Summary and Conclusion

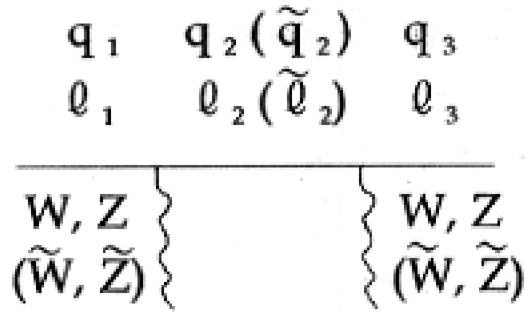
H. Sugawara, Fermilab, 1999

Past ⟶ LEP

Current and Near Term Projects

(1) Flavor Physics

(basically $H\bar{q}q$, $H\bar{\ell}\ell$)



- B factories (q_1 and/or q_3 = b)
  (SLAC and KEK)
- CESR
- DAFNE (q_1 and/or q_3 = s)
- τ-charm (q_1 and/or q_3 = C or τ)
- KTeV, HERAB, PSI ($\mu \rightarrow e\gamma$)

TH : P, CP, B, L, L, R, ······ Global symmetry T (x = small) = T (x = large) No spontaneous breaking

(2) QCD

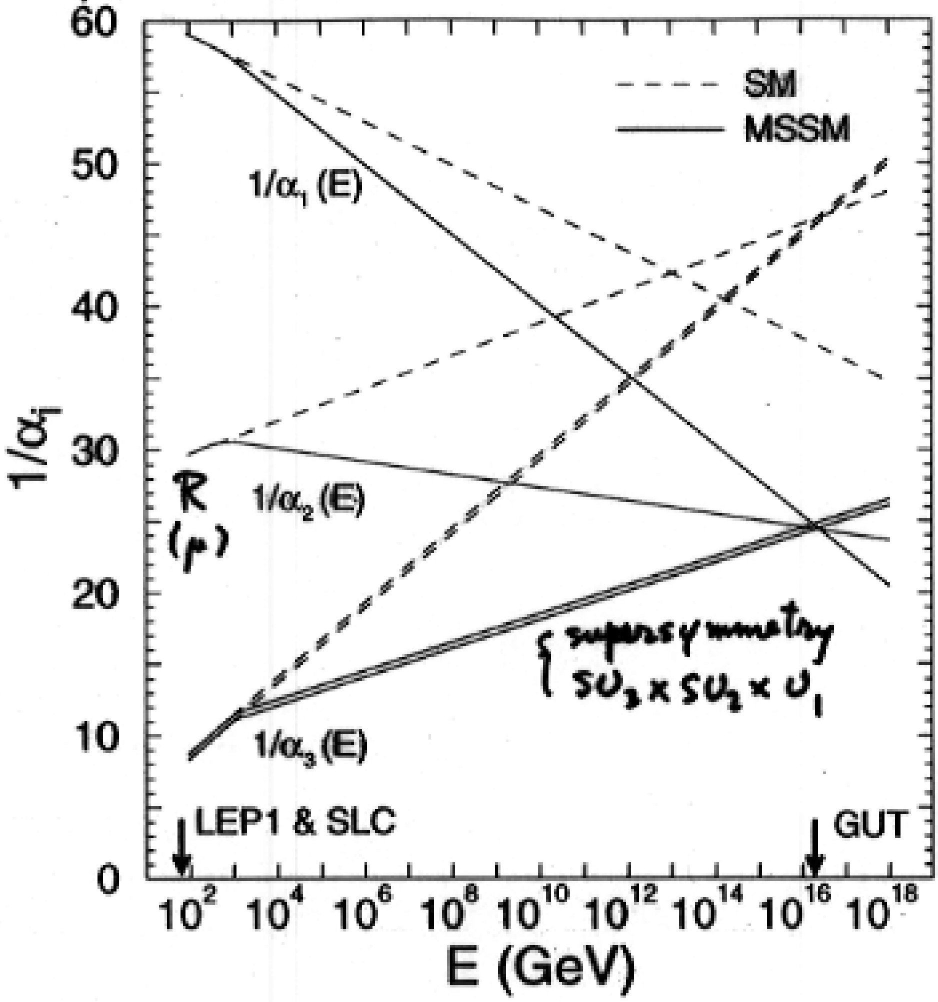
RHIC···long distance

HERA···short distance

(3) New Particle Searches

- Tevatron
- LHC

Running gauge couplings in the SM and in the MSSM with < TeV SUSY particles.

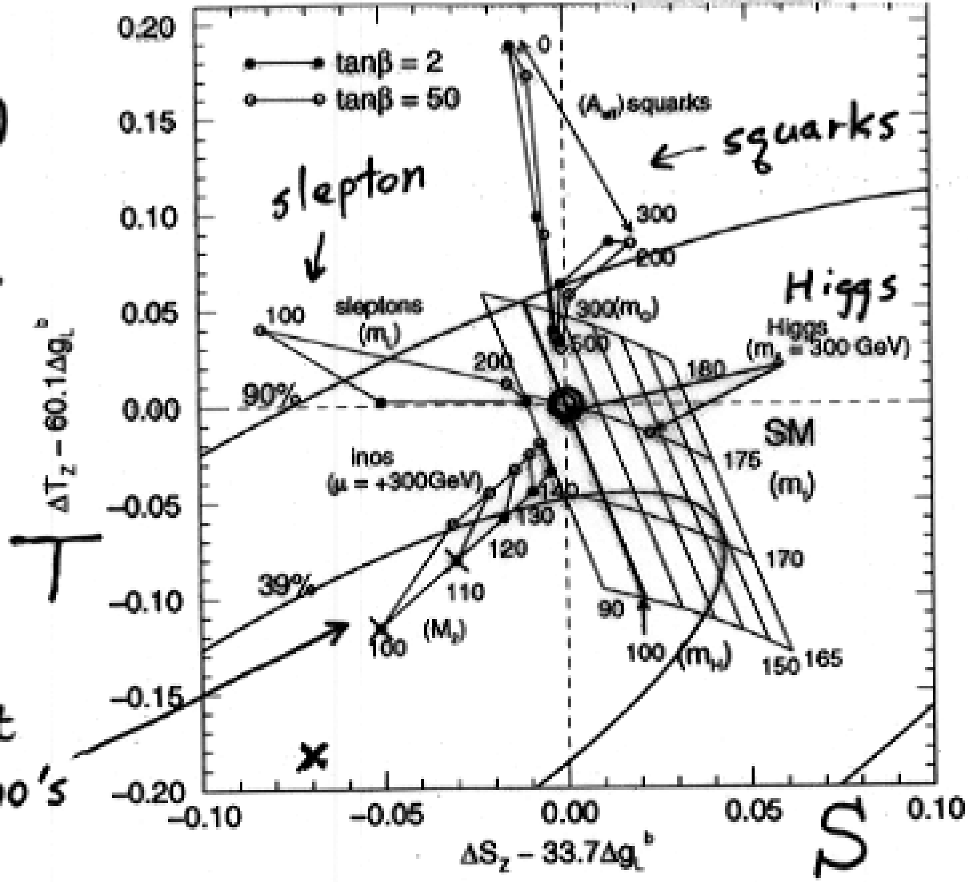


Next-to-leding order
with threshold effects
(SUGRA model)
by G.C. Cho (KEK, Pisa)

Comparison of models

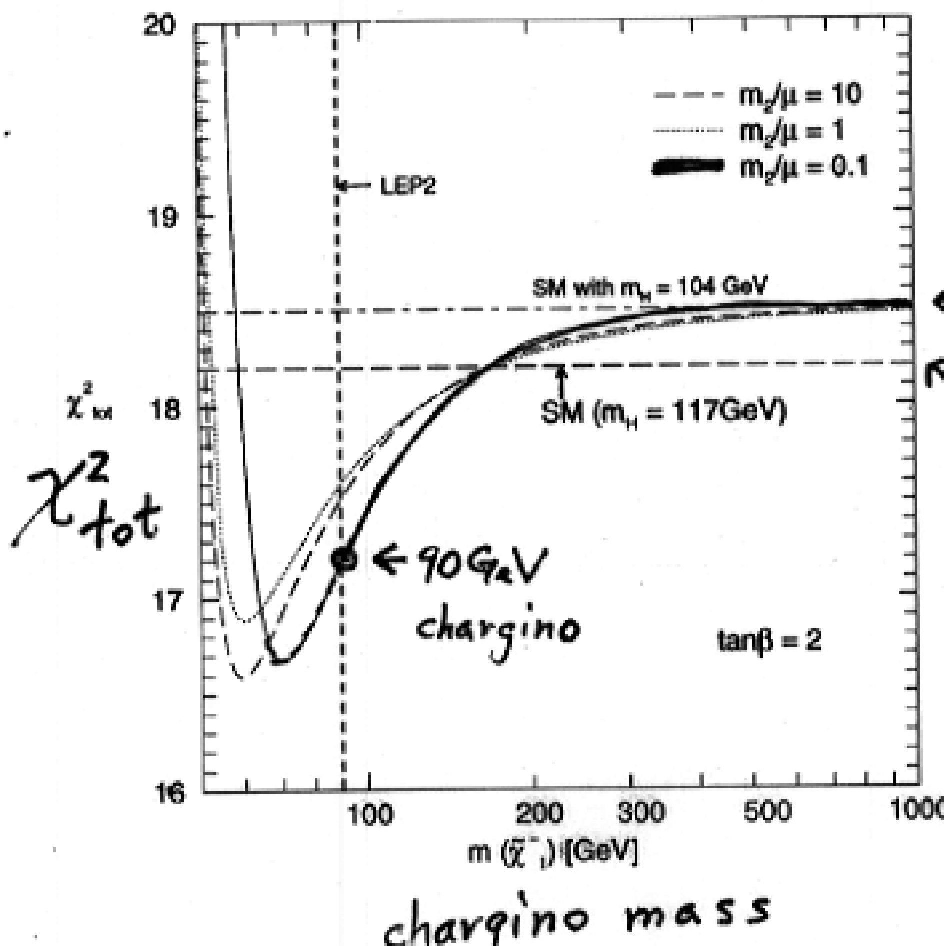
	Gravity mediated model		Gauge mediated model	Universe as brane
		With anomaly		
Cosmological constant	× (no scale model ◎ for tree)		×	
FCNC	m (gravitino mass) $\gtrsim$ several to 10 TeV m_f becomes large		○ (masses are generation independent) $m_f \sim m_g$ (gaugino mass)	
μ problem	× (but Giudice etal)		×	
$\mu \cdot B$ connection	○		△ { D-N : × MMM : renormalization DTM : ?	
Gravitino mass	large (FCNC)		small (1 KeV ~ 5 GeV)	
connection to string theory	○		where are the messengers ? ($E_8 \times E_8$)	
Moduli problem	○ if $m \gtrsim 10$ TeV (I doubt $m_{moduli} \sim m_{gravitino}$)		?	
$SU_3 \times SU_2 \times U_1$ breaking	renormalization		3 - loop	
LSP	neutralino		gravitino	

(S, T) vs SUSY



OSM with $m_t = 175$ GeV $m_H = 100$ GeV

χ^2_{tot} vs SUSY

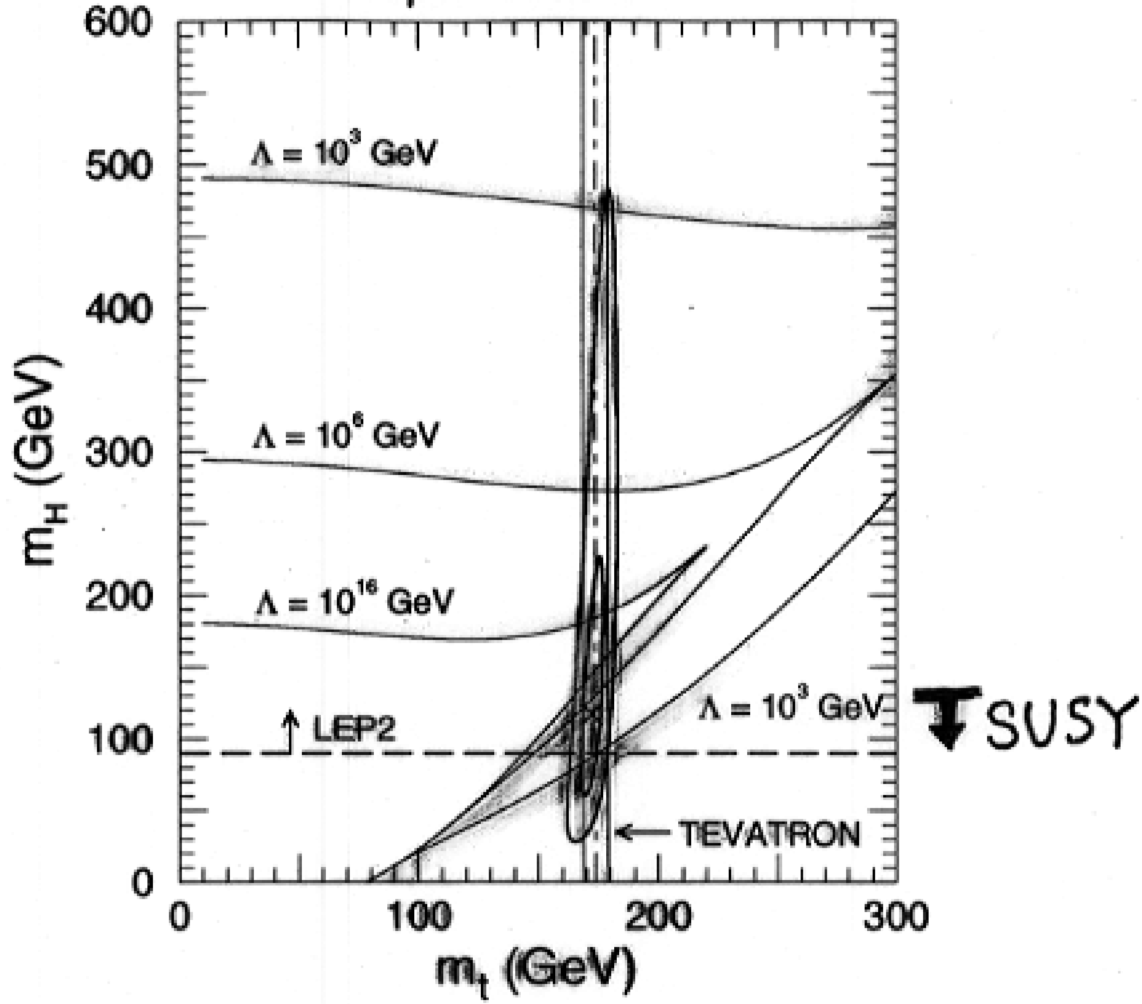


← SM @ m_H=104 (decoupling lim

SM best poi @ m_H=117Ge

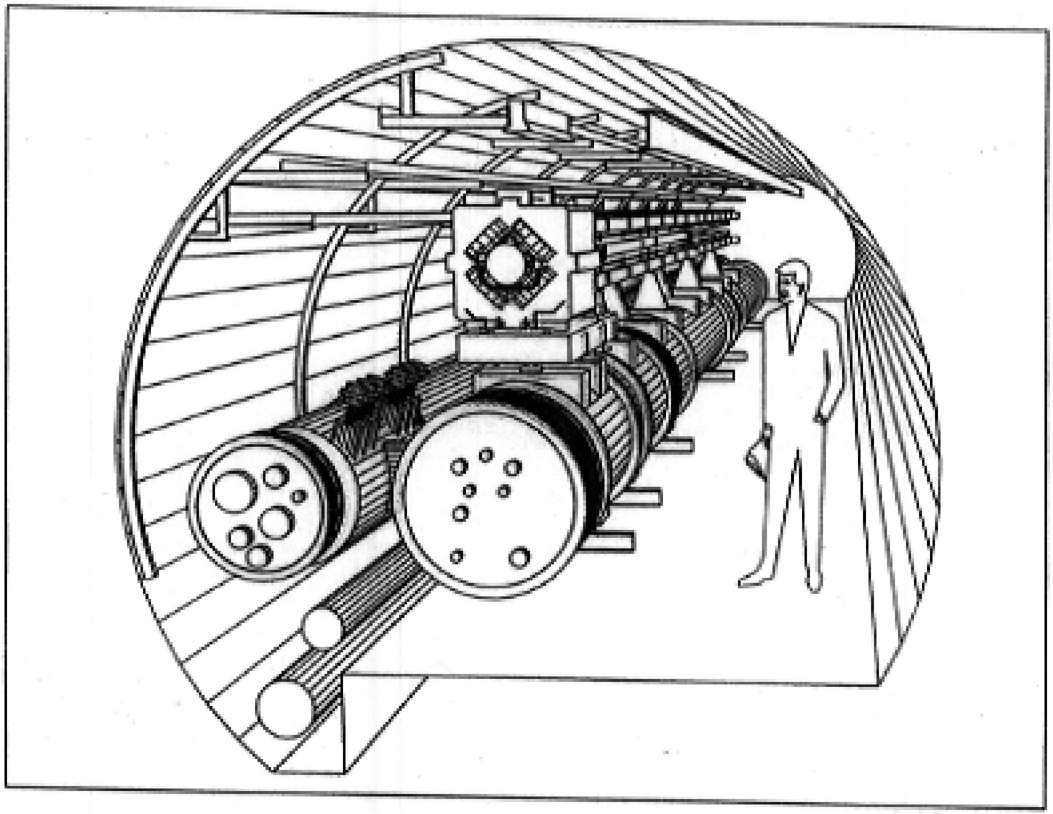
by G.C. Cho and K. Hagiwara
KEK-TH-648 (Sep. 1999)

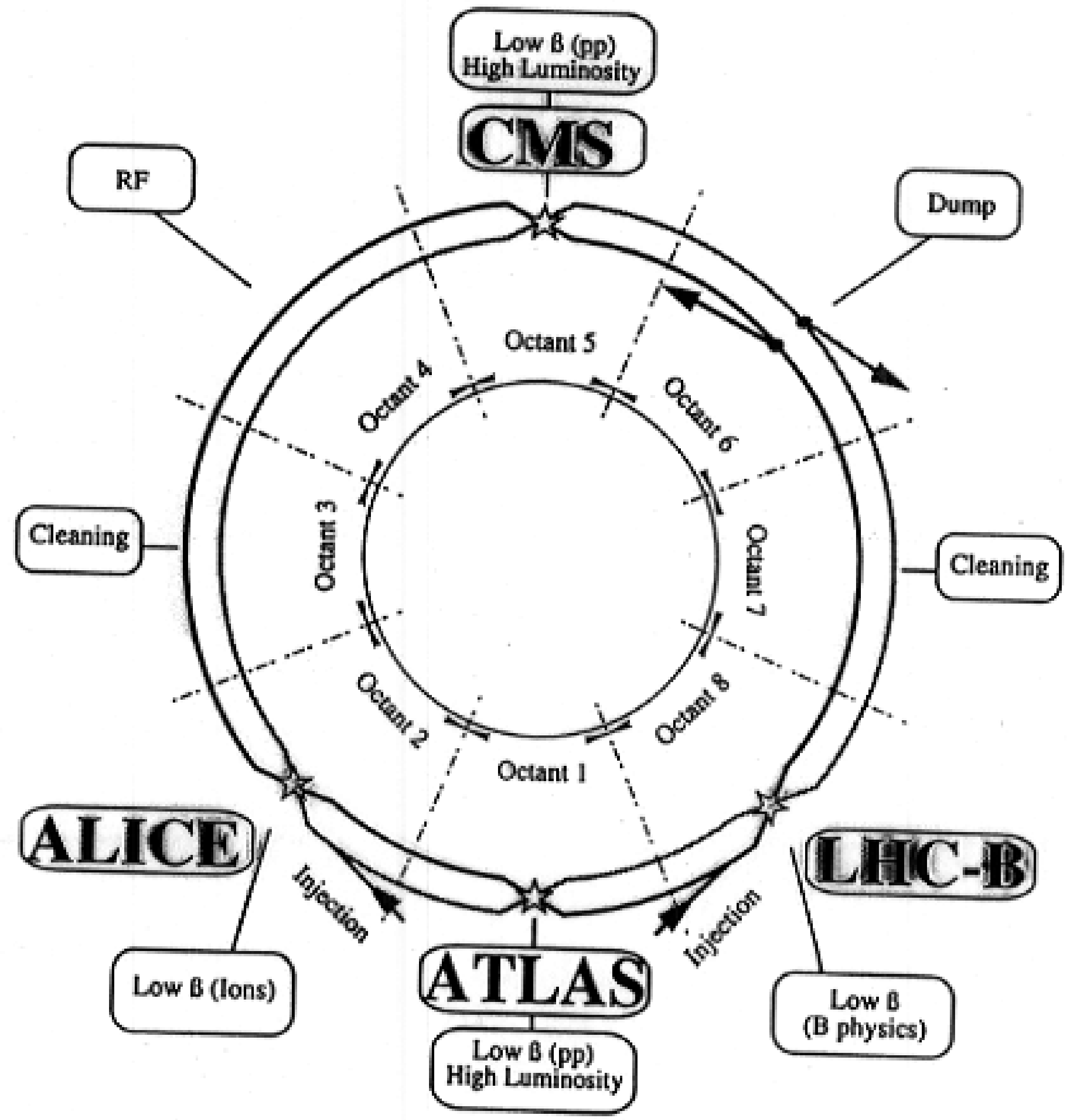
Theoretical bounds on (m_t, m_H) vs Experimental bounds.



90% (39%) CL allowed region from precision experiments at LEP, SLC, Tevatron (Sep., 1999).
Also shown are the triviality (upper) bounds and the vacuum stability (lower) bounds for the Higgs boson mass.

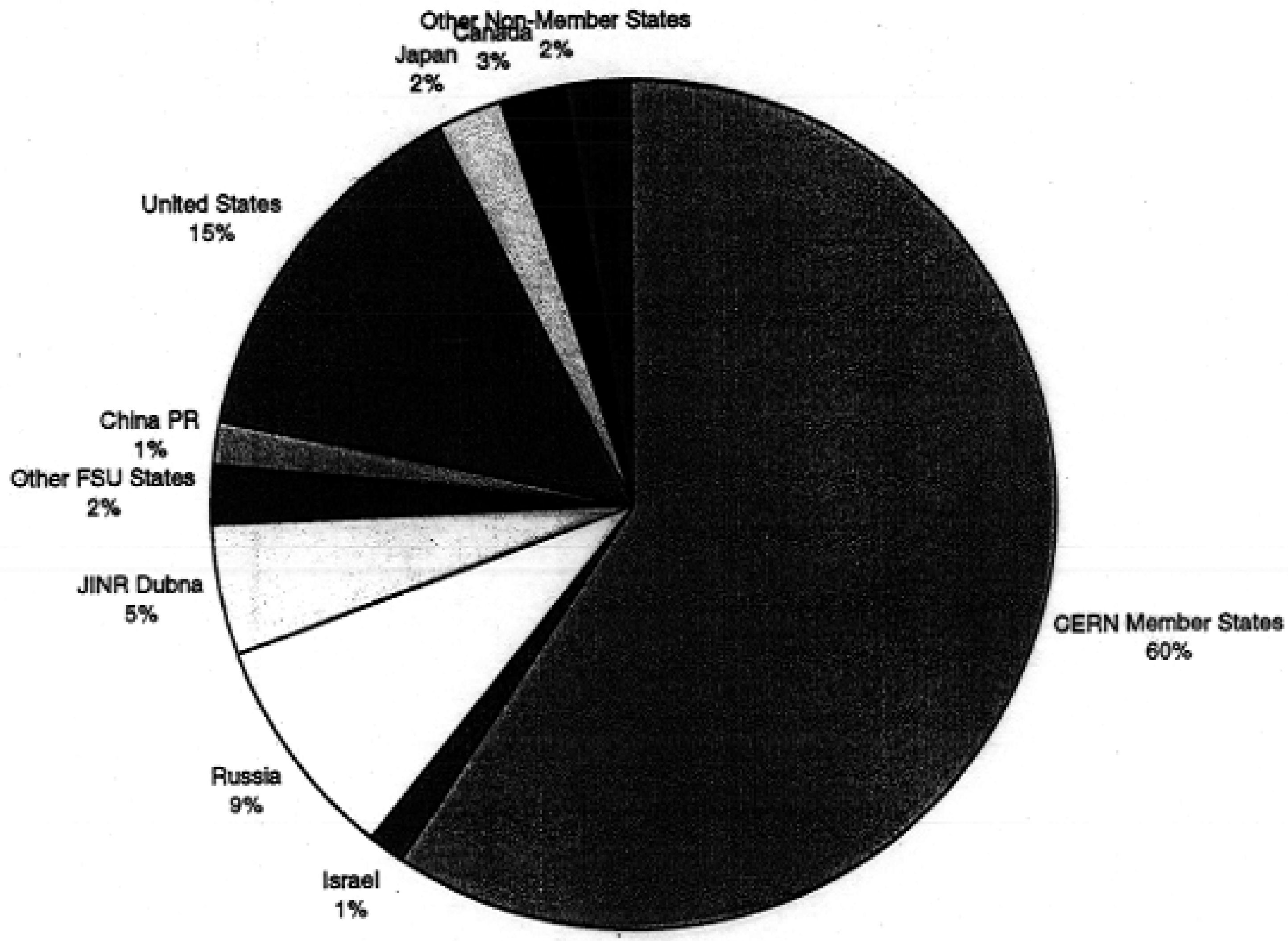
by G.C. Cho (KEK, Pisa)




Low ß (pp)
High Luminosity
CMS
RF
Dump
Octant 5
Octant 4
Octant 6
Octant 3
Octant 7
Cleaning
Cleaning
Octant 2
Octant 8
Octant 1
ALICE
LHC-B
Injection
Injection
ATLAS
Low ß (Ions)
Low ß
(B physics)
Low ß (pp)
High Luminosity

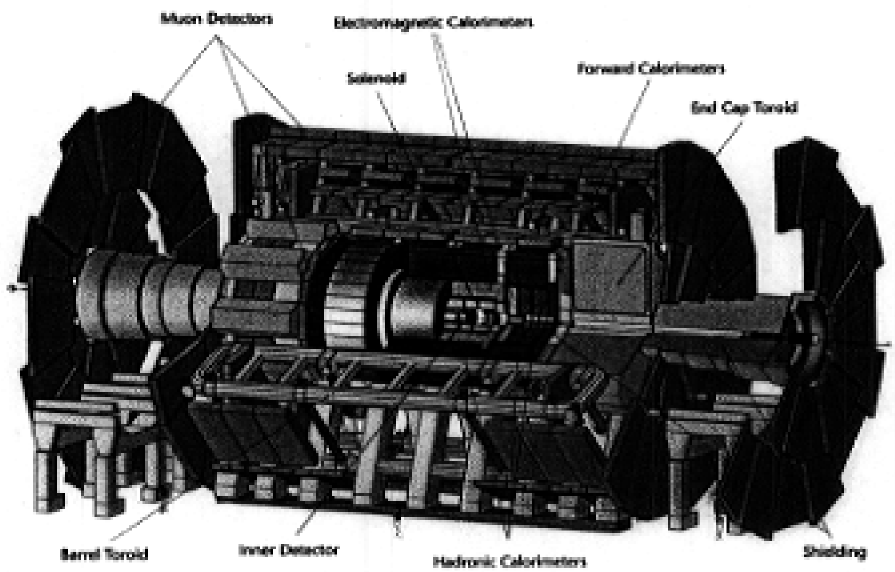
14/5/99

ATLAS Collaboration



ATLAS Collaboration

(148 Institutions, 34 Countries, 1850 Scientists)



All Technical Design Reports (TDR No 1 to 15) submitted and approved during 1996-1999 (in 2001: High Level Trigger/DAQ)

Construction has started on many detector sub-systems, in most cases after successful validation of full-scale prototypes in test beams:

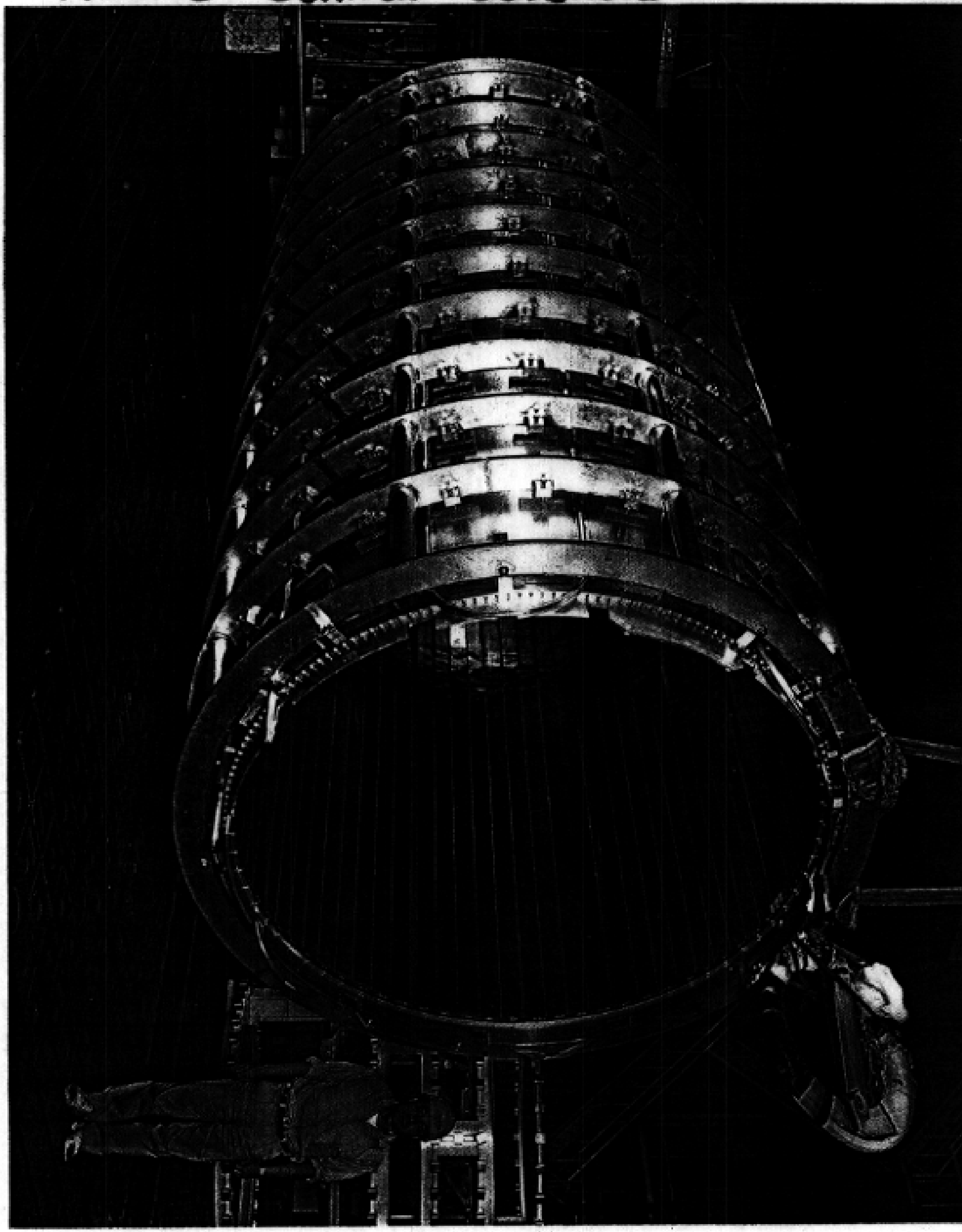
- **large components of the Common Projects (solenoid and toroid magnet coils, LAr calorimeter cryostats)**

- **series fabrication of detector modules at many production sites all over the world (calorimeters, muon trigger chambers)**

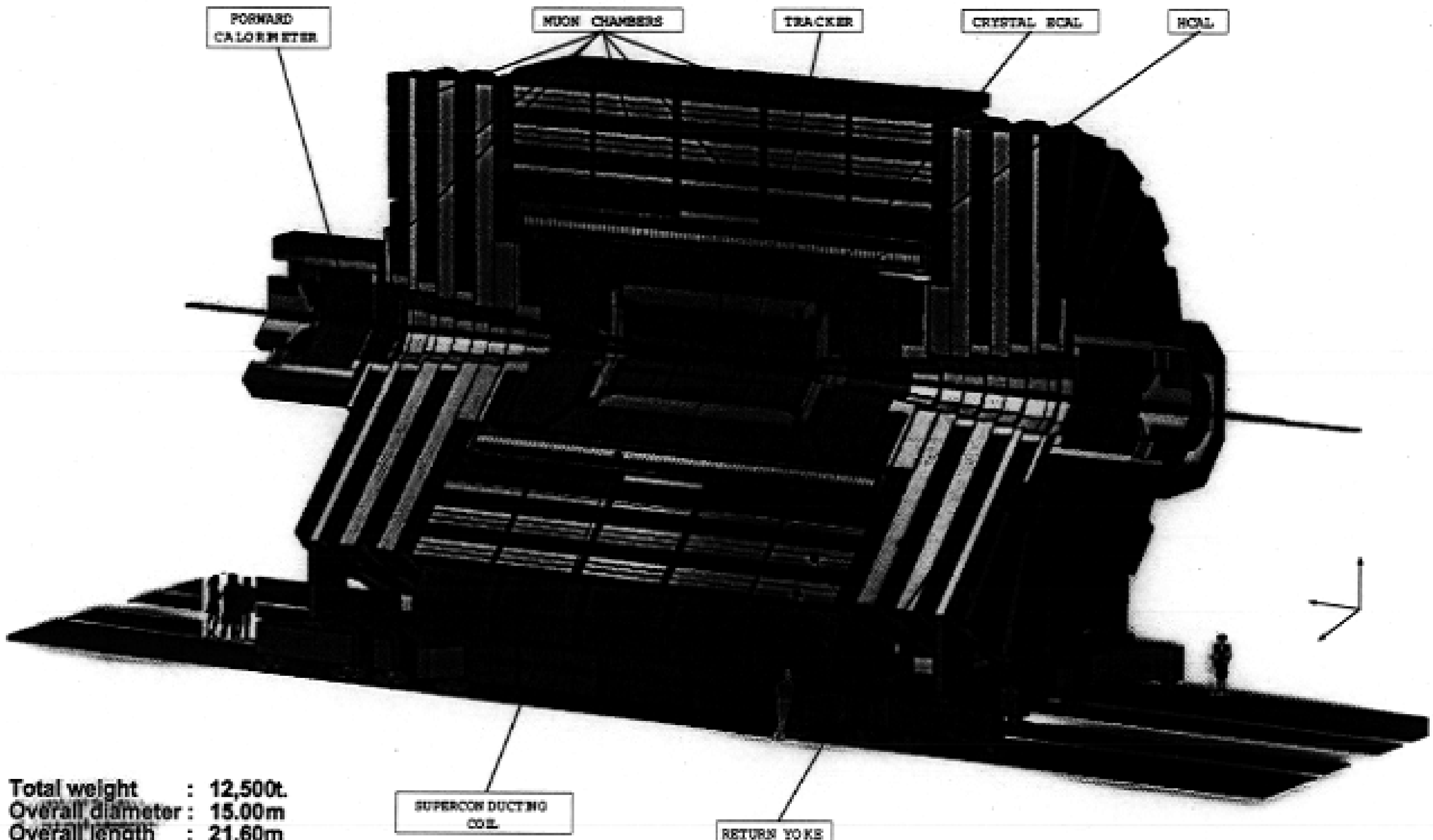
Final full-size prototypes are being completed until early next year (Inner Detector tracking system, muon precision chambers)

A great effort is made by the Collaboration and the CERN LHC civil engineering to meet the schedule for data taking in mid-2005

ATLAS Central Solenoid



CMS Detector



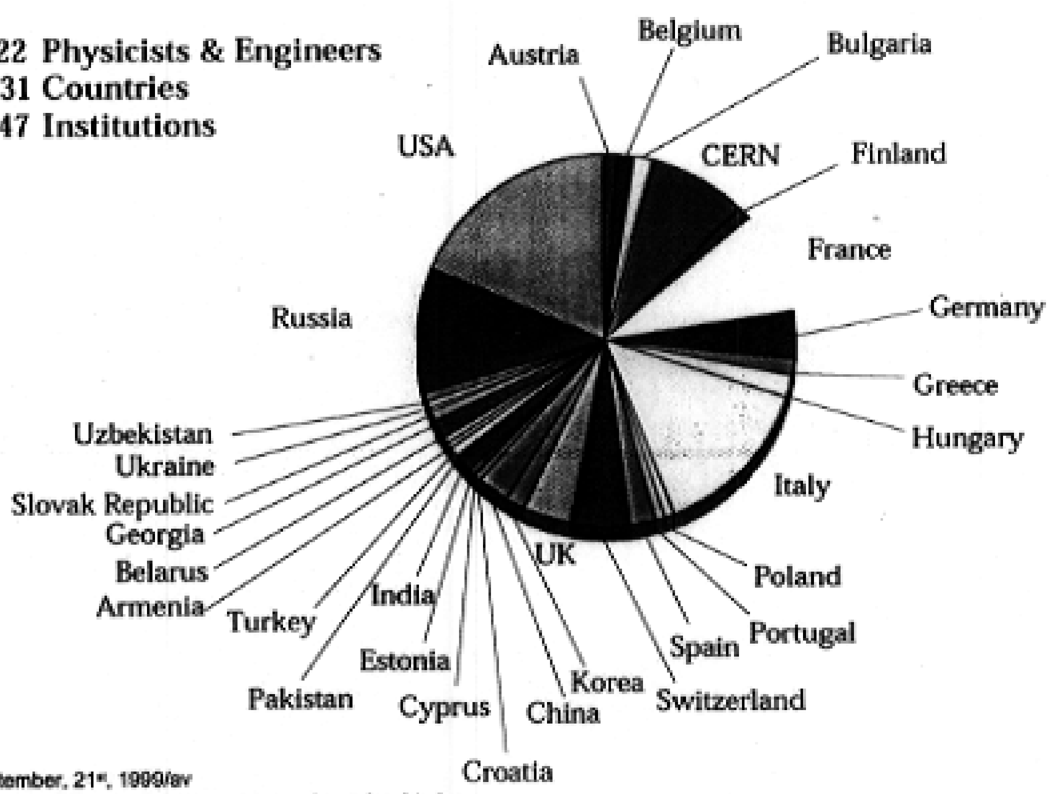
Total weight : 12,500t.
Overall diameter : 15.00m
Overall length : 21.60m
Magnetic field : 4 Tesla

CMS Collaboration

	Number of Laboratories
Member States	60
Non-Member States	51
USA	36
Total	147

	Number of scientists
Member States	1045
Non-Member States	443
USA	334
Total	1822

1822 Physicists & Engineers
31 Countries
147 Institutions



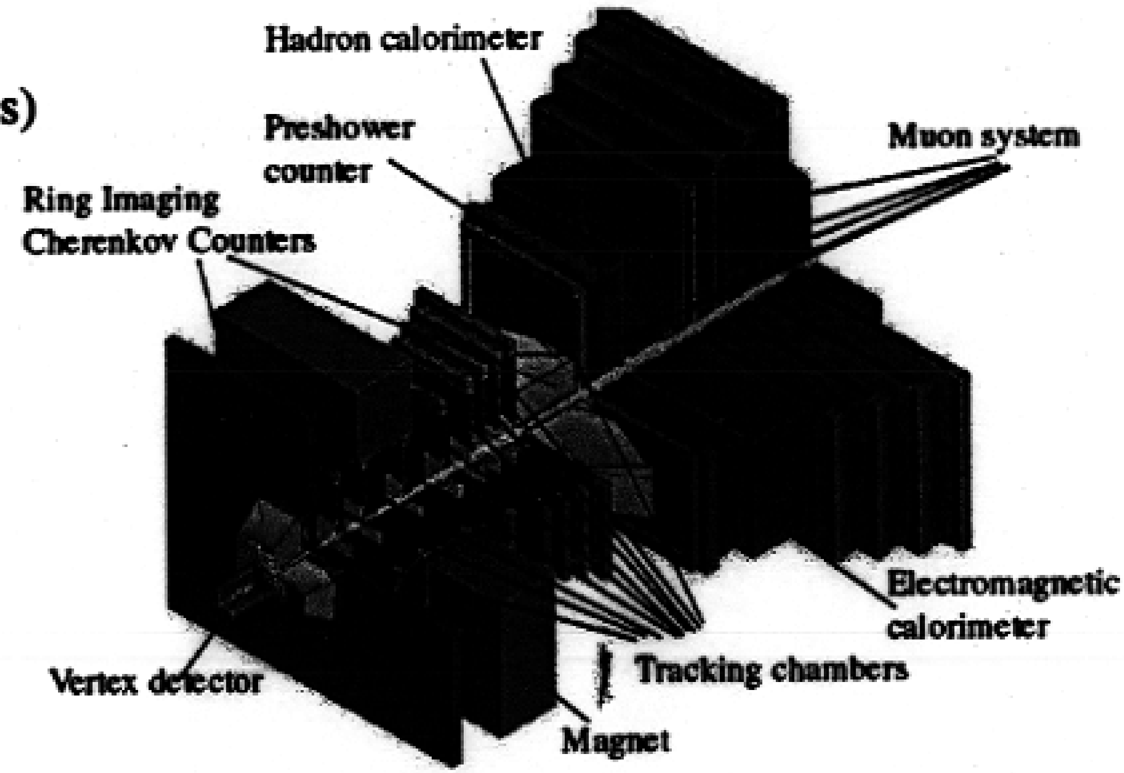
September, 21st, 1999/av
http://cmsdoc.cern.ch/pictures/cmsorg/overview.html

LHCb

(~450 people, 50 institutes, 15 countries)

Precision measurements of CP violation and other rare decays

- efficient and robust trigger
- particle identification
- excellent mass and decay time resolutions



Approved:
September 1998

Current activities:
R&D and prototype testing for Technical Design Reports

Expected TDR Submission dates:
December 1999 (Magnet) to July 2002 (Trigger, DAQ, Computing)

Goal:
Start data taking in 2005 when LHC becomes operational (full physics programme already with low luminosities)

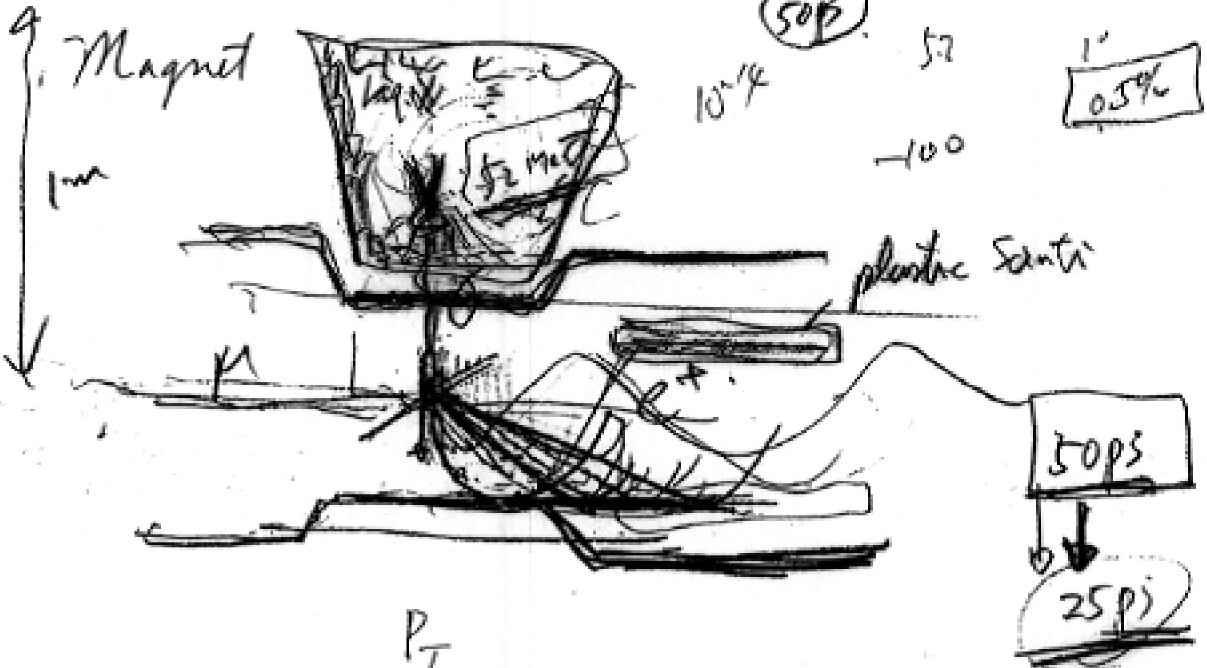
ALICE

A Large Ion Collider Experiment

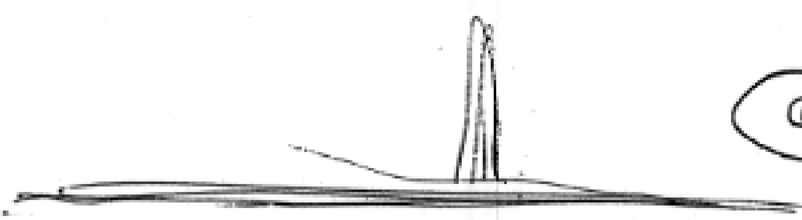
- **Physics**
  - ⇨ QCD phase transition to **QGP with heavy ions** at LHC
- **Experiment**
  - ⇨ **900** members, **28** countries, **74** Institutes, cost: ≈ **120 MSF**
- **Milestones**
  - ⇨ Technical Proposal — approved **2.1997**
  - ⇨ Technical Design Reports — 5 submitted, 3 more by **8.2000**
  - ⇨ MoU — ready **spring 2000**
- **Status**
  - ⇨ R&D mostly finished
  - ⇨ now: final design, construction & test of large prototypes
  - ⇨ construction of selected items has started in 1999
- **Major R&D Results in 1999**
  - ⇨ **radiation hard electronics** in 0.25 μm standard CMOS
  - ⇨ **new** high performance/low cost **TOF detectors**: multigap RP

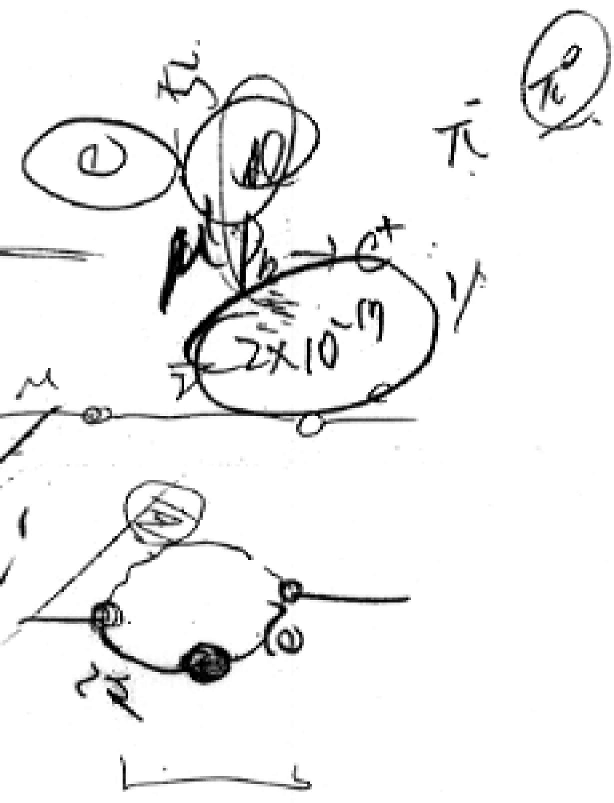
$\mu \to e, \gamma$

Minda Kami



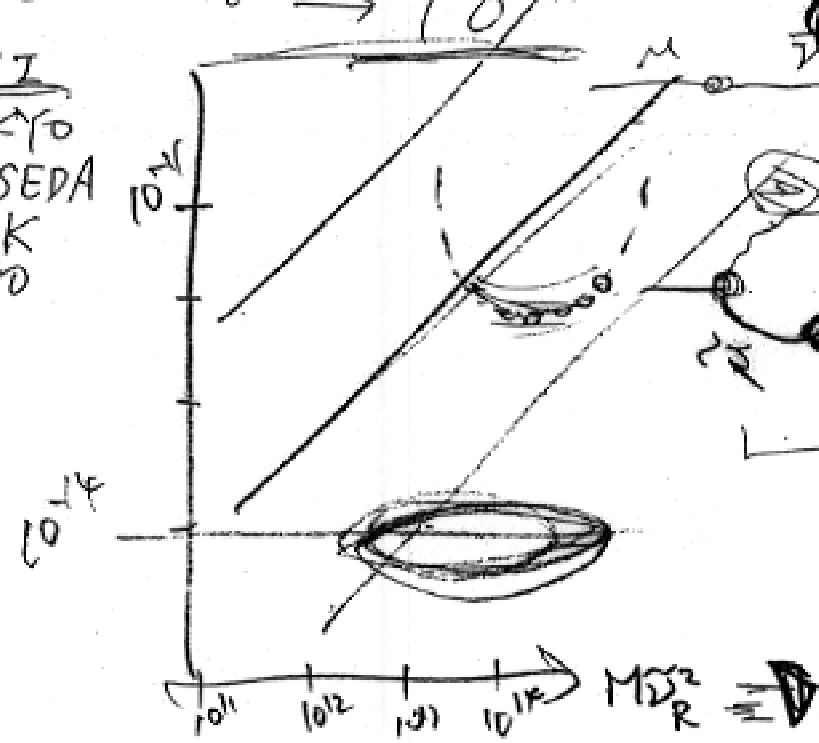
$\frac{P_T}{P_\parallel}$





$\mu \to e + \gamma$ $10^{-11} \to 10^{-14}$

PSI
TOKYO
WASEDA
KEK
KUNO



PEP-II and KEKB History

	PEP-II	KEKB
Start of construction	Nov. 1993	April 1994
First stored HER beam	June 16, 1997	Dec. 13, 1998
First stored LER beam	July 16, 1997	Jan. 12, 1999
First beam collisions	July 23, 1998	Feb. 5,1999
Detector installed	May 10, 1999 BaBar	May 24, 1999 BELLE
First detected events	May 26, 1999	June 1, 1999
Upsilon 4S energy scan	June 1999	July 1999
Present status	operation continued	shudown from August 4-Oct. 10, 1999
Max. luminosity observed	$1.2 \times 10^{33} cm^{-2} s^{-1}$	$0.3 \times 10^{33} cm^{-2} s^{-1}$

Neutrino Oscillations

1. Reactor

- Bugey L~100m
- Chooz 1500m — $\delta m \geq 10^{-3}$eV
- Kamland 150km — 10^{-5}ev
- (April, 2001) — solar large mixing (N/D)

2. Acc.

- Chorus (emulsion) — $\nu_\mu \rightarrow \nu_\tau$ — 10^{-4}eV
- Nomad (chamber) (kinematics) — $\nu_\mu \rightarrow \nu_\tau$ — 1~10eV
  - Karmen — $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$
  - LSND — $\nu_\mu \rightarrow \nu_e$, $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ — 0.1~1eV
  - Mini Boone — ν_μ — check LSND (8 GeV Proton)

3. Solar

- Galex, Sage — Ga — 233KeV
- Home Stake — Cl

K, SK	H_2O	
SNO	D_2O	
Borex	LS (2001) ν_ee scattering	Be7 → 400KeV, 870KeV

seasonal variation

→ vacuum oscillation

4. Atmospheric

SK H_2O
SUDAN2 Iron + Tracking
Macro up going μ (LS + proportional)

5. Long baseline

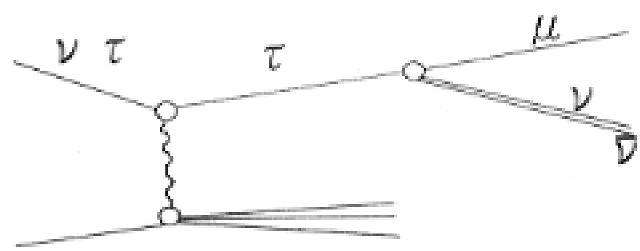
K2K disappearance
Minos 2003 Iron, scintillation fibre

→ Nagoya group: approved Sep 28, 1999

⇓ kinematics

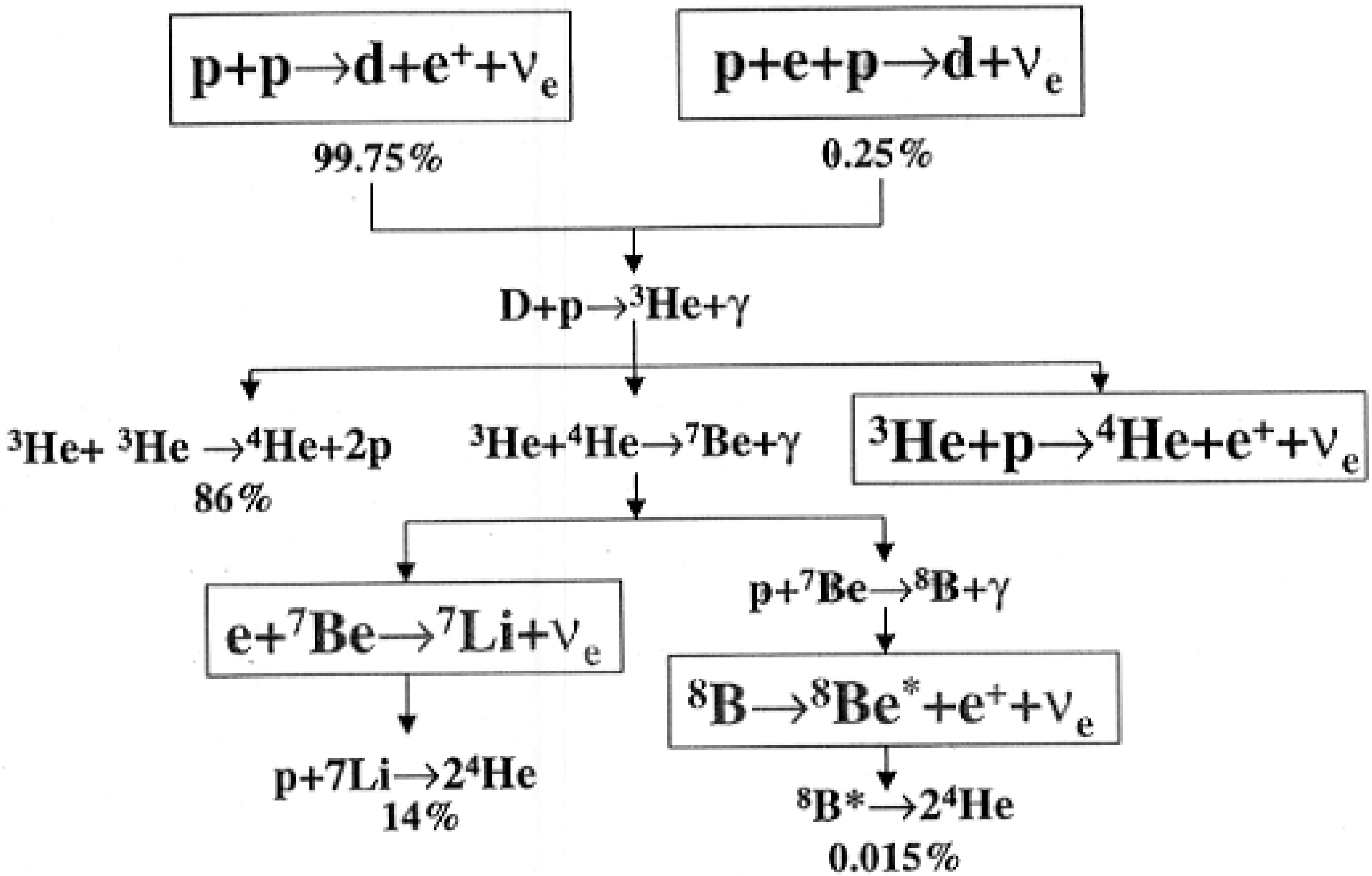
Opera (Emulsion)
Icarus (LiAr 600tons)

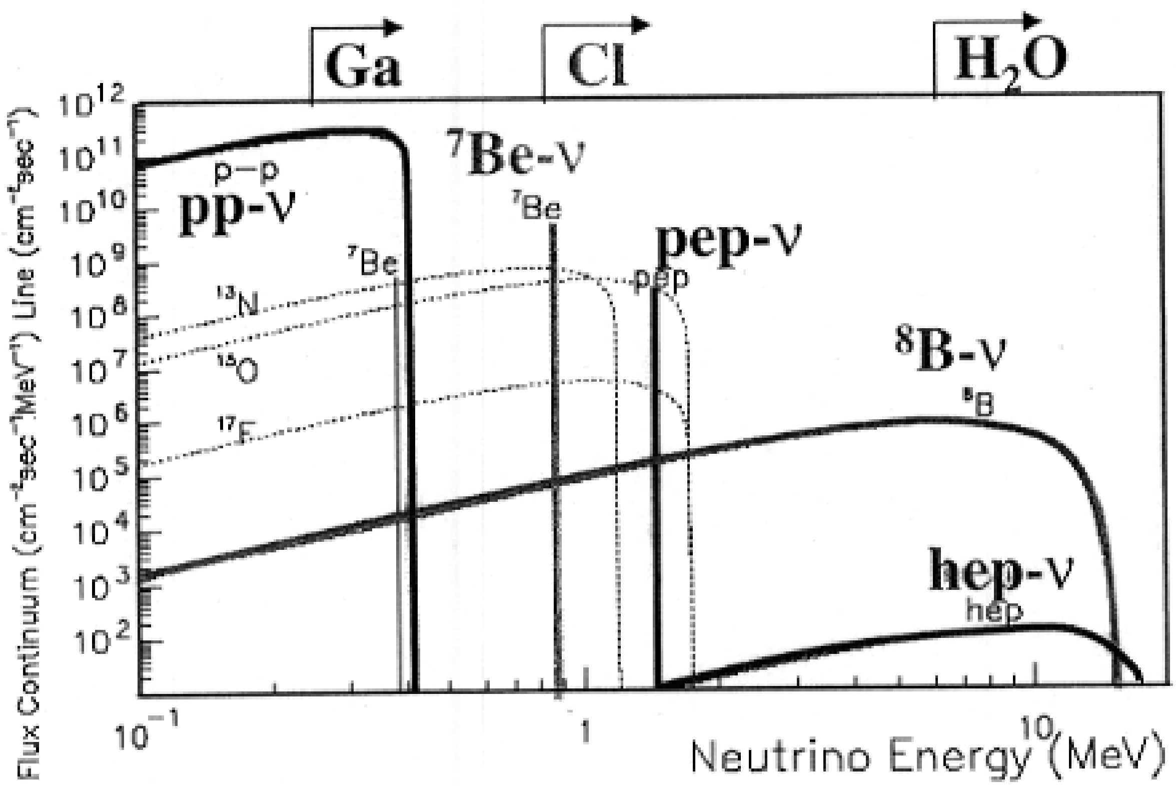
$$\frac{Fake N.C.}{C.C.} = F(\delta m^2, \sin^2\theta)$$



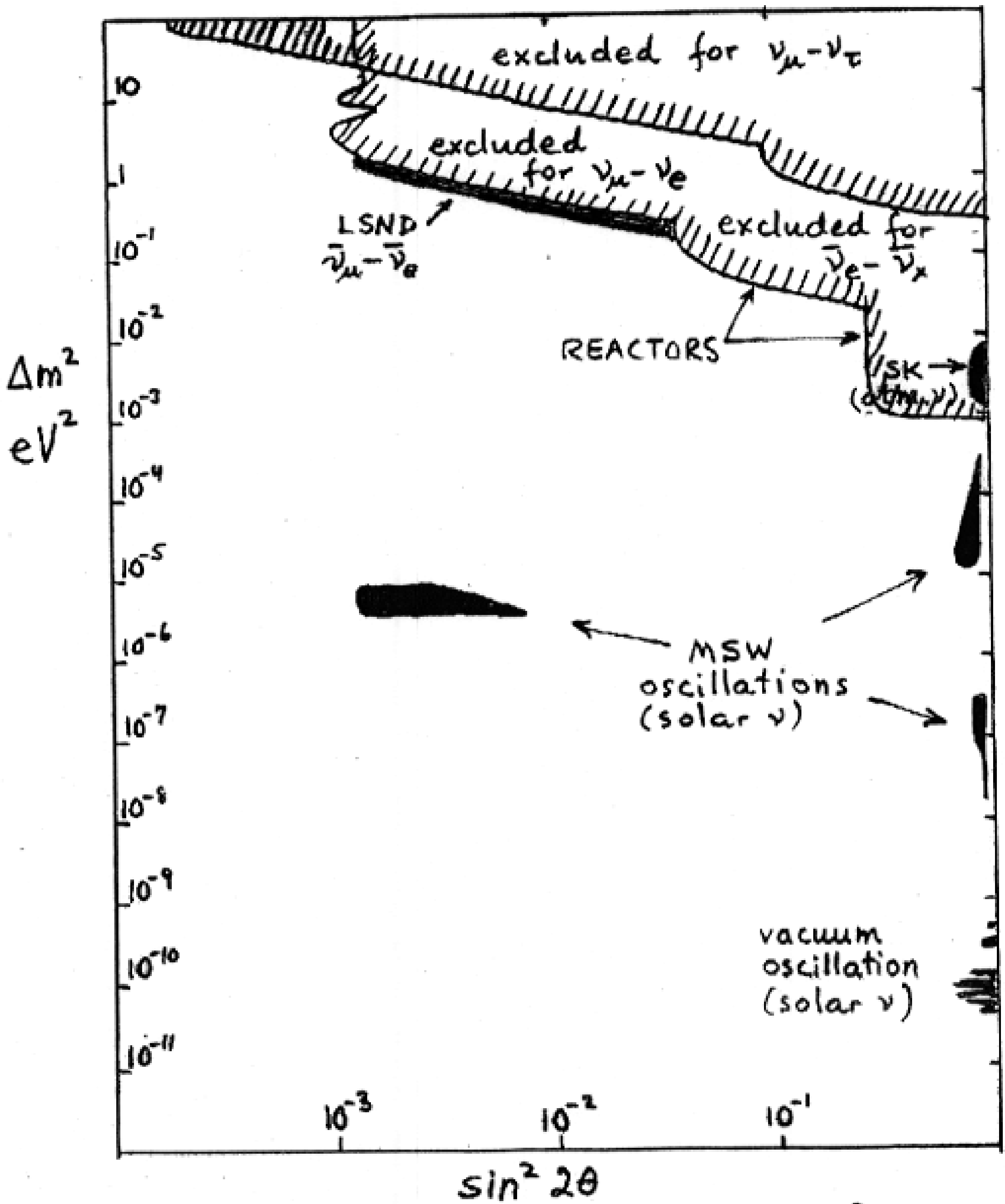
Solar neutrinos

The pp-chain



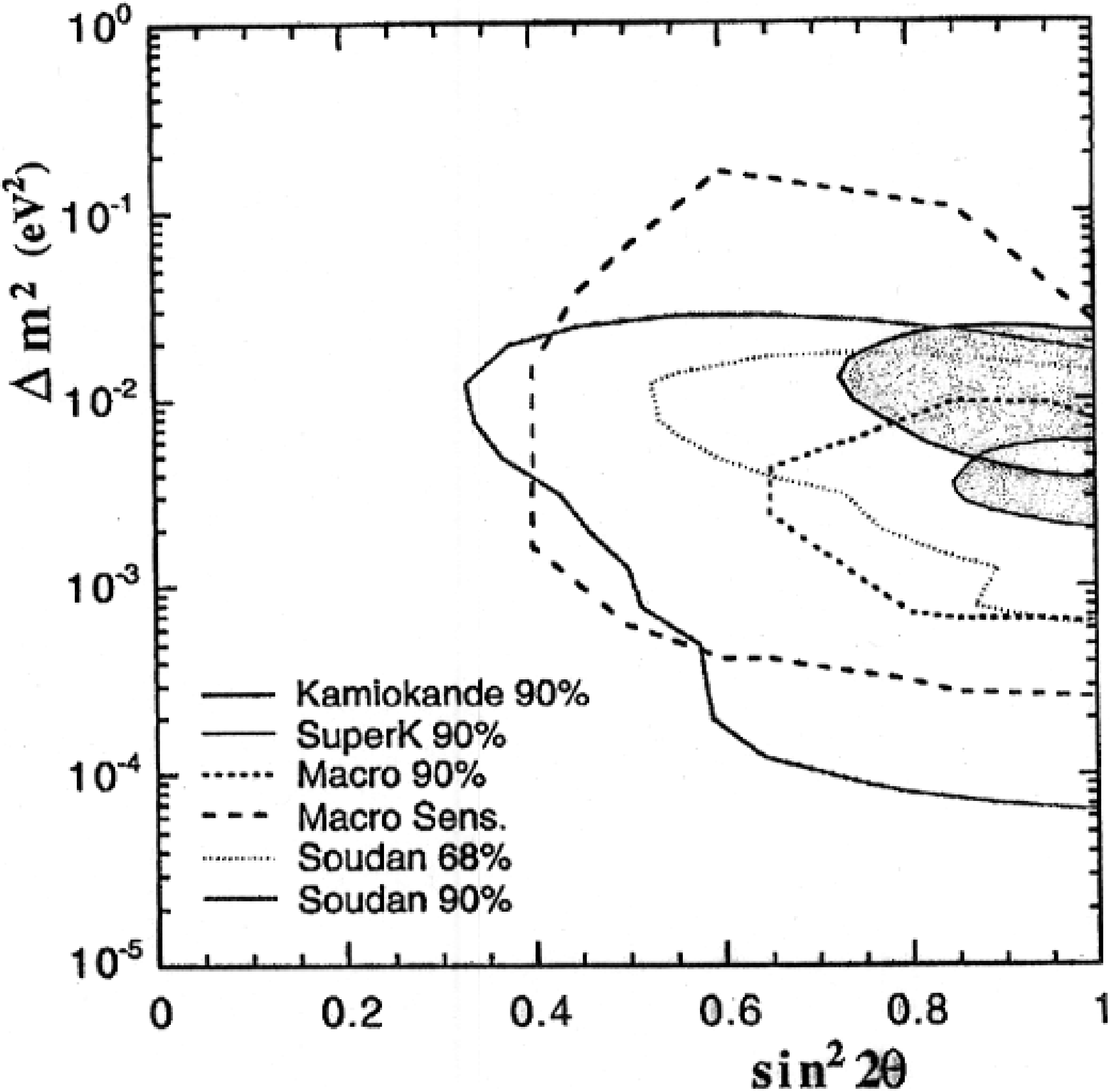


SUMMARY OF EXPERIMENTAL EVIDENCE/HINTS FOR NEUTRINO OSCILLATIONS ASSUMING TWO-NEUTRINO MIXING

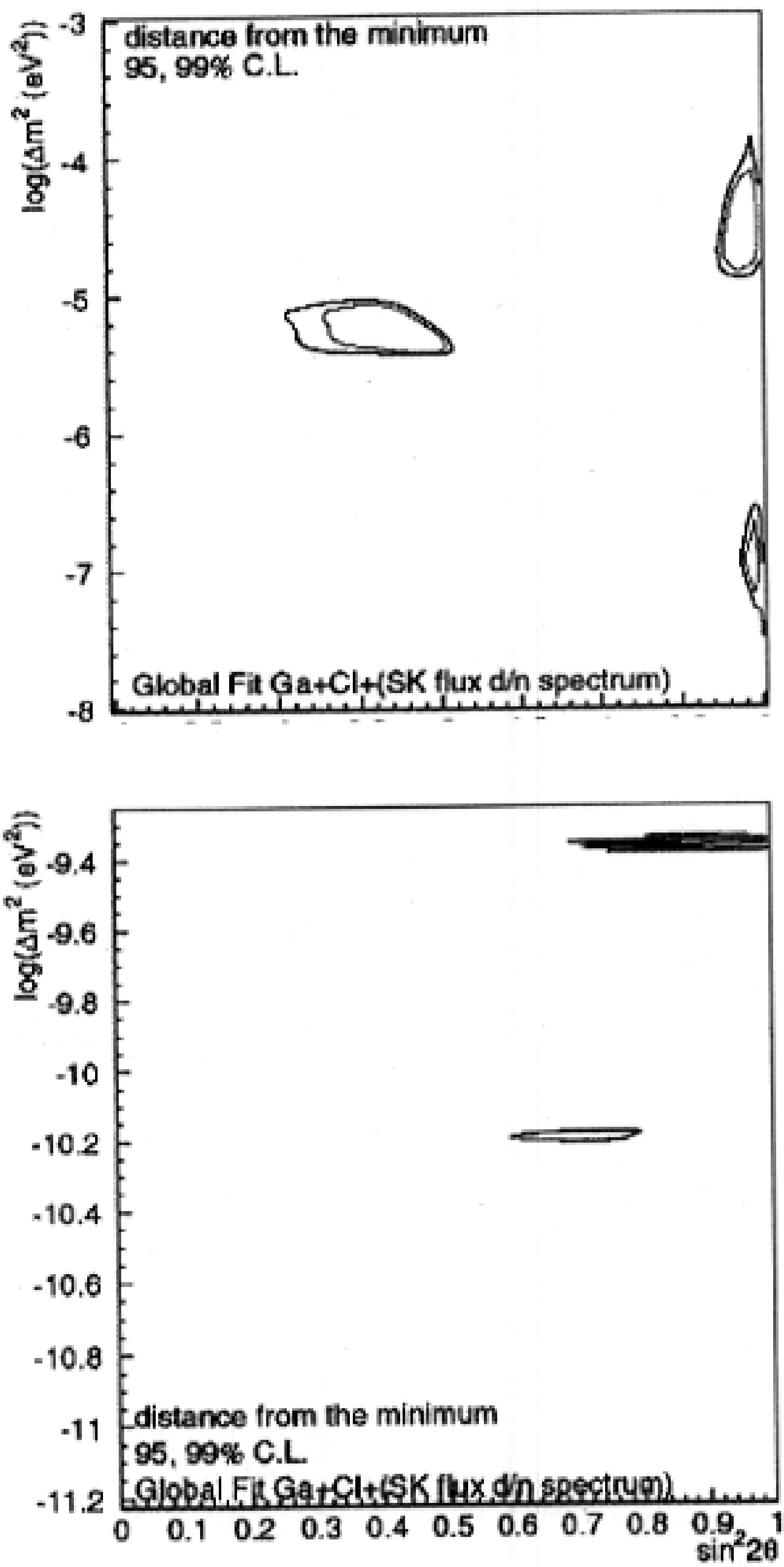


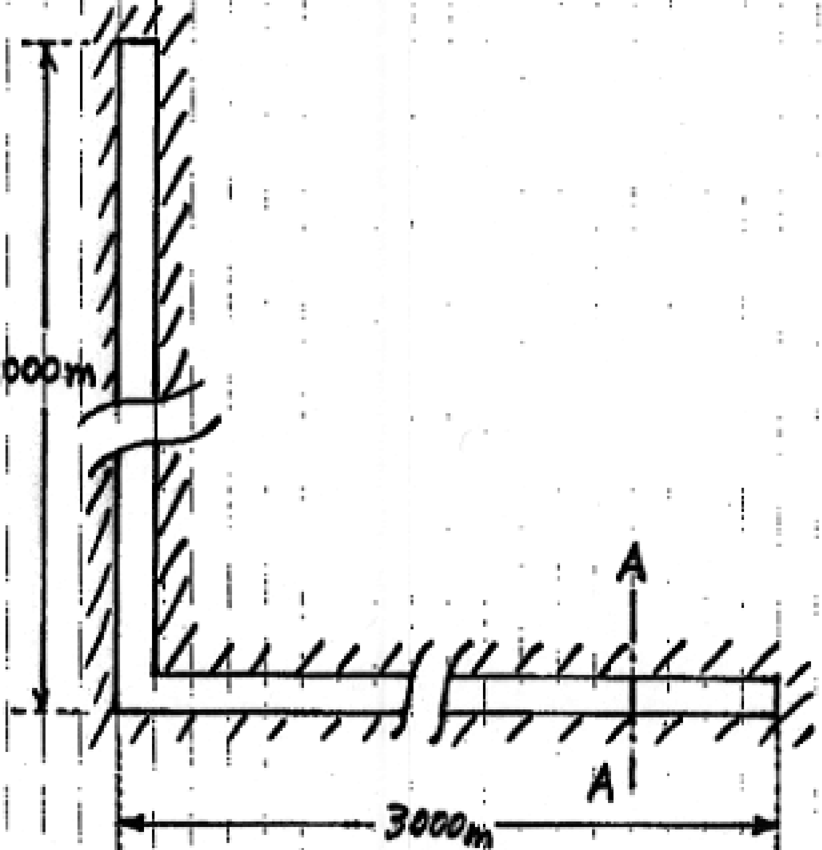
3 NEUTRINOS → 2 INDEPENDENT Δm^2 VALUES

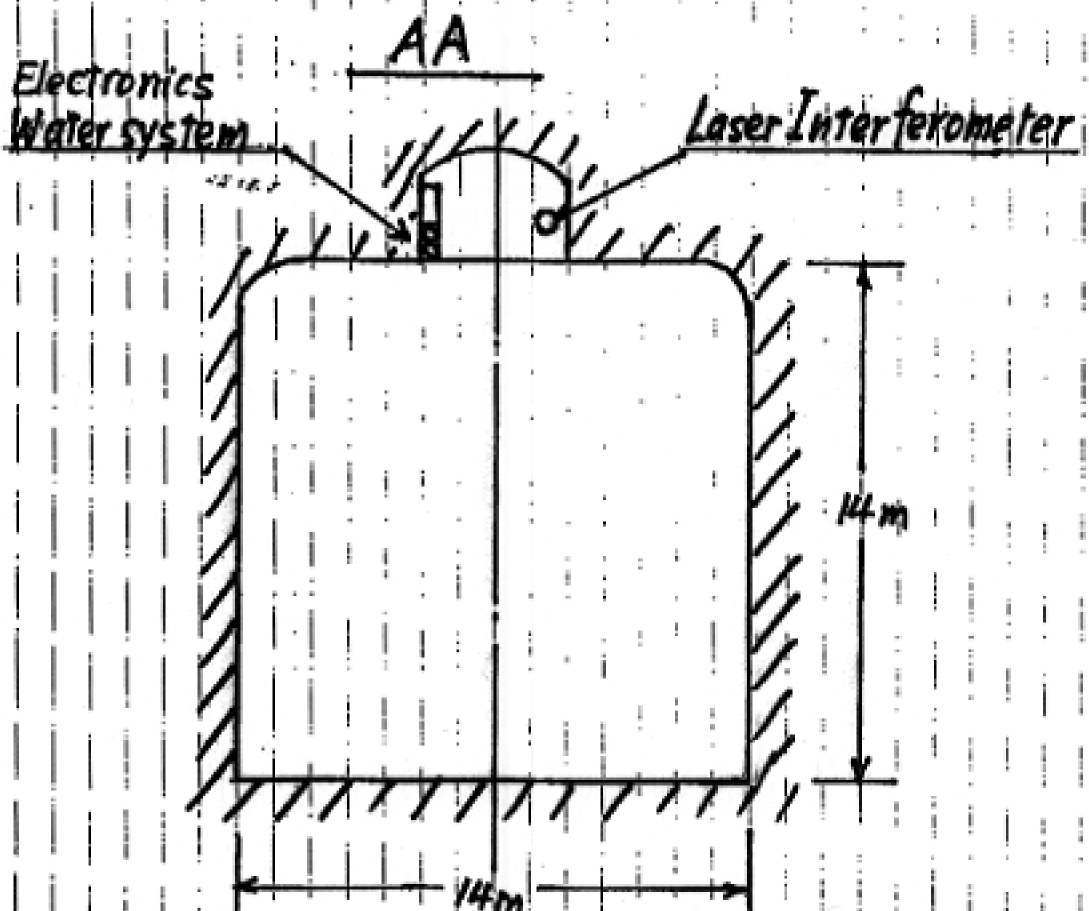
Oscillation Parameters - Best Fits:



Global (with SSM hep)




3000m
A
A
3000m


AA
Electronics
Water system
Laser Interferometer
14m
14m

- A water Cherenkov detector.
- A L-shaped tunnel with a cross section $14\,m \times 14\,m$ and each arm length $3\,km$.
- The total volume of the tunnel is $1.2 \times 10^6\,m^3$.
- About 200 intermediate layers segment the detector.

Conditions to build such a detector are:

- The cost must be no more than $40 \times 10^9\,yen$.
- The detector must be useful for other purposes;
  - A neutrino-oscillation experiment with a new high-intensity proton machine JHF.
  - Accommodate a laser interferometer for the gravitational-wave detection on top of the tunnel.
- Super-Kamioknade must find a good candidate to motivate building such a detector.

Linear Collider R/D and Proposed Projects

KEK

Power → C - Band, X - Band

ATF damping ring

→ **SLAC/KEK collaboration** ←

SLAC

Power → X - Band

ASSET, structure testing

DESY

superconducting linac

CERN

wake field acceleration

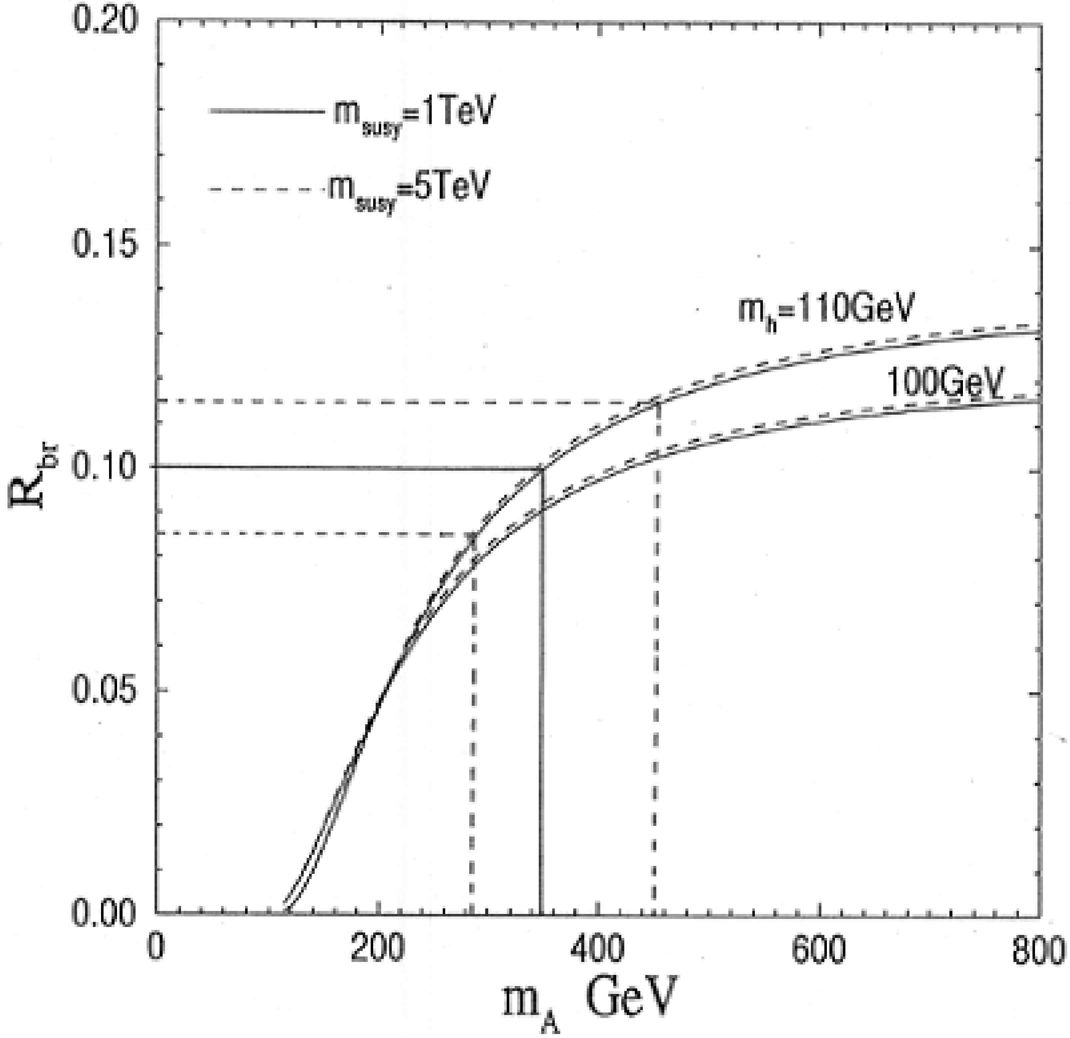
30GHz

Projects

NLC, JLC, TESLA, CLIC

> It is very important to:
>
> (1) Build a linear collider (E ≦ 500 GeV) as soon as possible to make a detailed study of the Higgs boson to make sure that it is a genuine Higgs and to decide the energy of the next stage.
>
> (2) invest as little as possible to the extendability of the machine but also maintain the attitude to maximize it. (technology choice) (× Snowmass '96)

$$R_{br} = \frac{B(h \to c\bar{c}) + B(h \to gg)}{B(h \to b\bar{b})}$$



J.Kamoshita, Y.Okada, M.Tanaka, LCWS 95 & PLB391(97)124
I.Nakamura, K.Kawagoe, LCWS 95, I.Nakamura, LCWS 99

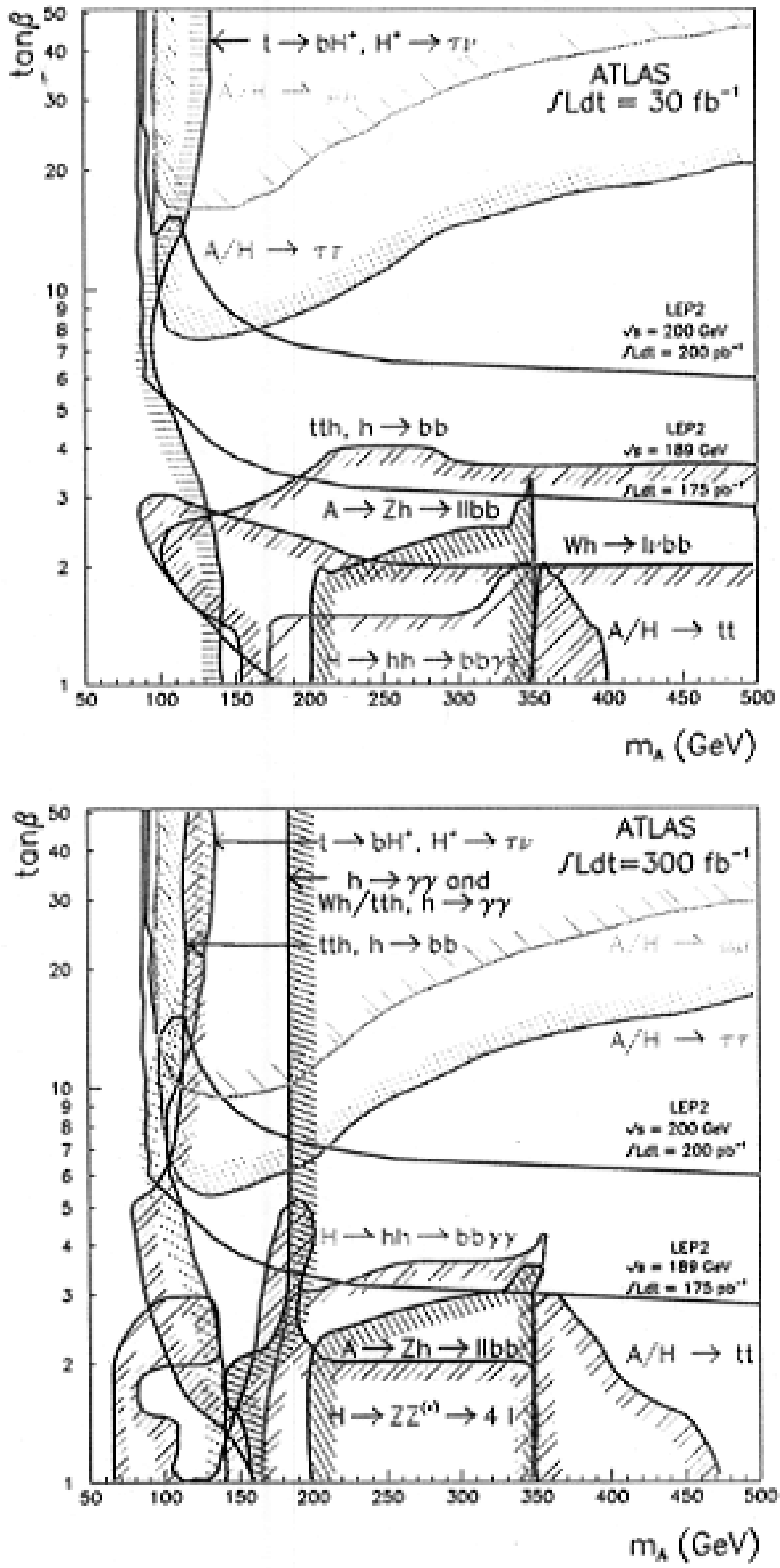


Figure 19-ii ATLAS sensitivity for the discovery of MSSM Higgs bosons (in the case of minimal mixing). The 5σ discovery contour curves are shown in the (m_A, tanβ) plane for individual channels and for integrated luminosities of 30 fb^{-1} (top) and 300 fb^{-1} (bottom). Also included are the present LEP2 limit (for an integrated luminosity of 175 pb^{-1} per experiment) and the expected ultimate LEP2 limit (for an integrated luminosity of 200 pb^{-1} per experiment at a centre-of-mass energy of 200 GeV).

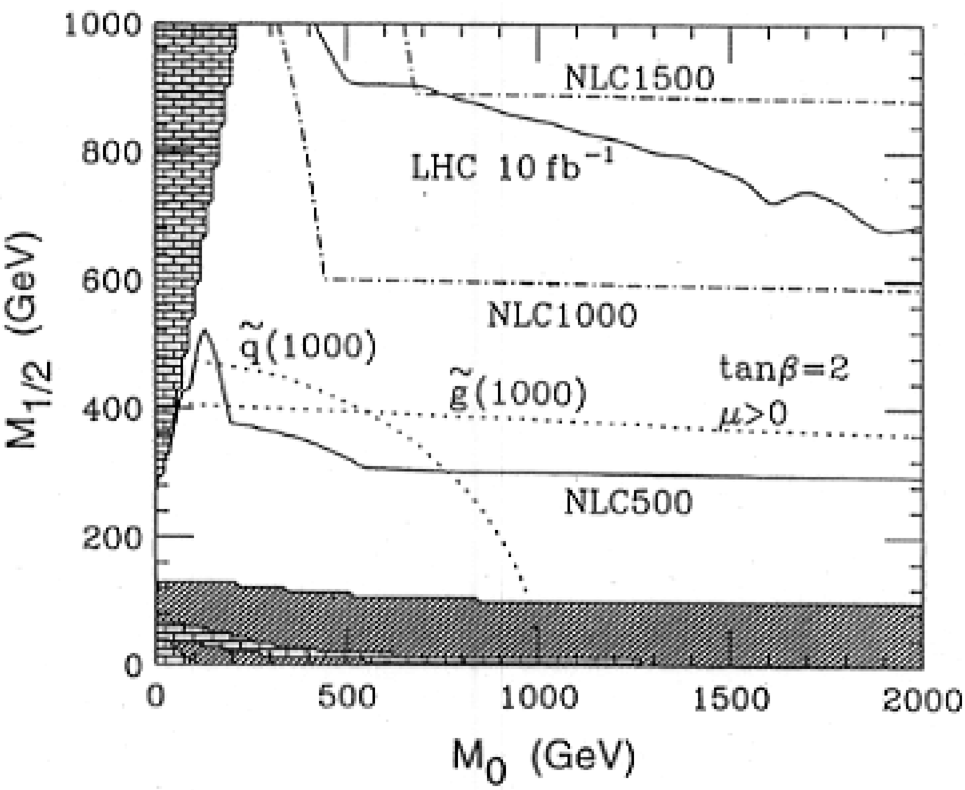
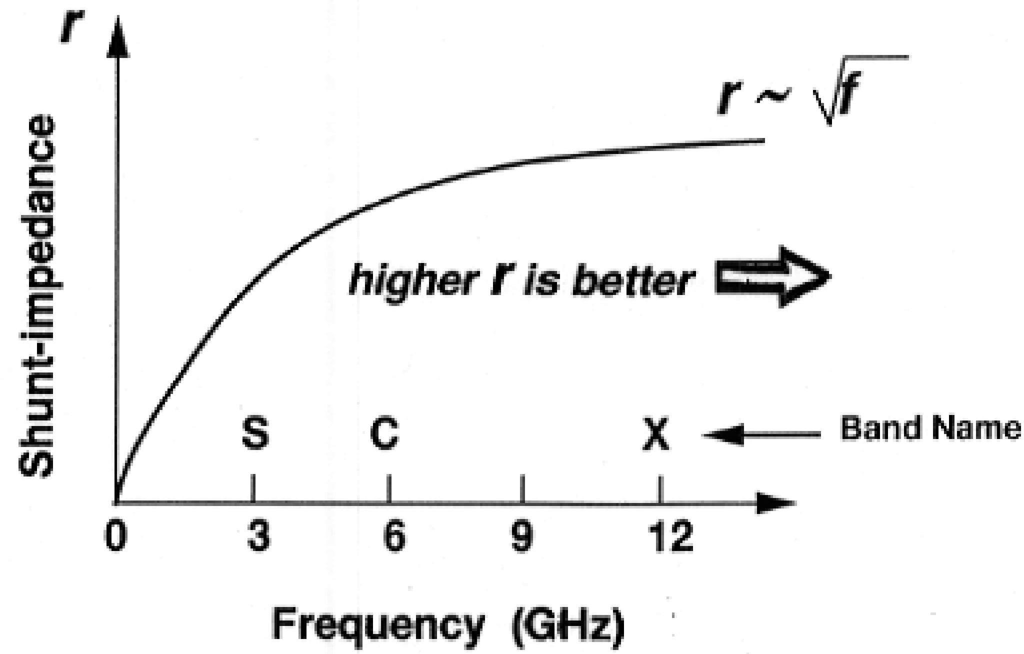
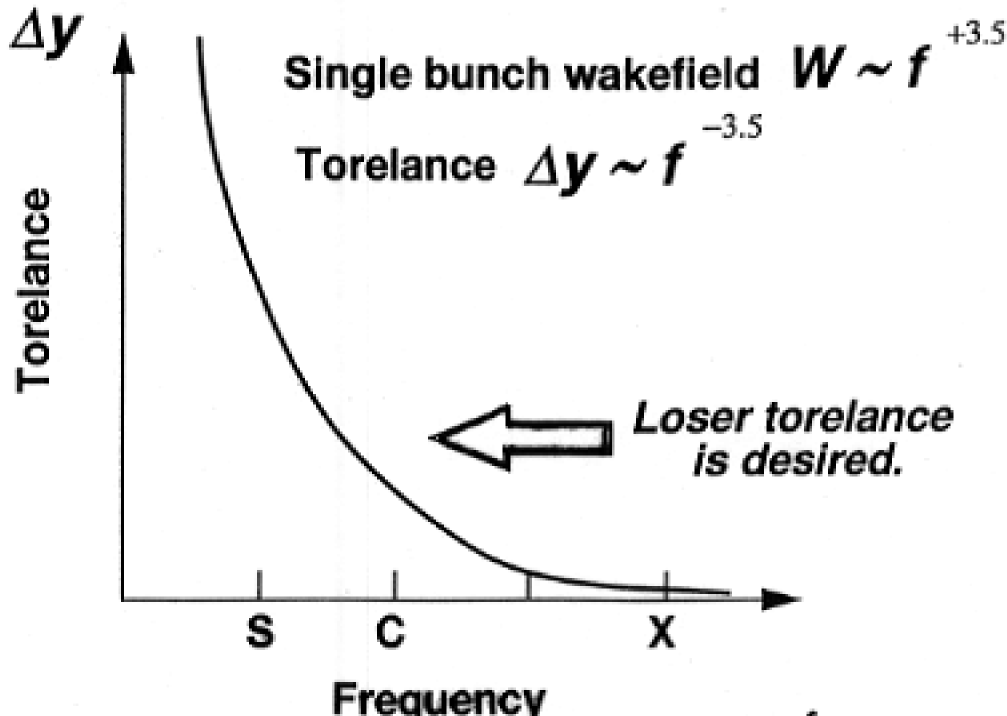


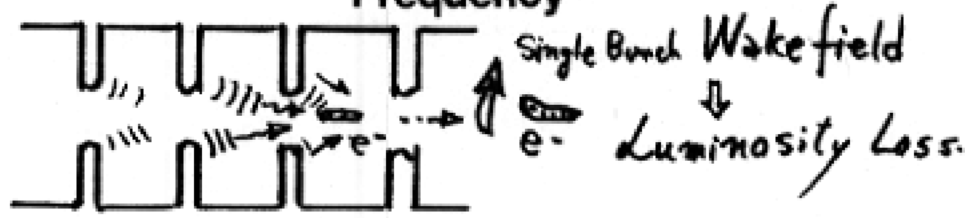
Figure 2. The supersymmetry reach of various facilities in the mSUGRA model, for $\tan\beta = 2$, $A_0 = 0$ and $\mu > 0$. Note that the reach of a 1.2 – 1.5 TeV NLC is approximately equivalent to that of the LHC.

Accelerating Structure Efficiency

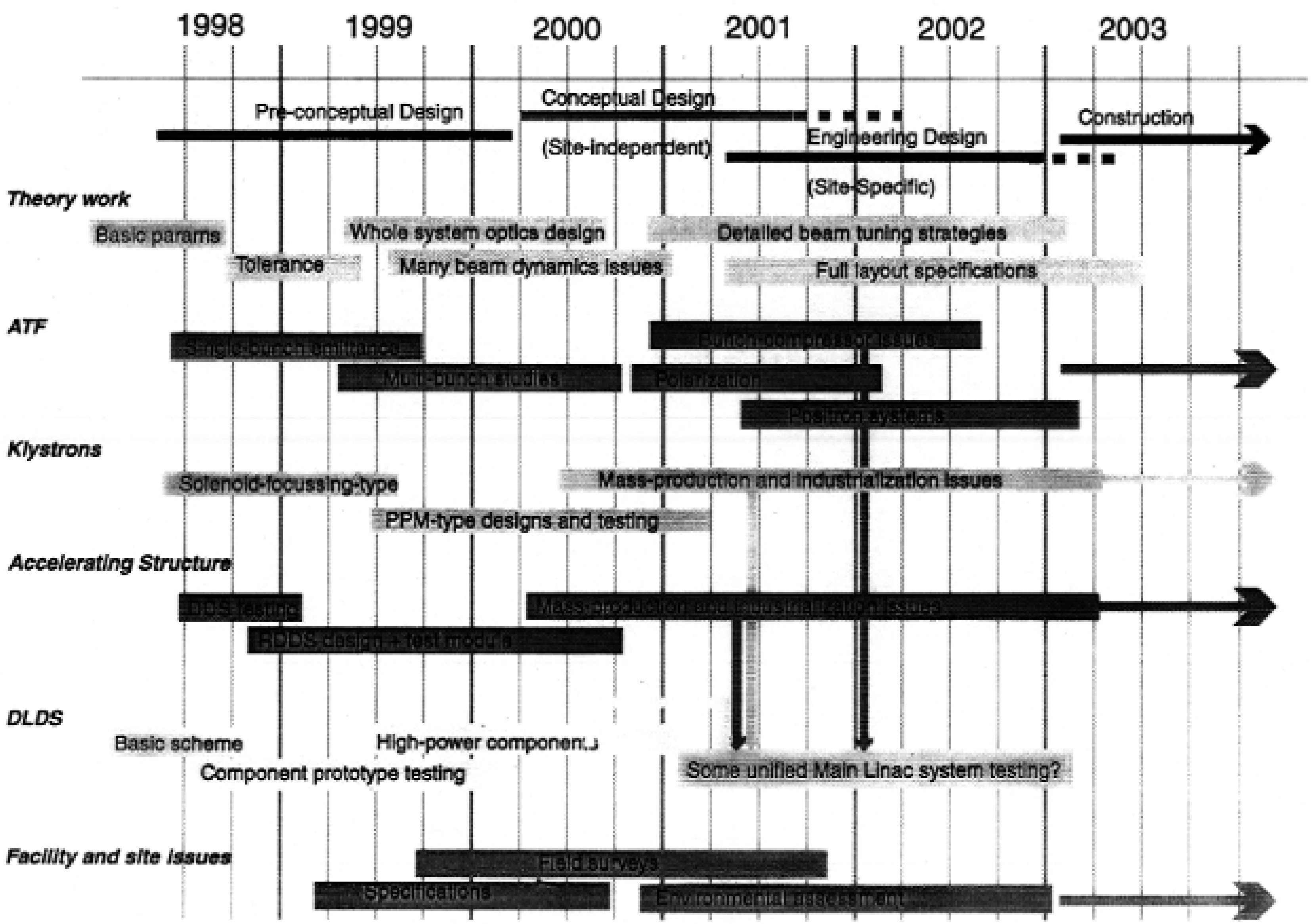


Alignment Torelance



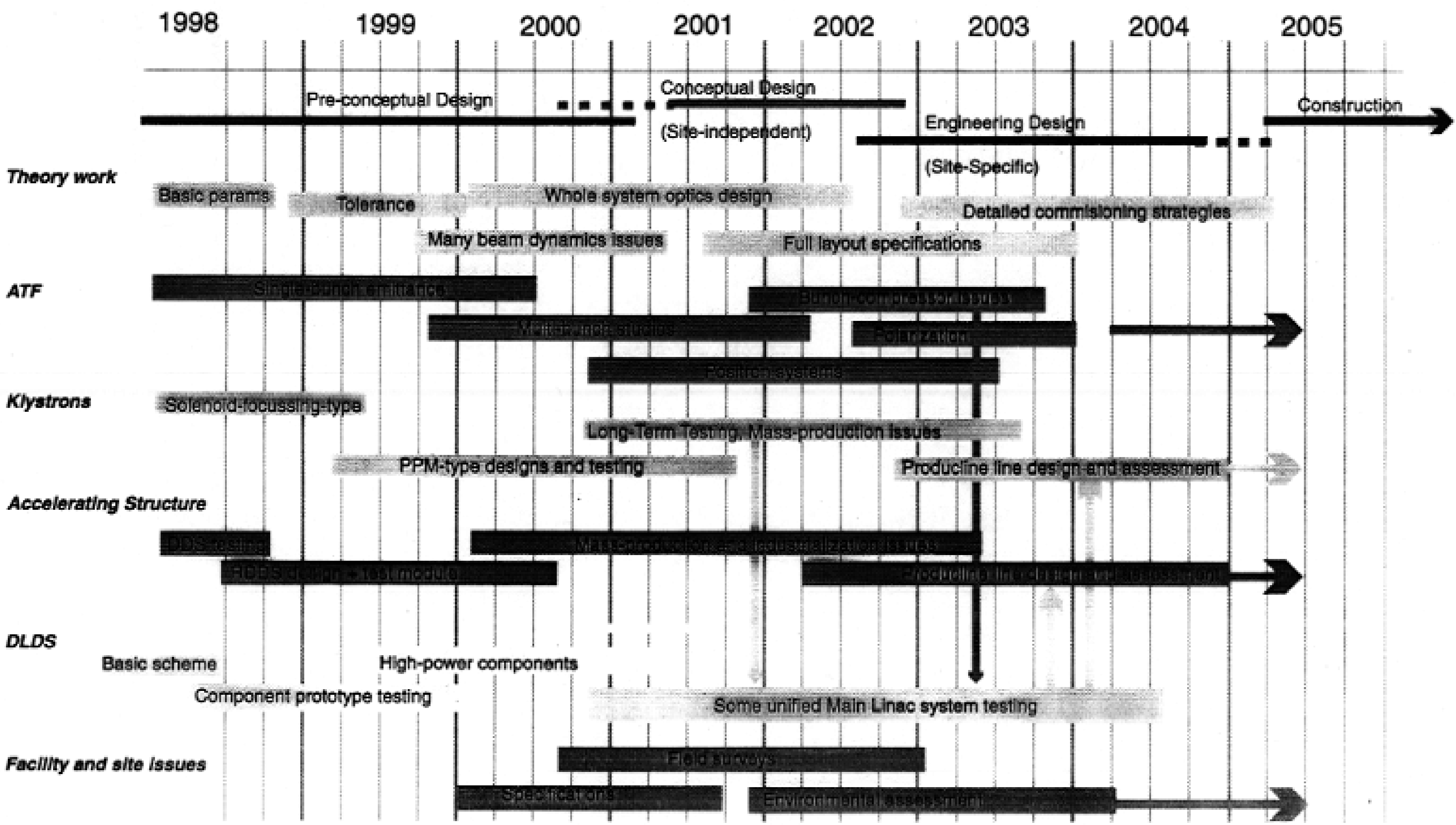


Fast Path Envisaged by the JLC Group (KEK) towards an LC



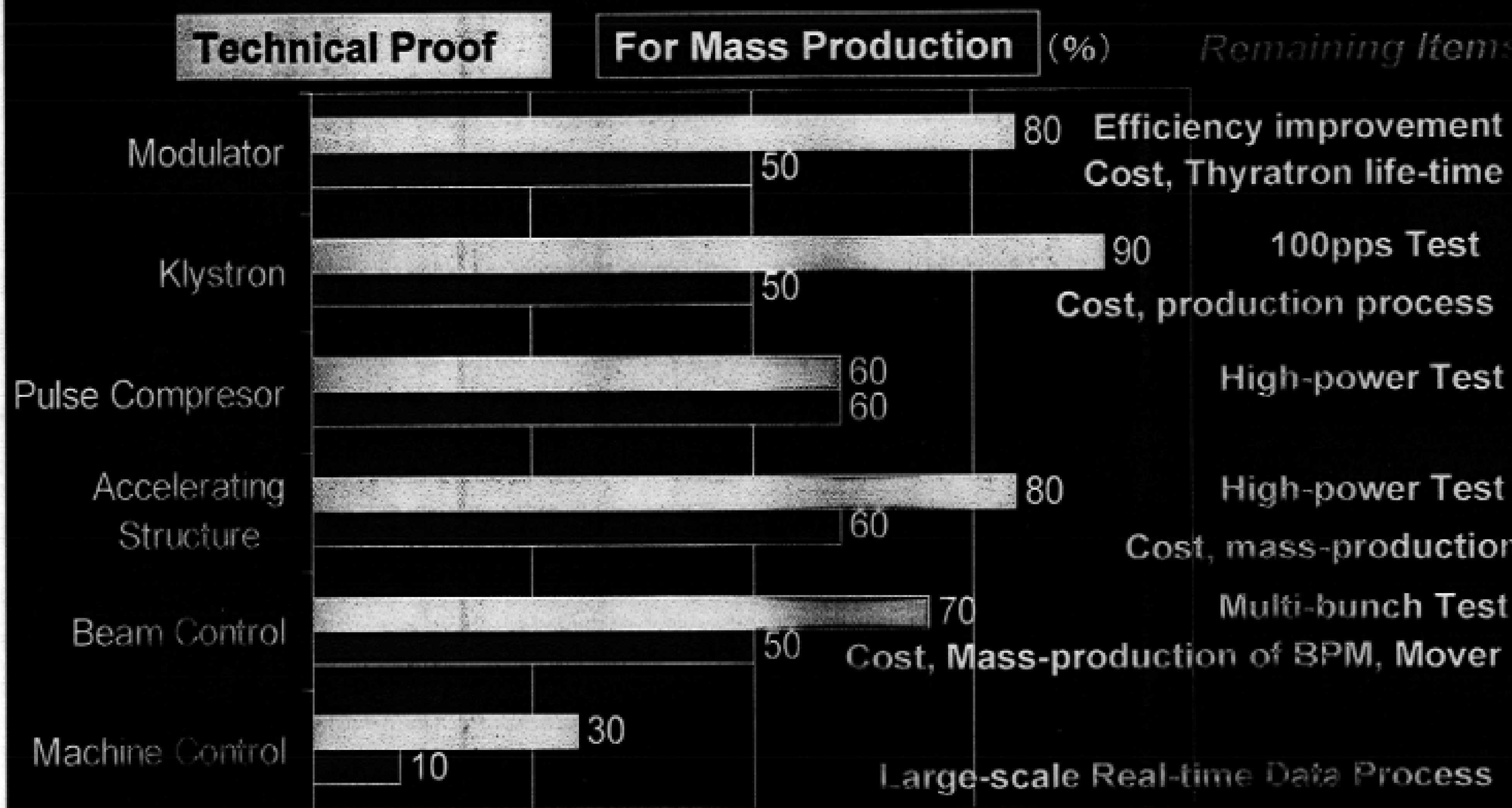
v.990928 NKT

Fast Path Envisaged by the JLC Group (KEK) towards an LC



R&D Achievement (1996~1999)

C-band JLC



Before the LC Construction

C-band JLC

Main-Linac R&D items during years 2000 - 2003.

- Operational test with actual beam

  Install C-band RF-system into B-factory injector.

- R&D Items for Mass-Production
  - Klystron Tube : Cost reduction, productivity improvement

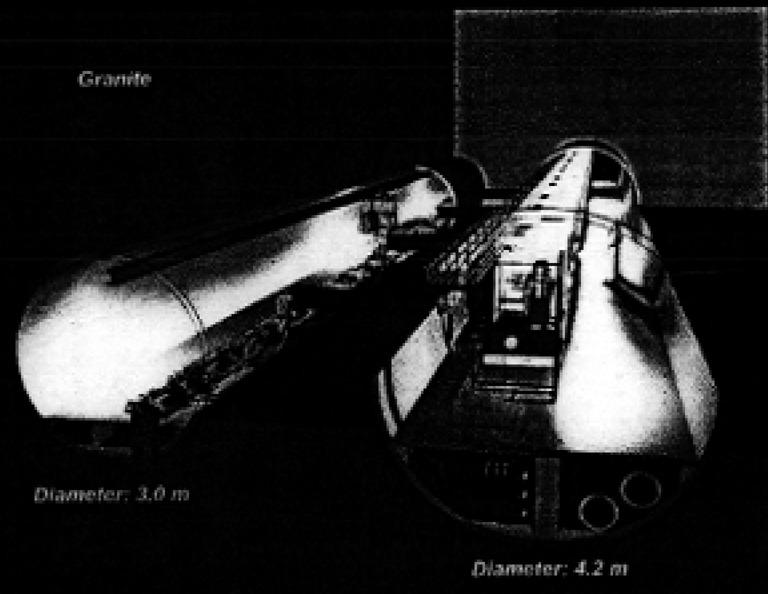
    Refine design details (material choice, baking process)
  - Modulator Power Supply : Cost reduction
    - Circuit components : Compact modular design.
    - Thyratron Switch: Reliability improvement, cost reduction

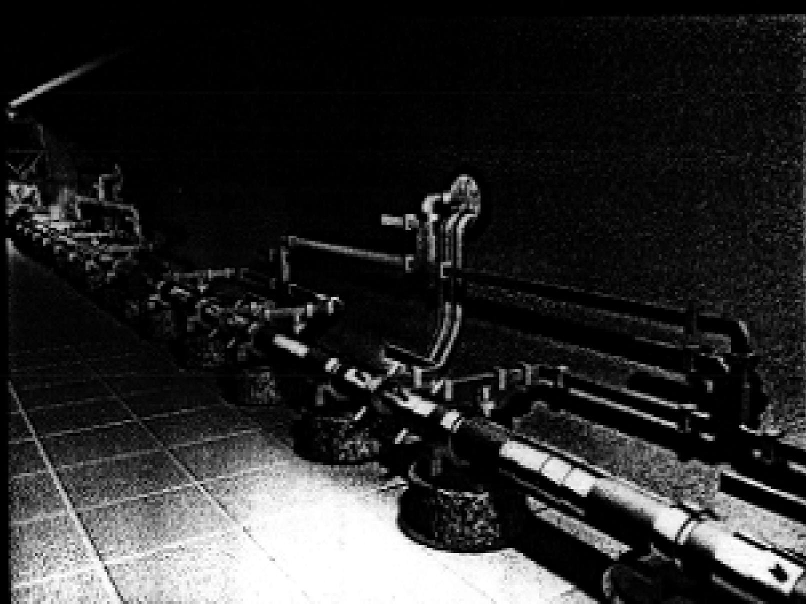
      Refine design details (material choice, H2 pressure control)
    - Solid-state Switch *will not be ready before 2003, keep it for future upgrade.*
  - Accelerating Structure : Cost reduction, productivity

    Refine machining and frequency tuning process.

    Optimize bonding procedure.

JLC C-band (5712 MHz) Main Linac Tunnel





Cosmic Rays and Astrophysics

◎ What is the source of the ultra-high energy cosmic ray beyond 10^{20}eV ?

Agasa (7 events), Flies eye (1), Pierre Auger (Čherenkov, Argentine & Utah)

(High Res Ⅱ, 7)

Telescope Array (Scin Tel), OWL (satellite, NASA 2005)

◎ γ - sources and γ - bursts

Cangaroo Ⅱ, Ⅲ (5 or 6), Virotas (Whipple), Germany (HESS, MAGIC, Hegra (3m Tel)), Egret (satellite≤ 30GeV), Glast

◎ high enerugy neutrino (AGN)

Amanda, Bikal Nestor, ・・・・

◎ Fundamental cosmological constants

Hubble $\left(\dot{R}/R\right)$

$\Omega\ (\rho) \quad = \quad \Omega_{bar} \quad + \quad \Omega_{dar}$

λ: cosmological constant

SDDS (Gravitational lens distribution), Supernova (Type Ⅰ) Cosmology Project

T: life time of the universe

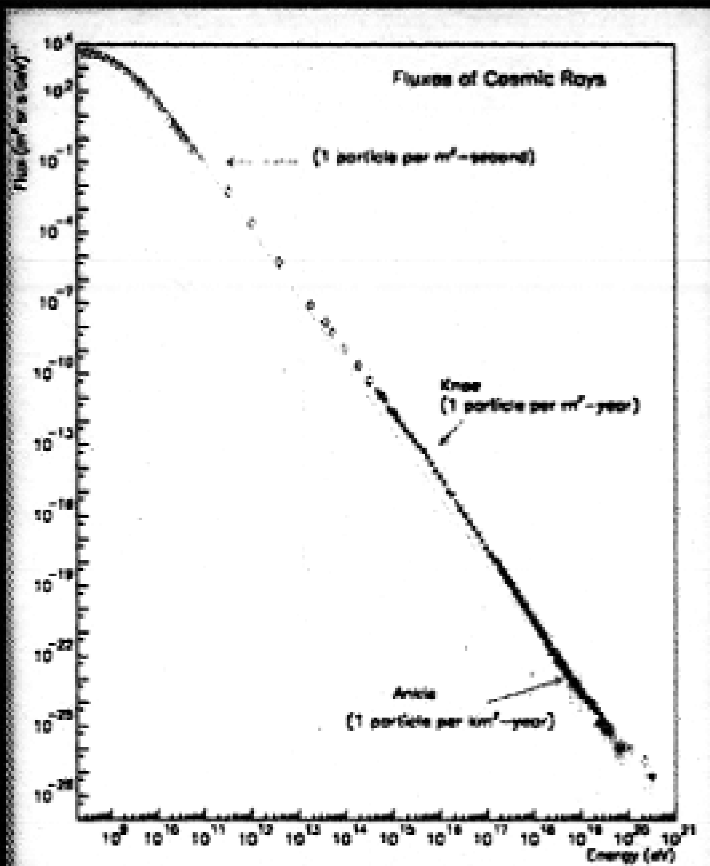
◎ Structure formation

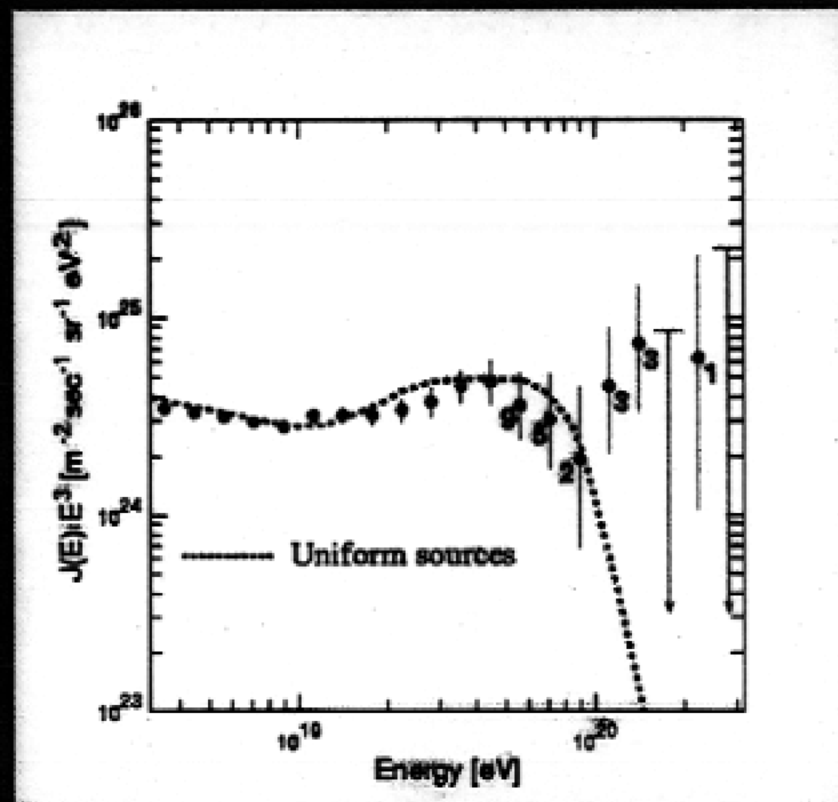
- Anisotropy in CMB
  : COBE et al.
- large structure
  : SDDS up to Z = 0.2, π steradion

Are these consistent with CDM - inflation model?

Cosmic Ray Energy Spectrum

- AGASA '99



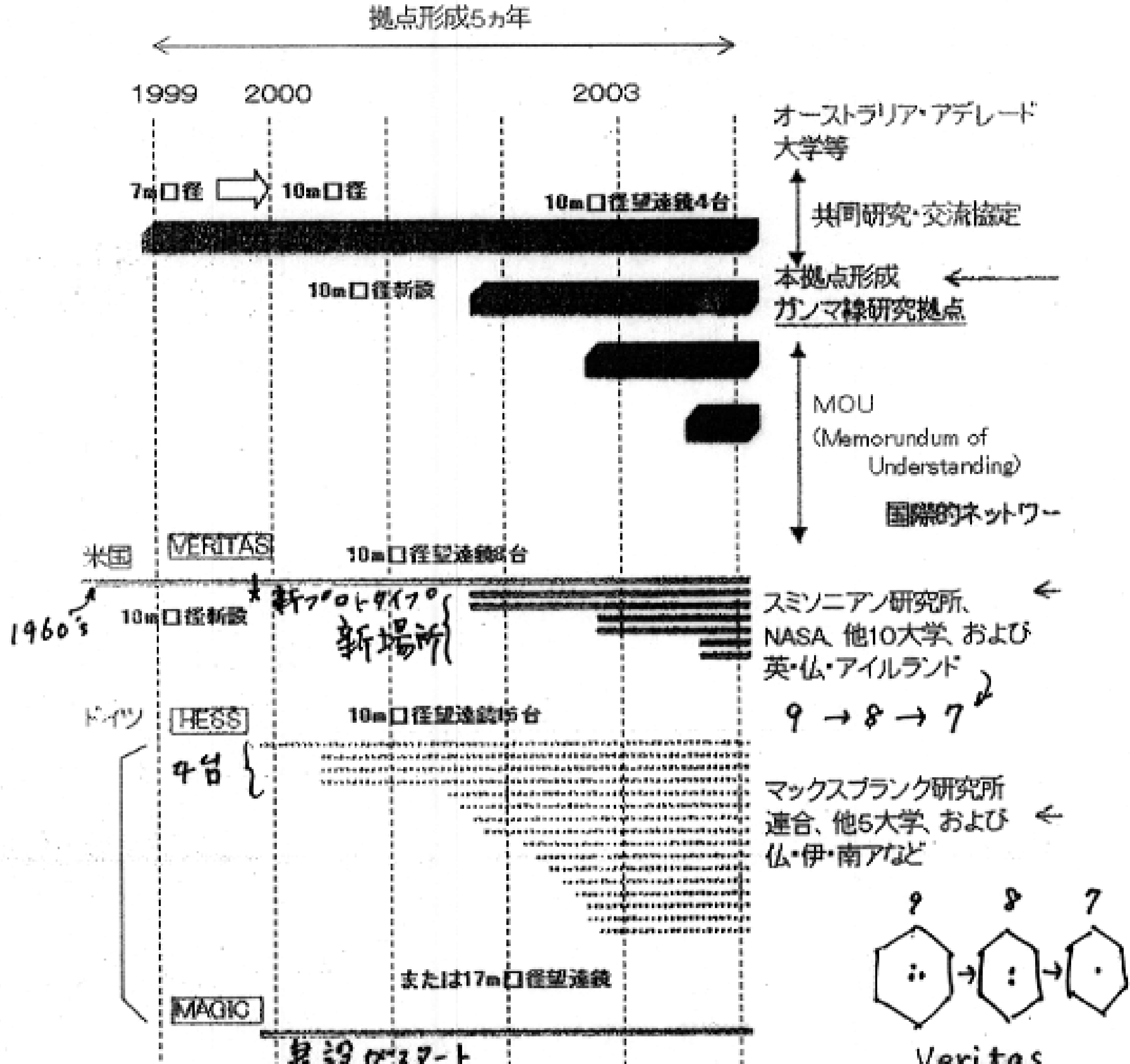


TeV γ-ray Sources classified by "confirmation rank"
(from T.C. W. [illegible] 1999)

分類	天体名	グループ	備考
Class A	Crab	多数	Plerion
	PSR1706-44	CANGAROO, Durham	Plerion
	Mrk421	多数	AGN (BL Lac)
	Mrk501	多数	AGN (BL Lac)
Class B	SN1006	CANGAROO	SNR
	Vela	CANGAROO	Plerion
	RXJ1713.7-3946*	CANGAROO	SNR
	PKS2155-304*	Durham	AGN (BL Lac)
	1ES1959+650*	Utah7TA	AGN (BL Lac)
Class C	Cas A*	HEGRA CT	SNR
	Cen X-3	Durham	X-ray binary
	1ES2344+514	Whipple	AGN (BL Lac)
	3C66A*	Crimea	AGN

表 1　Trevor Weekes による TeV ガンマ線天体カタログ。天体名に付された*は 2 年前の宇宙線国際会議以降に報告されたもの。

年次計画と外国の計画



建設がスタート

両方認めるらしい。Heidelbergでは4台。
MAGICのため、16 → 減るはず。

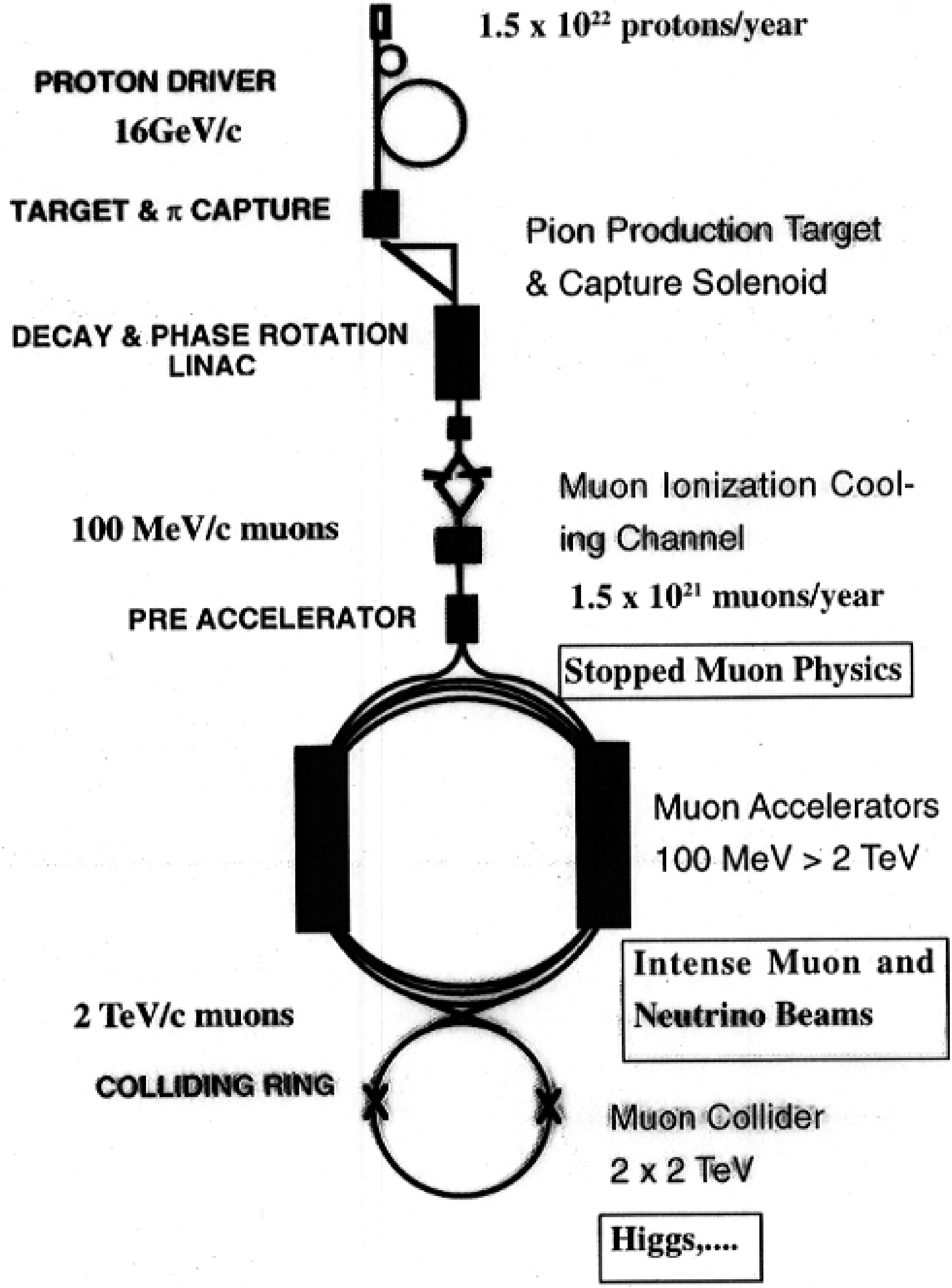
Veritas
2台目の予算

Muon Collider Parameter

muon collider : 4 TeV & 100 GeV (CoM Energy)

CoM Energy (GeV)	4000	100	
Proton energy (GeV)	16	16	
Proton bunch population(10^{13})	2.5	5	
Proton beam power (MW)	4	4	
Repetition Rate (Hz)	15	15	
No. of μ bunches/sign	2	1	
μ bunch population (1012)	2	1	
Collider circu. (m)	8000	260	
Free space l^* at IP (m)	6.5	5	
RMS momentum spread $\Delta p/p$	0.12%	0.12%	0.003%
Normalized emittance ε_n(πmm mrad)	50	85	280
β^* at IP (cm)	0.3	4	13
Bunch length σ_z (cm)	0.3	4	13
RMS beam radius at IP σ_r (mm)	2.8	83	270
Beam-beam tune shift ξ	0.04	0.05	0.015
Luminosity $(nbs)^{-1}$	100	0.12	0.01

MUON COLLIDER COMPLEX



Muon Collider : technical issues

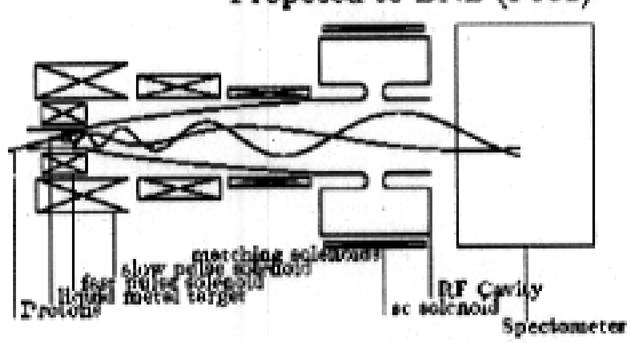
Proton driver

- 15 GeV, 2 x 10^{14} ppp, 15Hz
- short bunch width : $\sigma \sim 1$ nsec

Target, capture & phase rotation

- liquid metal target (Exp at BNL)
- low frequency rf (30 - 90 MHz)
  - >>1 GeV/c pion & muon beams
  - >> high gradient (3-6 MV/m)

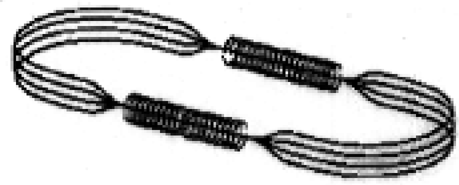
Proposed to BNL (P951)



Cooling

- high frequency rf
  - >> very high gradient (30MV/m)
- high field solenoid (15 T)
- Cooling Exp at FNAL

Acceleration



Energy < few GeV

- Linac (one pass)

Energy > few GeV

- Baseline: reciculating-linac (~10 turns)
- Under study: FFAG's

Energy > 200GeV

- Hybrid Pulsed & SC synchrotron (40 turns)

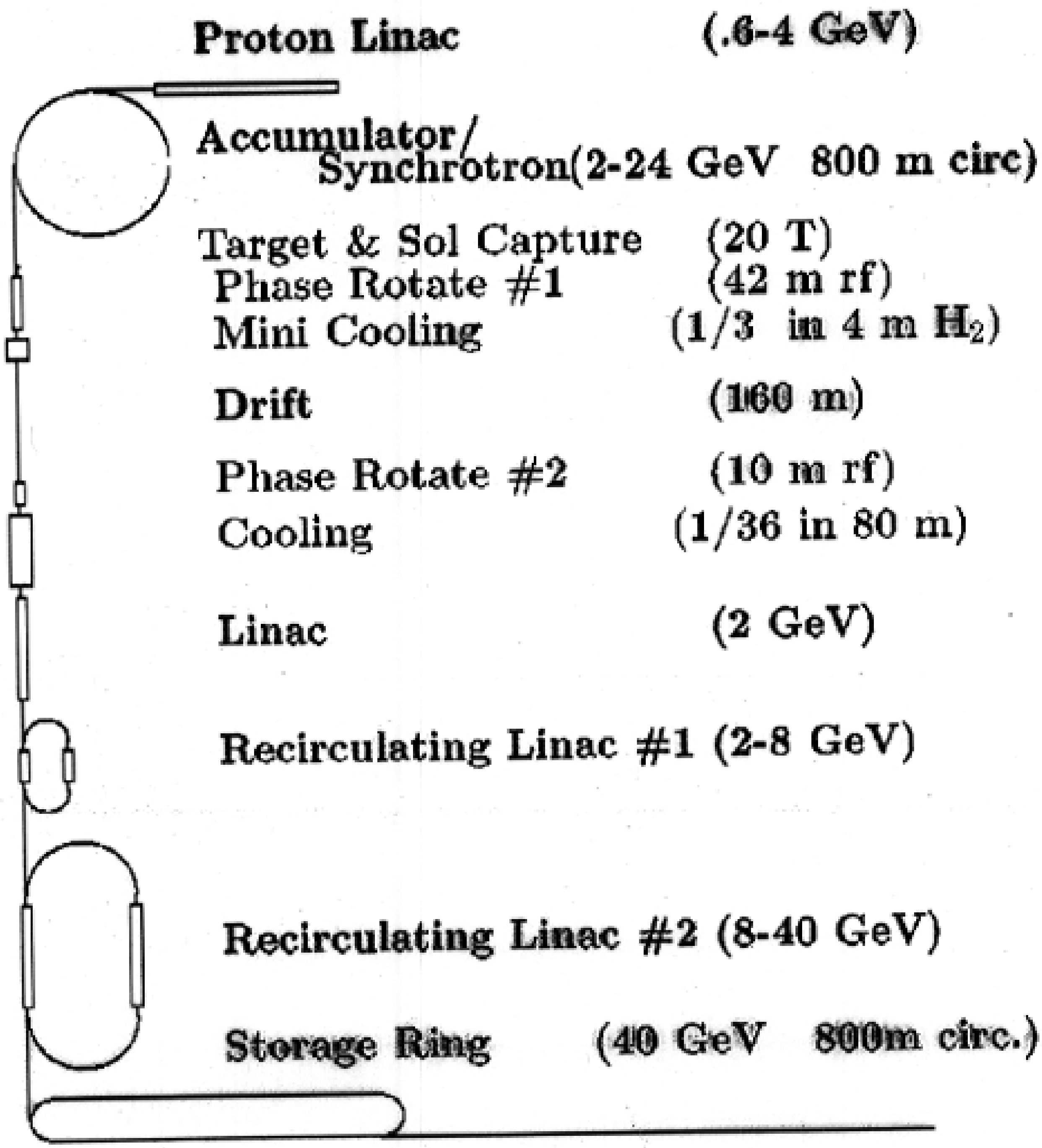
Collider ring

- short bunch
  - >> isochronous ring
  - >> flexibel momentum compaction : FMC lattice
- low beta
- beam shield
  - >> 6cm(tungsten) @ 3 TeV

Radiation : neutrino shield

- radiation ∞ $E^3/depth$: Limit = 10 mR/year
- Neligible at 1.5 GeV ~ 1 mR/year
- 300m depth at 3 TeV ~ 10 mR/year
- E > 3 TeV
  - >> beam wobbles
  - >> special locations
  - >> better cooling

Neutrino Factory



Neutrino Factory in Japan

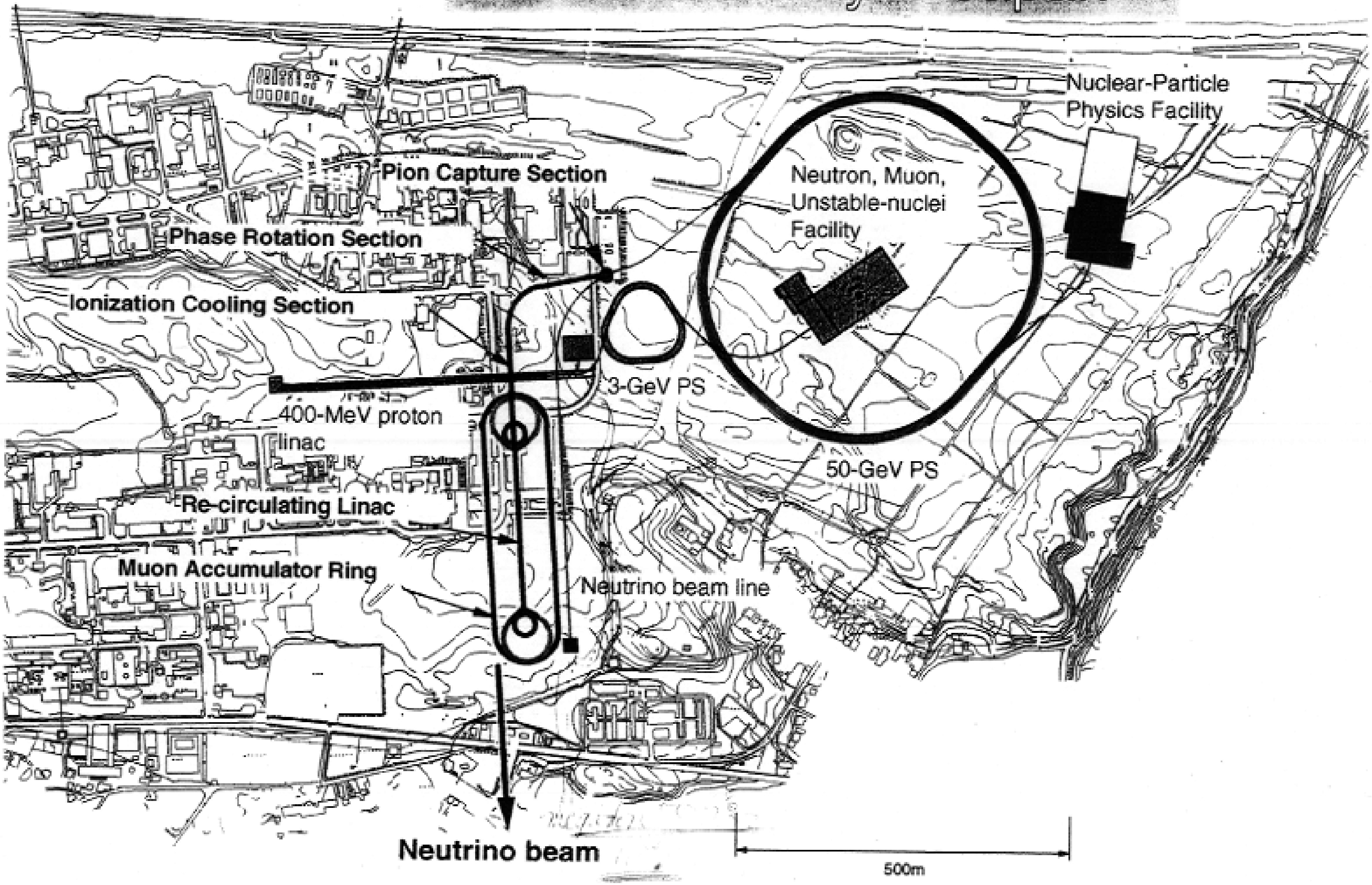
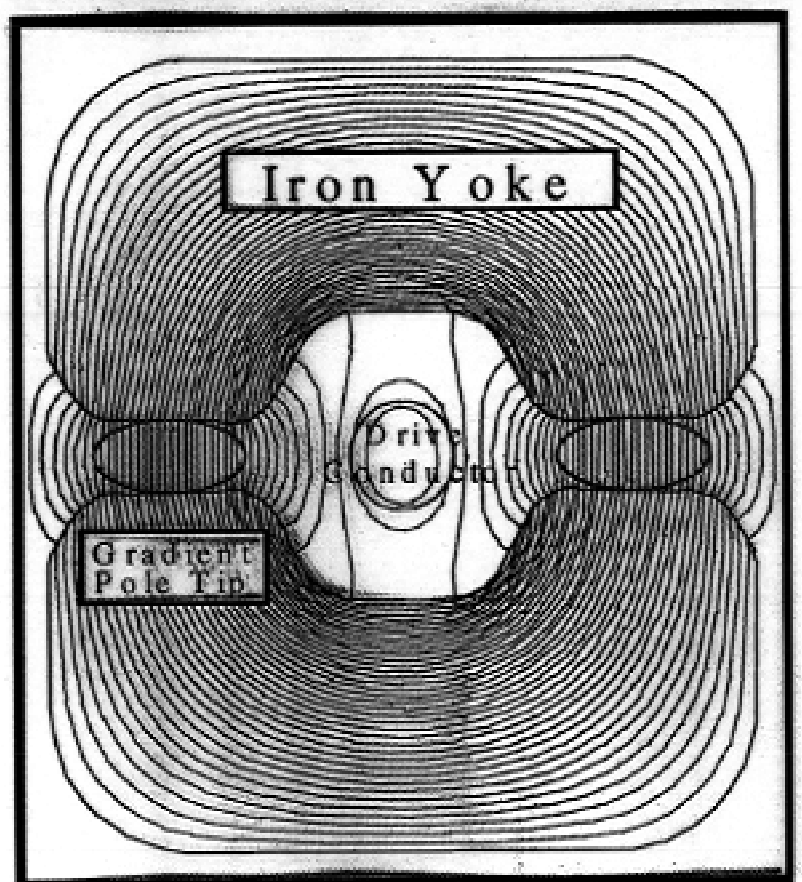


Table I : Machine parameters

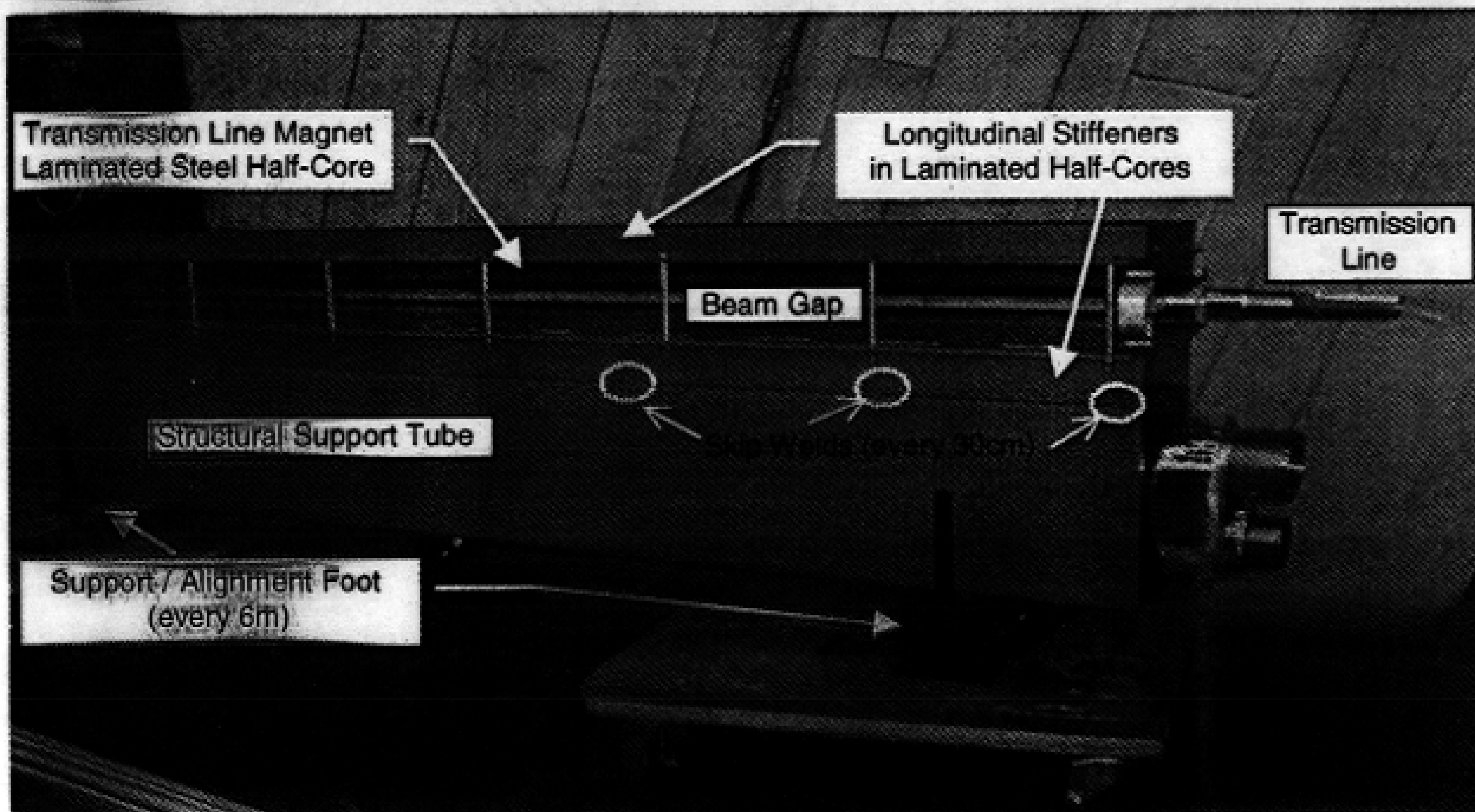
Parameter	High field-new technology	High field-known technology	Low Field	Units
CM Energy	100	100	100	TeV
Dipole field	12.6	9.5	1.8	T
Circumference	104	138	646	km
Synchrotron radiation damping time (horizontal amplitude)	2.6	4.6	*antidamped*	hr
Initial/peak luminosity	.35/1.2	.35/1.0	1./1.	10^{34} cm^{-2}sec^{-1}
Integrated luminosity per day	500	500	700	pb^{-1}
Number of stores per day	2	2	1	
Initial rms normalized emittance	1.	1.	1.	π μm-rad
β^*	20	20	20	cm
Protons/bunch	0.5	0.5	0.94	10^{10}
Number of bunches	20794	27522	129240	
Equilibrium emittance (x)	144.2	62	1.8	10^{-3} π μm-rad
Bunch spacing	16.7	16.7	16.7	nsec
Beam stored energy	.89	1.18	9.73	GJ
Synchrotron radiation power/ring	189	143	48	kW
Total protons/ring	1.1	1.5	12.2	10^{14}
Initial/peak interactions/crossing	7.5/21.5	7.5/21.5	21.5/21.5	
Beam lifetime (pp collisions only)	34	45	130	hr
$\sigma_{inelastic}$	130	130	130	mbarn
Initial beam-beam $\Delta\nu$ (total)	5.1	5.1	11.6	10^{-3}
Revolution frequency	2.89	2.18	.46	kHz
Synchrotron frequency	8.9	5.8	.86	Hz
Rf Voltage	100	100	100	MV
Radio-frequency	360	360	360	MHz
Energy loss/turn	3678	2778	526	keV
Rms relative energy spread(collision)	15.6	18.0	39.0	10^{-6}
Fill time	16.3	16.3	28	min.
Acceleration time	5.8	7.6	35.9	min.
Total time: fill and accelerate	22.1	24	63.9	min.
Longitudinal impedance threshold: $\frac{Z_{\parallel}}{n}$(collision)	3.6	2.7	1.1	Ω
Transverse impedance threshold: $Z_{\perp}$(injection)	731	635	250	MΩ/m
Resistive-wall transverse impedance: $Z_{RW}(\frac{c}{\sigma_z})$ (injection)	0.4	0.5	98	MΩ/m
Resistive-wall multibunch instability growth time	472	310	.36	turns
Total current	.05	.05	.09	Amp
Peak current(inj)	3.6	3.6	4.2	Amp
<β>	255	255	382	m
Tune	65	86	269	
Half cell length (assumed 90°cells)	200	200	300	m
Beam pipe radius	1.65	1.65	1.0	cm
Beam pipe	Cold, Cu	Cold, Cu	Warm, Al	

“Double-C” Iron Yoke



- 80-100kA current drives two beam apertures.
- Gradient Pole tips provide bend and focussing (no quads).
- Iron shapes field: superconductor position not critical.
- Iron Yoke is ~2/3 of magnet cost.

Components of the Transmission Line Magnet



Conclusion

1. We have quite an active field with lots of interesting and promising on-going projects and many ambitious new ideas and R/D efforts for future projects. There is a huge amount of knowledge still to be cultivated before we can claim that we understand nature.

2. Nevertheless, the public support for our field is not as strong as we wish it to be. We need to make our utmost efforts to earn it.

3. The role of ICFA is rather limited as is typical of all the international organizations, including even the U.N..

See you in three years in ________!!