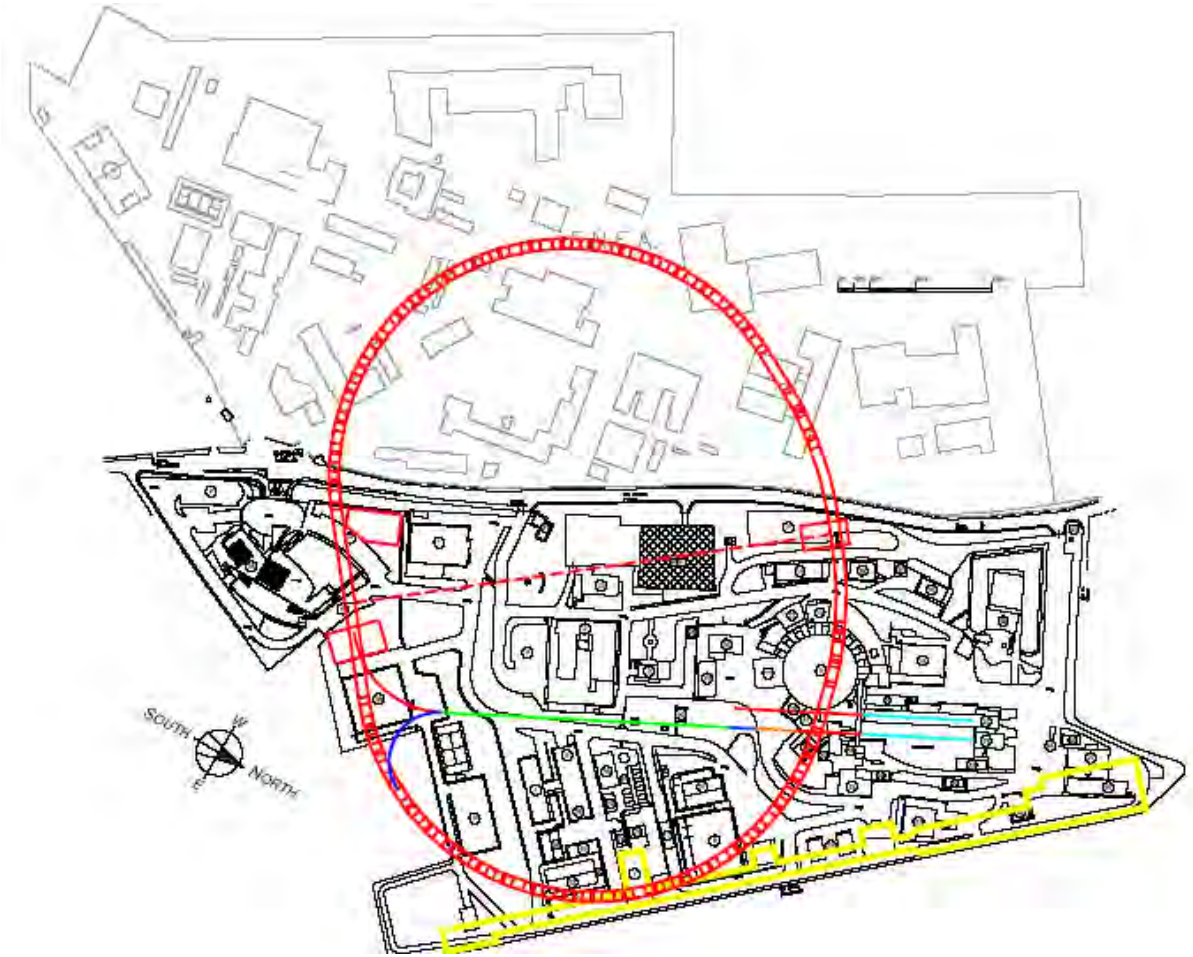
  IT government decision by the end of 2009 followed by negotiation to setup an International Consortium to build and to operate the Super-B factory.
  Construction to start after the approval of TDR?

LNF option with reduced length



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  AT(1), AU(2), CZ(1), DE(3), RU(1), SI(4), US(4)

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  Plan to become online in ~2013 starting with a moderate luminosity with continuous improvement.

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- After BABAR, Belle, CDF and D0, LHCb will be the next player and SuperB factories must go beyond the physics of LHCb.
- For physics, luminosity is the issue, reaching quickly to $\sim 10^{36} \mathrm{cm}^{-2} \mathrm{s}^{-1}$, and even beyond, is a must. Reliable machine operation is also a must.

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- After KEK revised their design, machine parameters for INFN SuperB factory and KEKB Upgrade are very similar.
- INFN: the inventor of the novel concept vs. KEK: a holder of the proven record to construct and operate the world highest luminosity storage rings. Competition is good, but do we need two machines of a same kind to be constructed? May be another way to maintain the competition?

more thoughts are needed…