Dave B. Cline

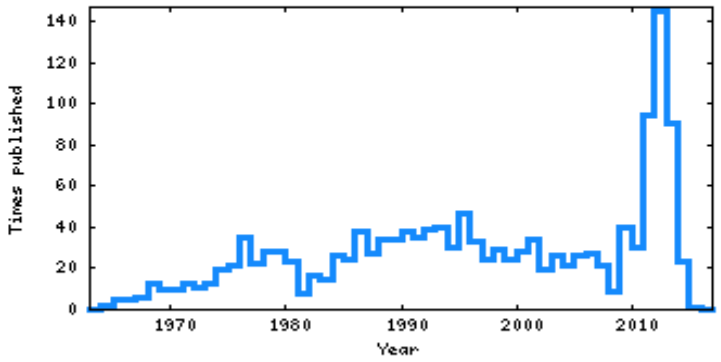
From Solar Neutrinos to the Higgs Boson –
Accompanying Dave as a Physicist, Colleague and Friend

Thomas Müller, KIT

UCLA, Feb. 21, 2016

DAVE AS A SCIENTIST

CMS (347)
UA1 (64)
ICARUS (22)
CDF (16)
XENON100 (8)
SDC (7)
E771 (6)
E-771 (5)
RD5 (4)
HPW (3)
less
JEM-EUSO (3)
LBNE (3)
Neutrino Factory and Muon Collider (3)
Optical Trigger (3)
Fiber Tracking Group (2)
Harvard-Purdue-Wisconsin (2)
NOE (2)
NOvA (2)
Plasma Lens (2)
Berkeley-CERN-Hawaii-Wisconsin (1)
CAPTAIN (1)
DarkSide (1)
E789 (1)
E853 (1)
EUSO (1)
FERMILAB-HARVARD-OHIO STATE-PENNSYLVANIA-RUTGERS-WISCONSIN (1)
HPWFOR (1)
HPWFR Group (1)
ICANOE (1)
ICARUS-Milano (1)
less
IDS-NF (1)
MICE (1)
P865 (1)
Quark Flavor Physics Working Group (1)
REX-ISOLDE (1)
SFT (1)
Solenoidal Detector (1)
SPLIT (1)
TOTEM (1)
XENON (1)



Subject Categories

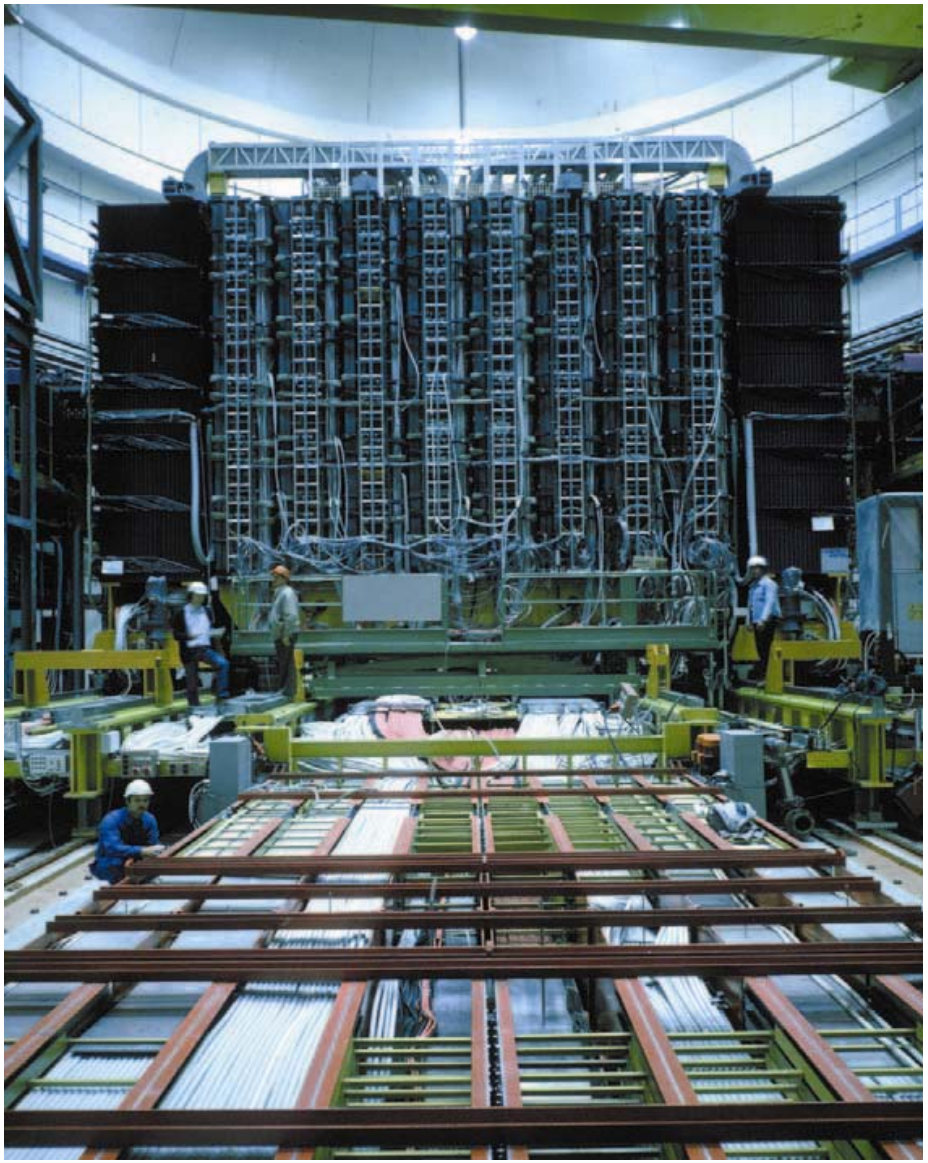
Experiment-HEP (582)
Instrumentation (204)
Accelerators (197)
Astrophysics (154)
Experiment-Nucl (112)
Phenomenology-HEP (62)
Theory-Nucl (18)
Gravitation and Cosmology (10)
General Physics (5)
Computing (2)
less
Theory-HEP (2)
Lattice (1)
Other (1)

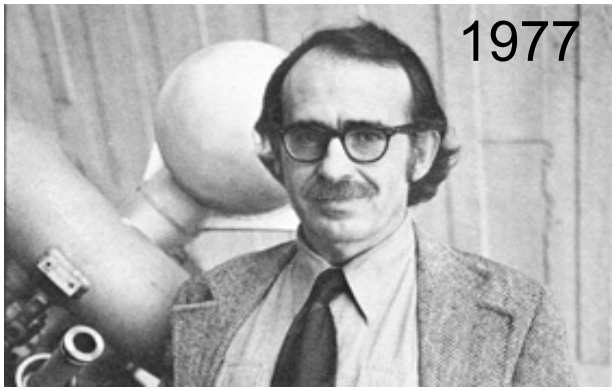
UCLA (840)
Wisconsin U., Madison (266)
Rochester U. (58)
Fermilab (46)
CERN (32)
Harvard U. (22)
Pennsylvania U. (11)
Purdue U. (9)
SLAC (7)
Brookhaven (5)
less
Hawaii U. (5)
Particle Beam Lasers, Northridge (5)
Wisconsin U. (3)
LBL, Berkeley (3)
Turin, Cosmo-Geofisica Lab (3)
Fudan U. (2)
INFN, Pisa (2)
Argonne (1)
Colorado U. (1)
Liverpool U. (1)
Granada U. (1)
Washington U., Seattle (1)
ICTP, Trieste (1)
Particle Beam Lasers, Madison (1)
Yale U. (1)
Frascati (1)
UC, Berkeley (1)
INFN, Trieste (1)
Southern California U. (1)
Cal State, L.A. (1)
less
Rutherford (1)
Clark U. (1)
Daresbury (1)
Texas A-M (1)
LLNL, Livermore (1)
California U., Los Angeles (1)
Vanderbilt U. (1)
Tennessee U. (1)
Illinois U., Urbana (1)
MUONS Inc., Batavia (1)
Michigan U. (1)
Stanford U., Phys. Dept. (1)
Paris, IN2P3 (1)

UA1

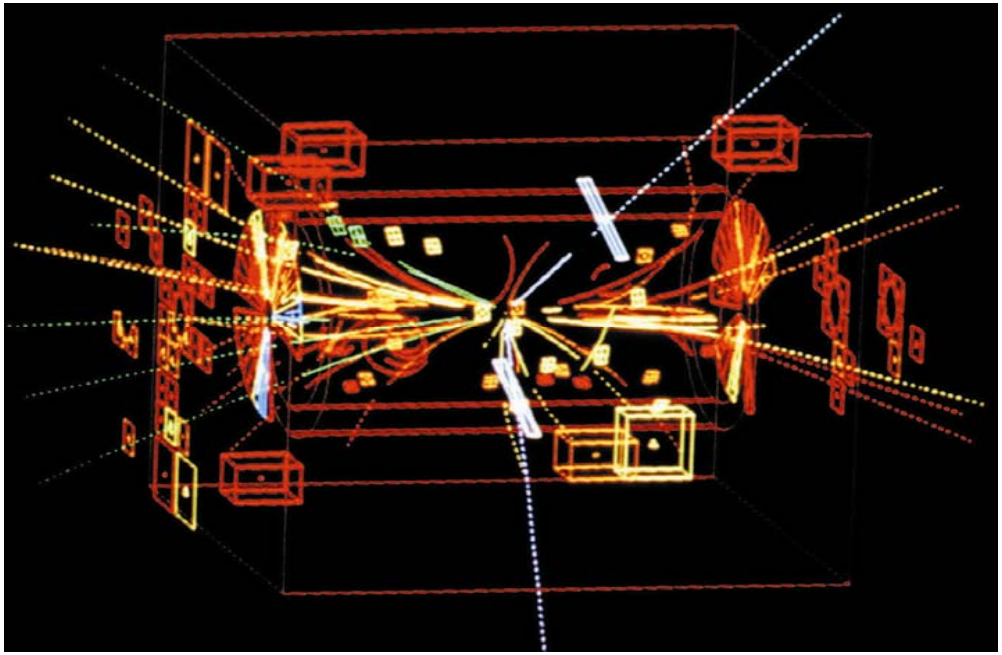
THE FIRST DISCOVERY MACHINE

UA1 AT THE CERN $P\bar{P}$ COLLIDER

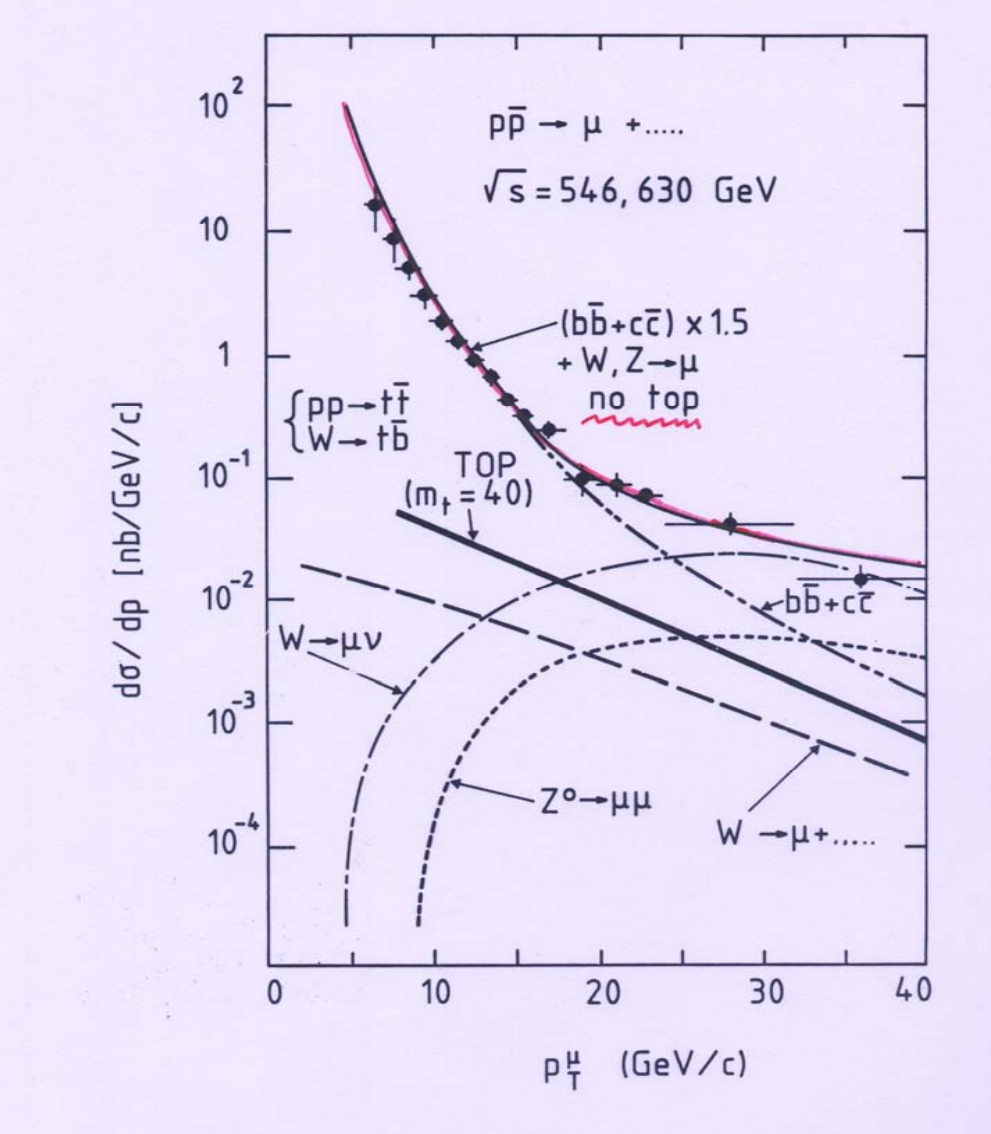




DISCOVERY OF THE Z BOSON

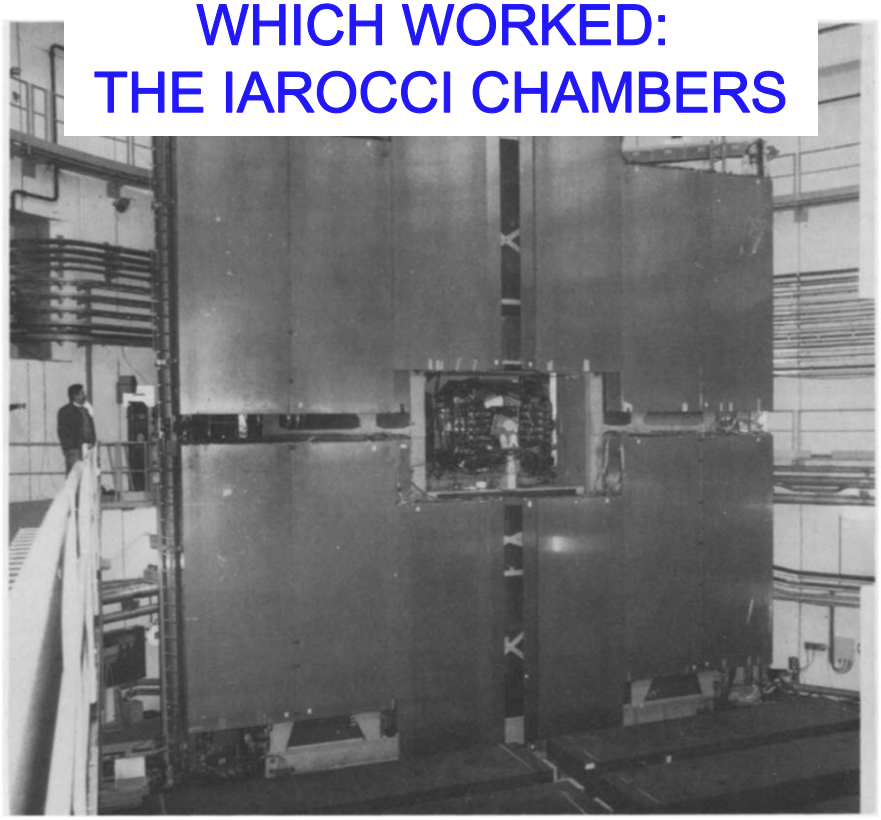


MUONS ARE THE KEY TO NEW PHYSICS

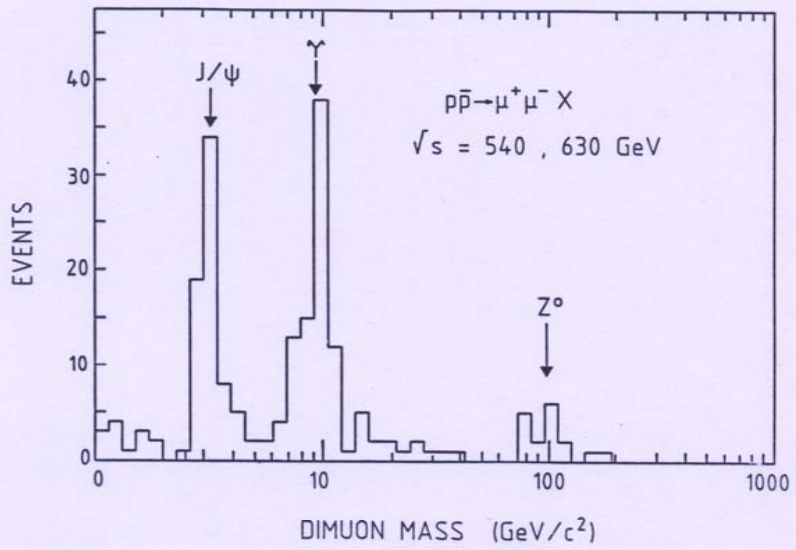


- B PHYSICS
- W, Z PHYSICS
- SEARCH FOR TOP QUARKS
- FOURTH GENERATION

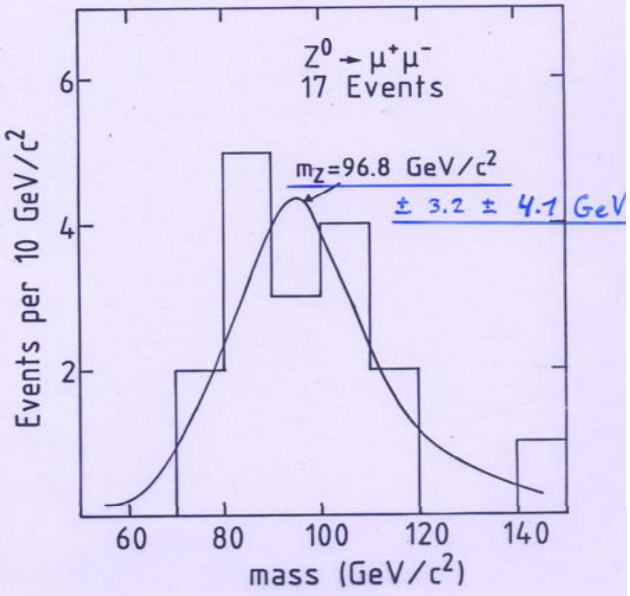
THE ONLY UA1 UPGRADE
WHICH WORKED:
THE IAROCCI CHAMBERS



$Z^0 \to \mu^+\mu^-$



Untergrund:
< 1.1 Ereignisse



DAVE's INTEREST: EWK FITS

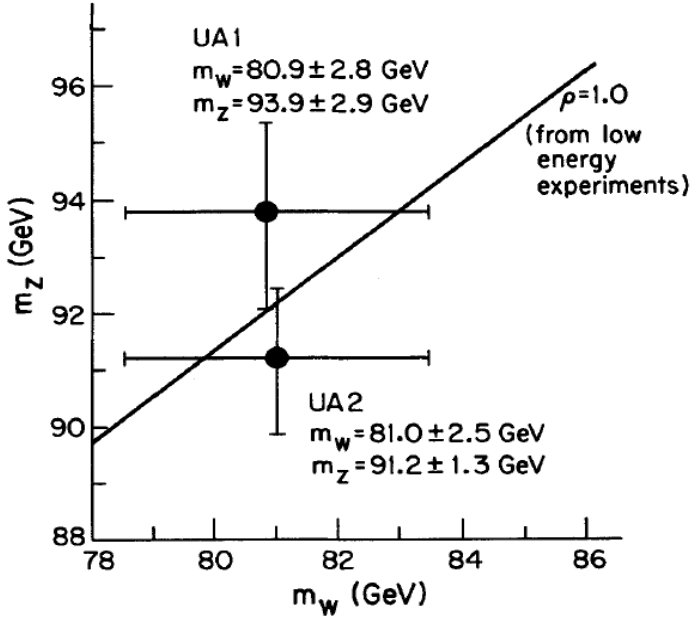
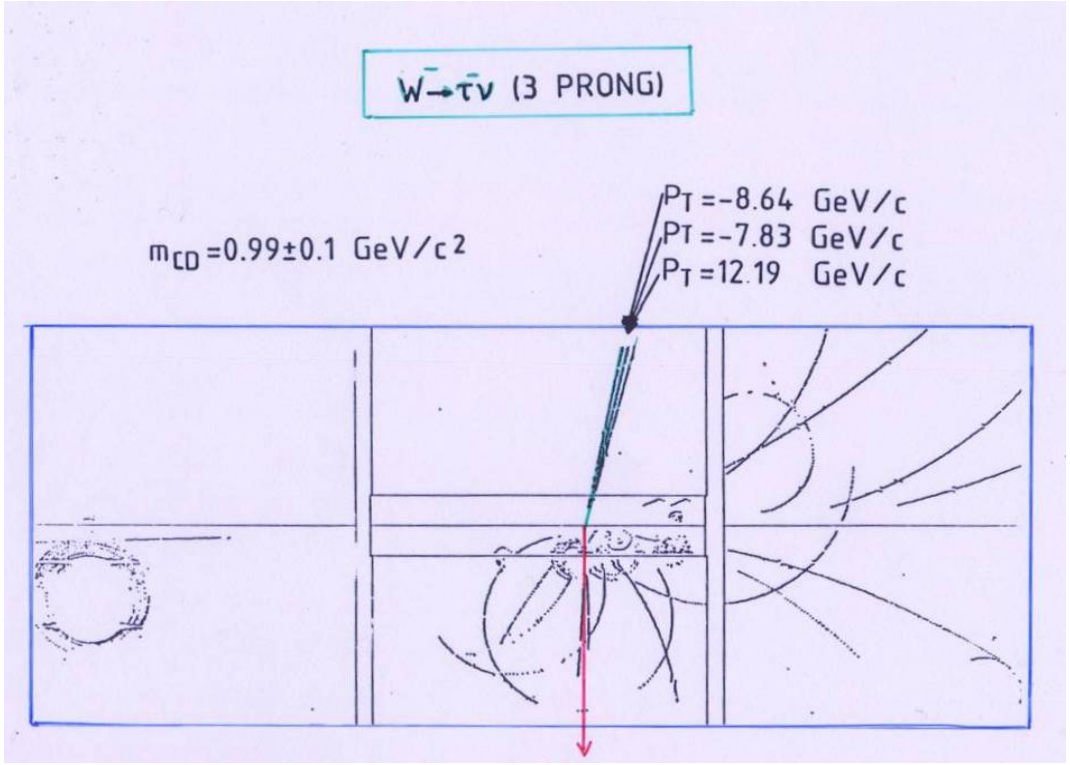


FIGURE 1. A comparison of the M_Z and M_W as measured by the UA1 and UA2 groups.

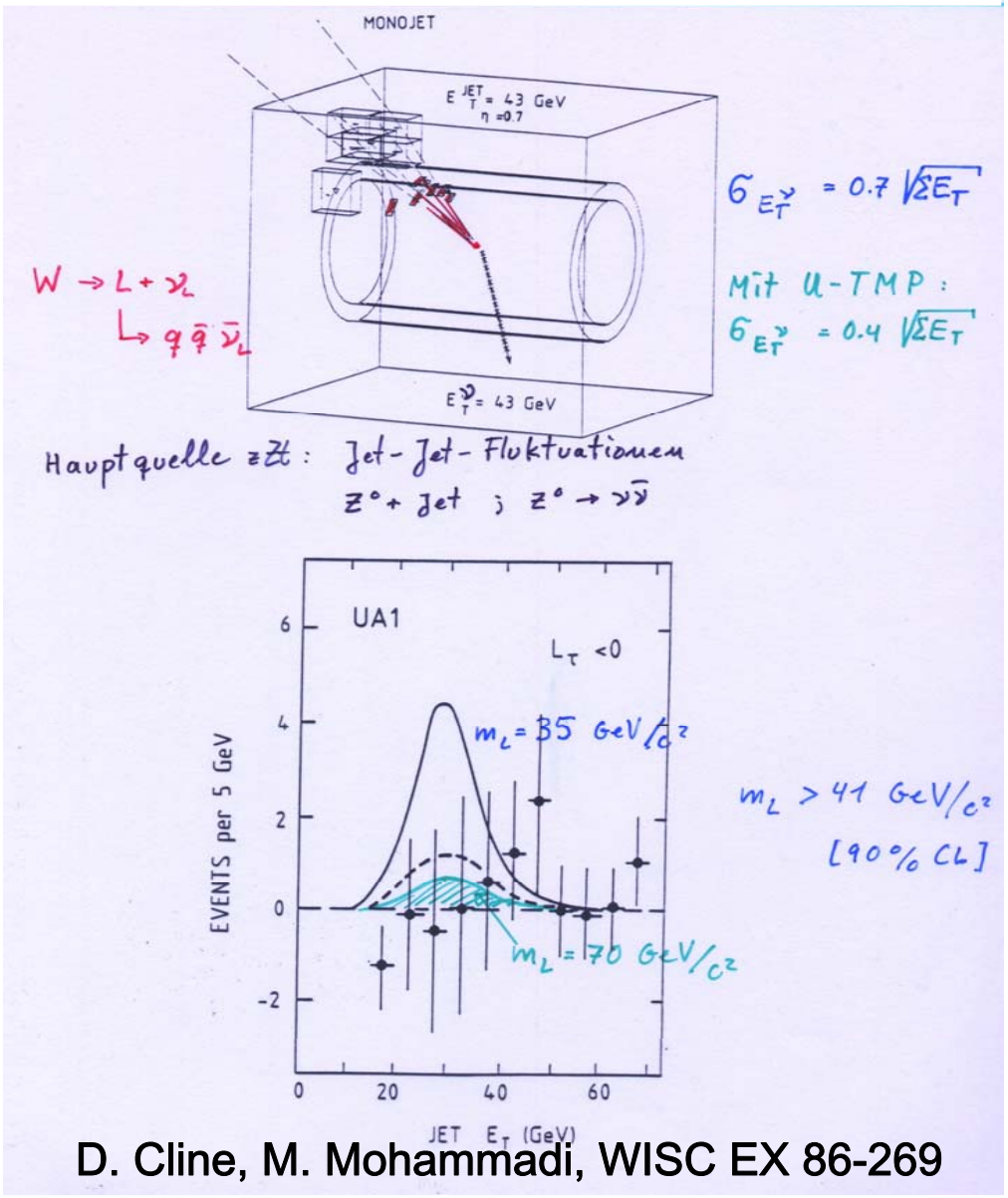
ADDING JETS AND MISSING ENERGY

DISCOVERY OF W DECAY INTO TAU



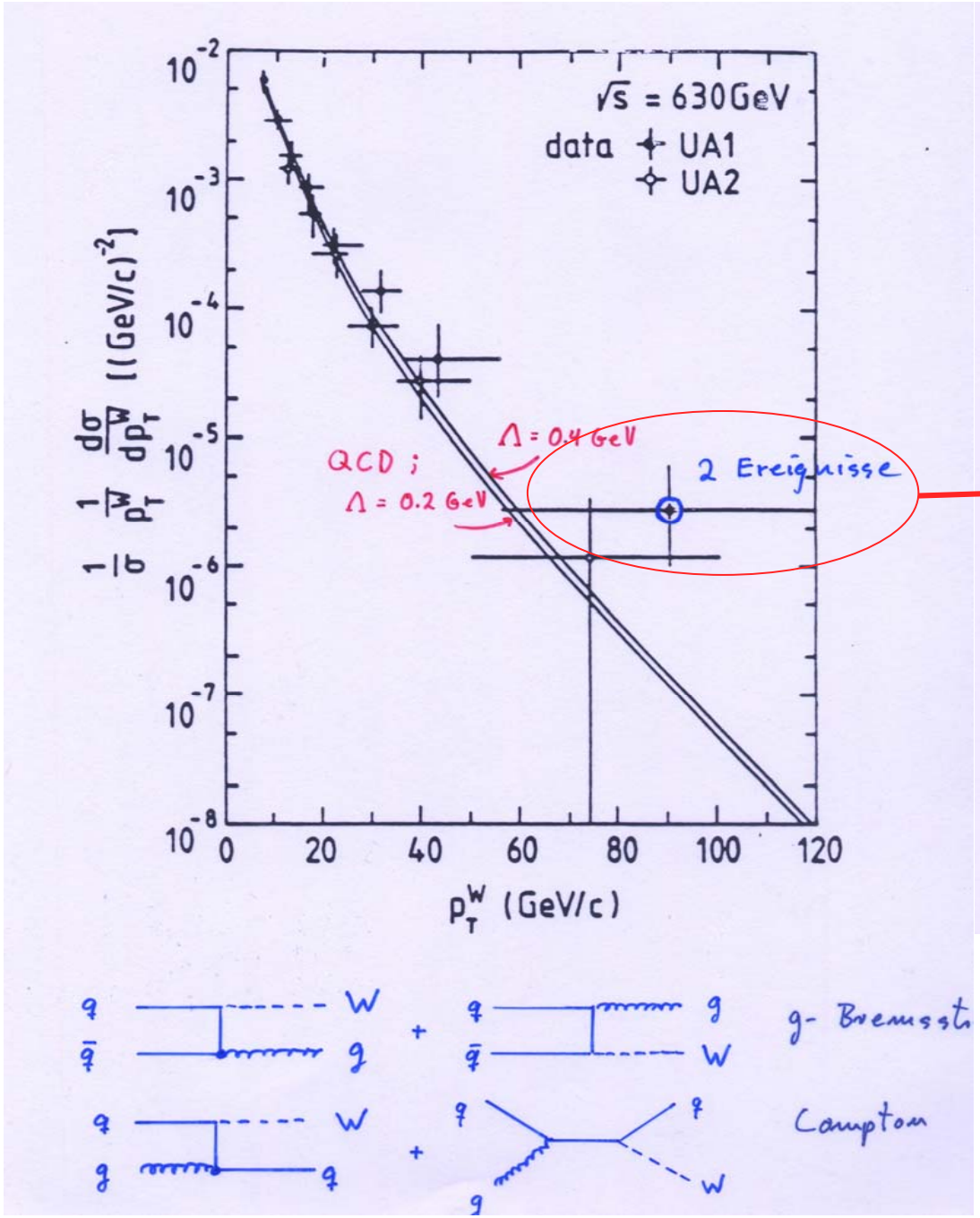
The tau neutrino found in 1985 !

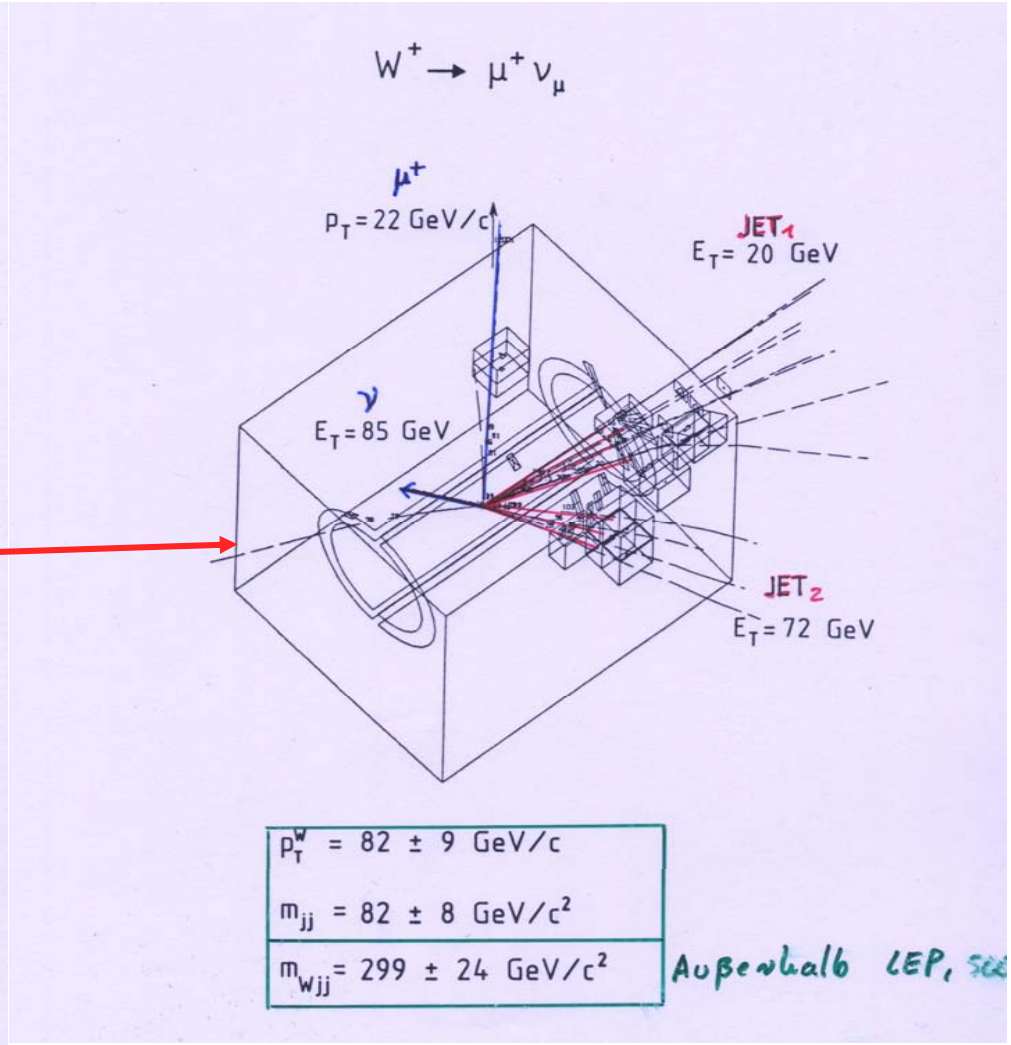
SEARCH FOR THE FOURTH FAMILY



D. Cline, M. Mohammadi, WISC EX 86-269

SEARCH FOR EXOTIC W PRODUCTION





SPECULATION:
300 GEV HIGGS->WW

RARE B DECAYS AND THE TOP

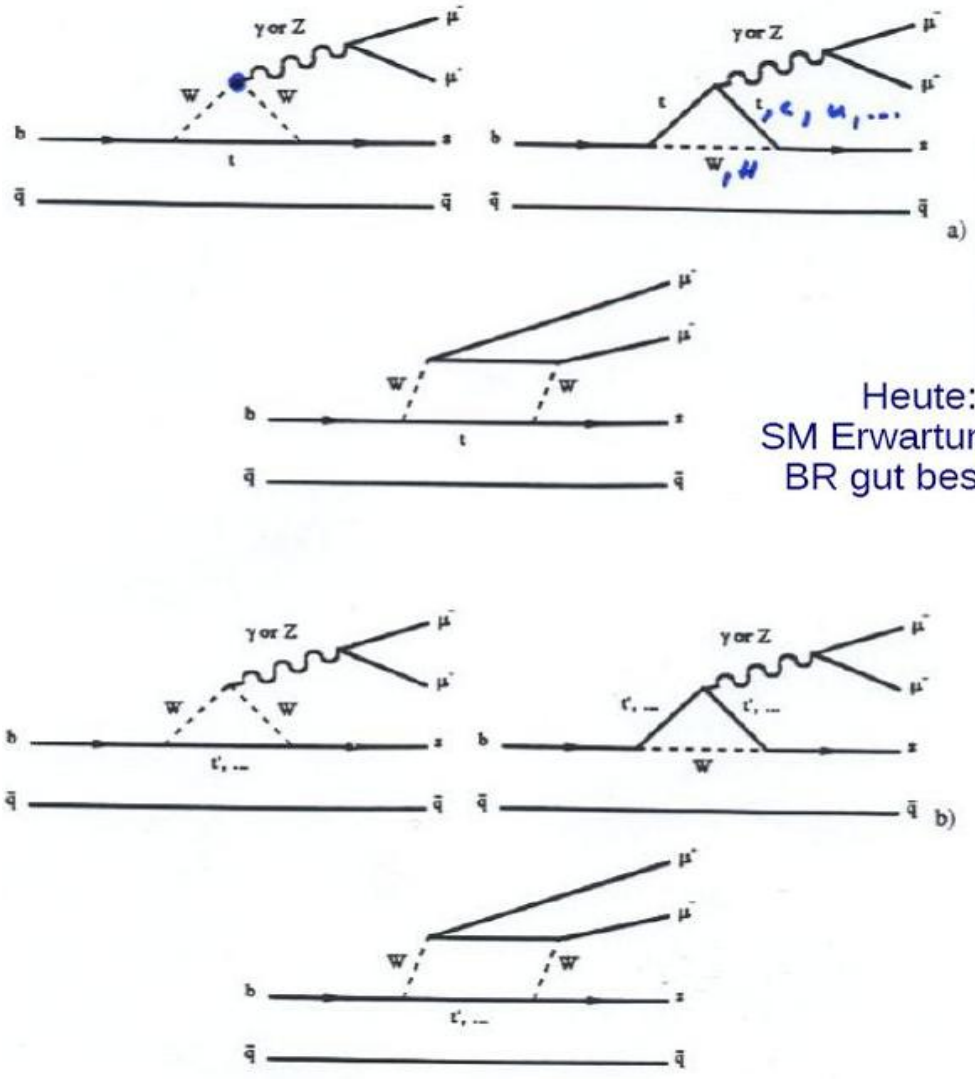


Figure 2.10: Penguin diagrams giving dominant contributions to the transitions $B \to \mu^+\mu^- X$ and $B_d \to \mu^+\mu^- K^{0*}$ a) in the Standard Model, b) in the case of four or

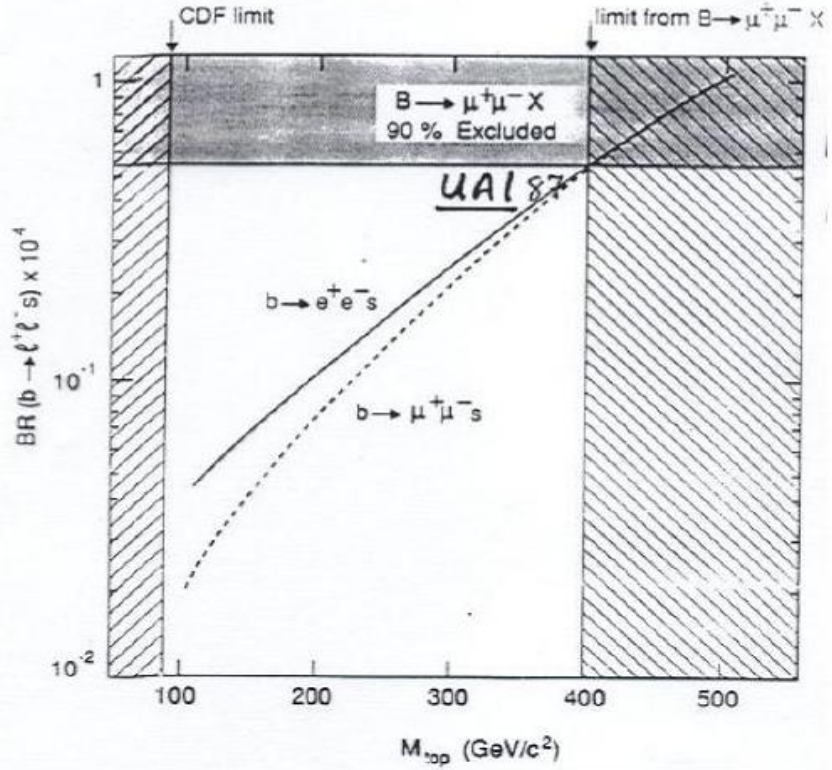
For $m_t = \infty \Rightarrow$ BR (B -> μμX) = 0.12 % !

$(m_{\mu\mu} \neq m_{\psi,\psi'}$ ...

dh. keine Resonanzen

≈ 0

Heute:
SM Erwartung der
BR gut bestätigt



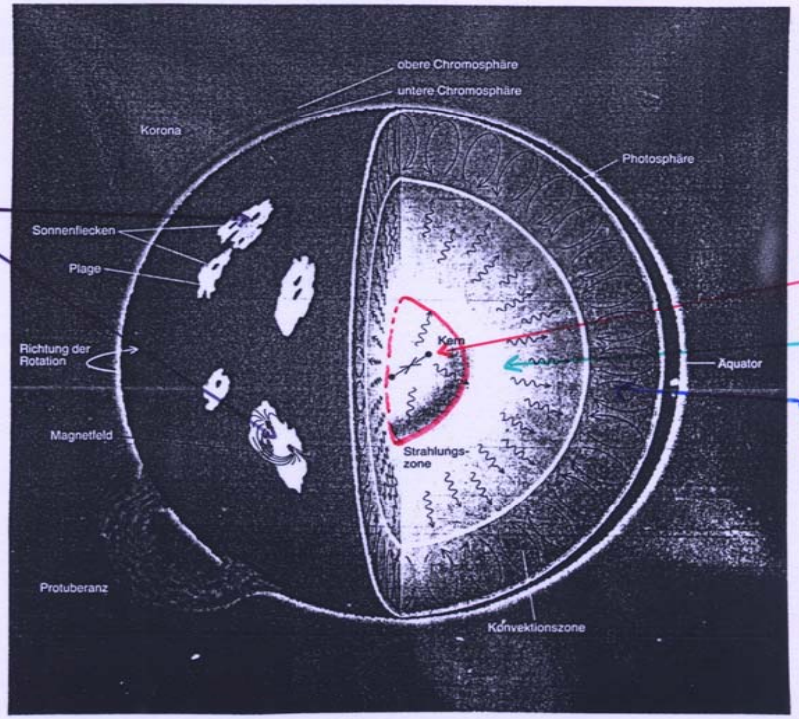
MTOP < 400 GEV !

ICARUS

SOLAR NEUTRINOS AND PROTON DECAY

ICARUS I: SOLAR NEUTRINOS …

THE STRUCTURE OF THE SUN



Sun spots with magnetic field

Nuclea

Radiati

Convec zone

IN GENERAL :

Nuclear fusion in the centre

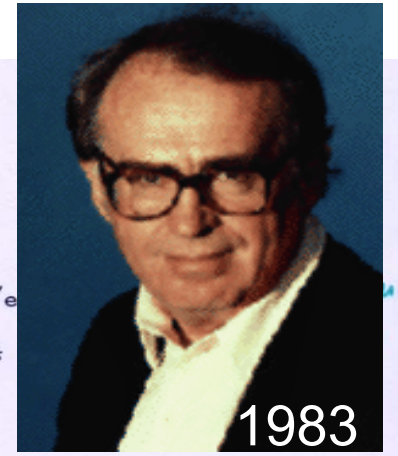
T_{cent}	15500000° C
Pressure	10^{11} atm
Density	150 g/cm^3

Every second :

Transformation of 700 M tons hydrogen into Helium

Loss of mass through radiation : 4.3 M tons.

Transport of energy through radiation and convection



FUSION PROCESSES IN THE SUN

1. PROTON-PROTON - CYCLE (98.5 %)

$p+p \rightarrow D+e^+ + \nu_e$ (99.75 %)

$p+e^- + p \rightarrow D + \nu_e$ (0.25 %)

$D+p \rightarrow {}^3He+\gamma$

$^3He+{}^3He \rightarrow {}^4He+2p$

p-p I (~87 %)

$^3He+{}^4He \rightarrow {}^7Be+\gamma$

$^7Be+e^- \rightarrow {}^7Li+\nu_e$

$^7Li+p \rightarrow 2\,{}^4He$

p-p II (~13 %)

$^7Be+p \rightarrow {}^8B+\gamma$

$^8B \rightarrow {}^8Be^* + e^+ + \nu_e$

$^8Be^* \rightarrow 2\,{}^4He$

p-p III (~ 0.017 %)

^8B neutrin

1.5 … 15 Me

Balance : 4 p -> ^4He + 2 e^+ + 2 ν_e + 26.2 MeV

Published 1987 Talmud mtg Book

WISC-EX-86-283
July, 1986

ON THE MEASUREMENT OF THE MAGNETIC MOMENT OF THE NEUTRINO

DAVID B. CLINE

Department of Physics University of Wisconsin–Madison Madison, WI 53706

ABSTRACT

The existence of a large magnetic moment of the neutrino ($\mu > 10^{-11}\mu_B, \mu_B = e/2m_e$) would have profound implications for theories of elementary particles that may include either composite mass, super symmetry or left–right symmetry. We show how a magnetic moment could be detected using ^8B solar neutrinos and the ICARUS detector or using very low energy neutrino sources and novel detectors operating below 1 MeV energy deposit. We show that a low energy threshold detector operating at a pulsed neutrino source can be used to search for $\mu_\nu \leq 10^{-11}\mu_B$ in the next few years.

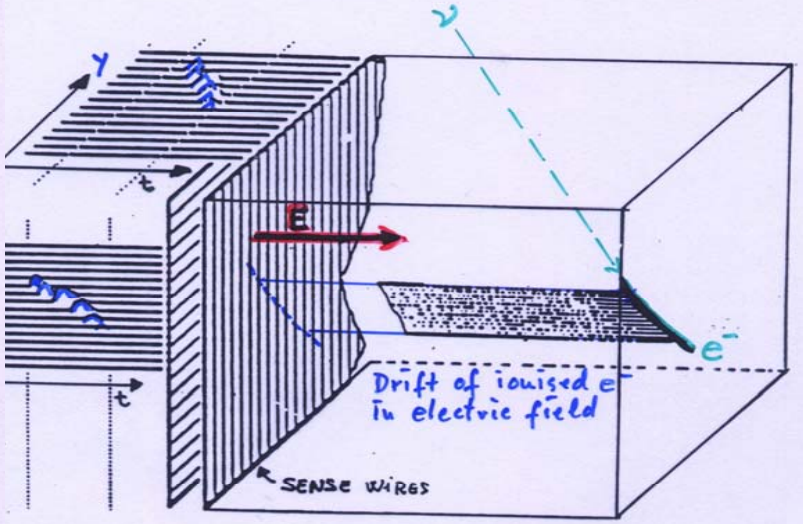
… WITH A LIQUID ARGON TPC

- **PRINCIPLE :** Electronic track reconstruction of the recoil electrons / of charged particles

Three-dimensional image of the event

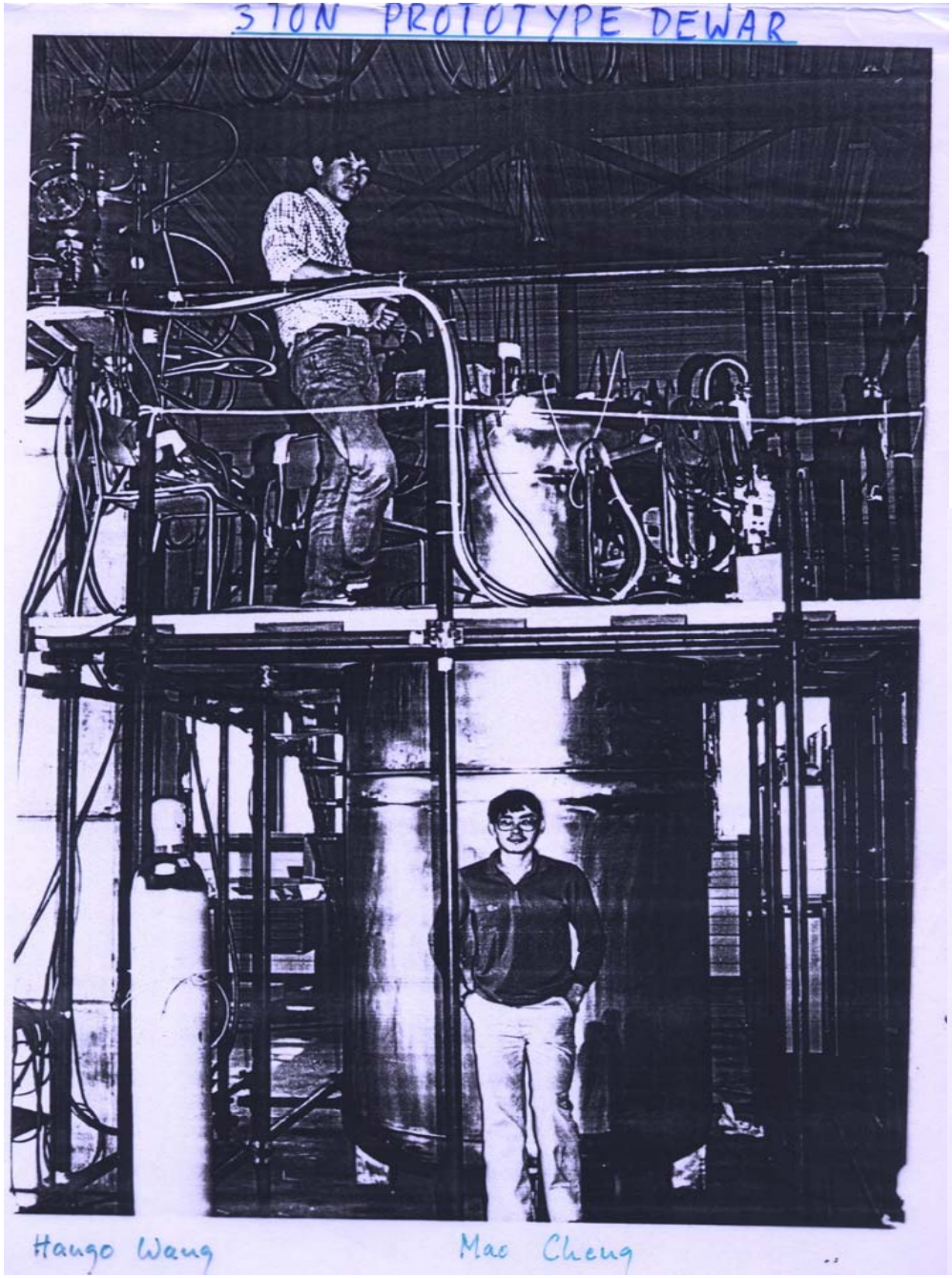
Determination of energy and direction of the e^- / γ (μ, $K^\pm$, $\pi^\pm$)

Real time event recording

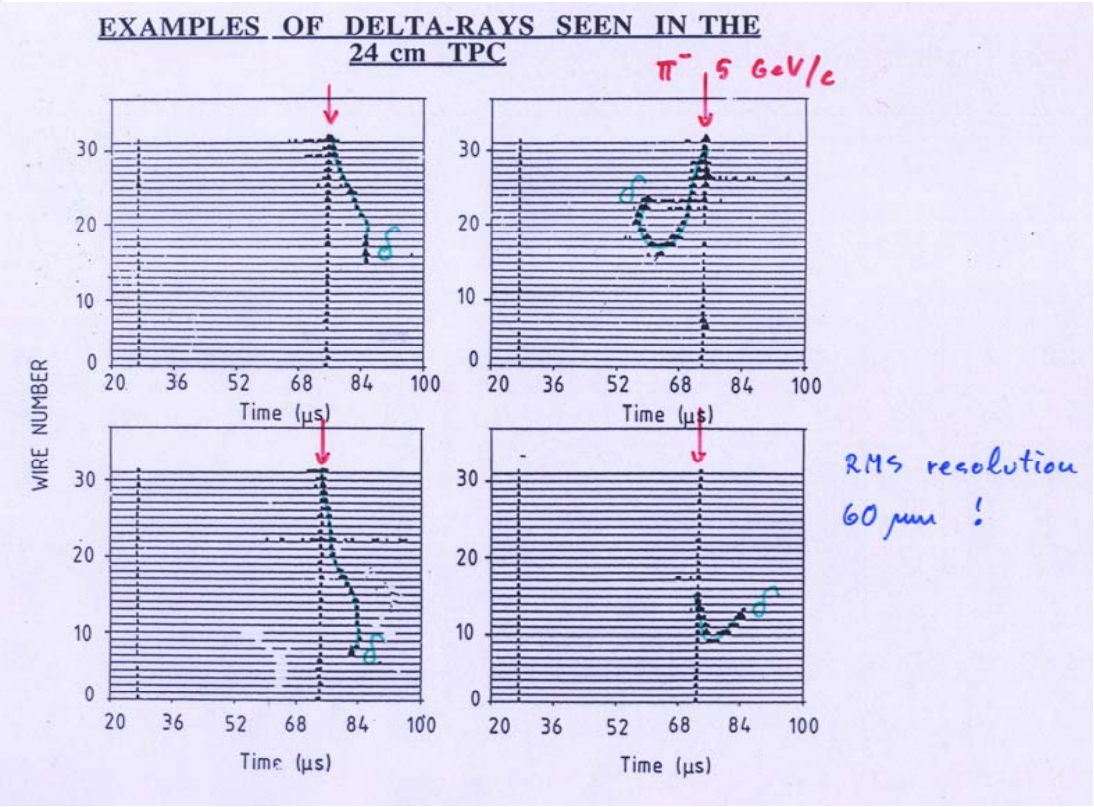


VERY HIGH TECHNICAL REQUIREMENTS :

- Small signals : 7000 e^- / wire (1 fCb)
- Extreme purity of the Argon : $< 10^{-10}$ (0.1 ppb)
- High information density : 140 Mbyte / event



THE PROOF OF PRINCIPLE: DELTA RAYS IN AN ICARUS PROTOTYPE



Proposal

to

The United States Department of Energy

In Support of: Construction of a Liquid Argon Purification System
for the Solar Neutrino Detector ICARUS I
and Its 3 Ton Prototype

For the Period: January 1, 1990 to December 31, 1990

In the Amount: $406,000

Task Manager: Thomas Müller

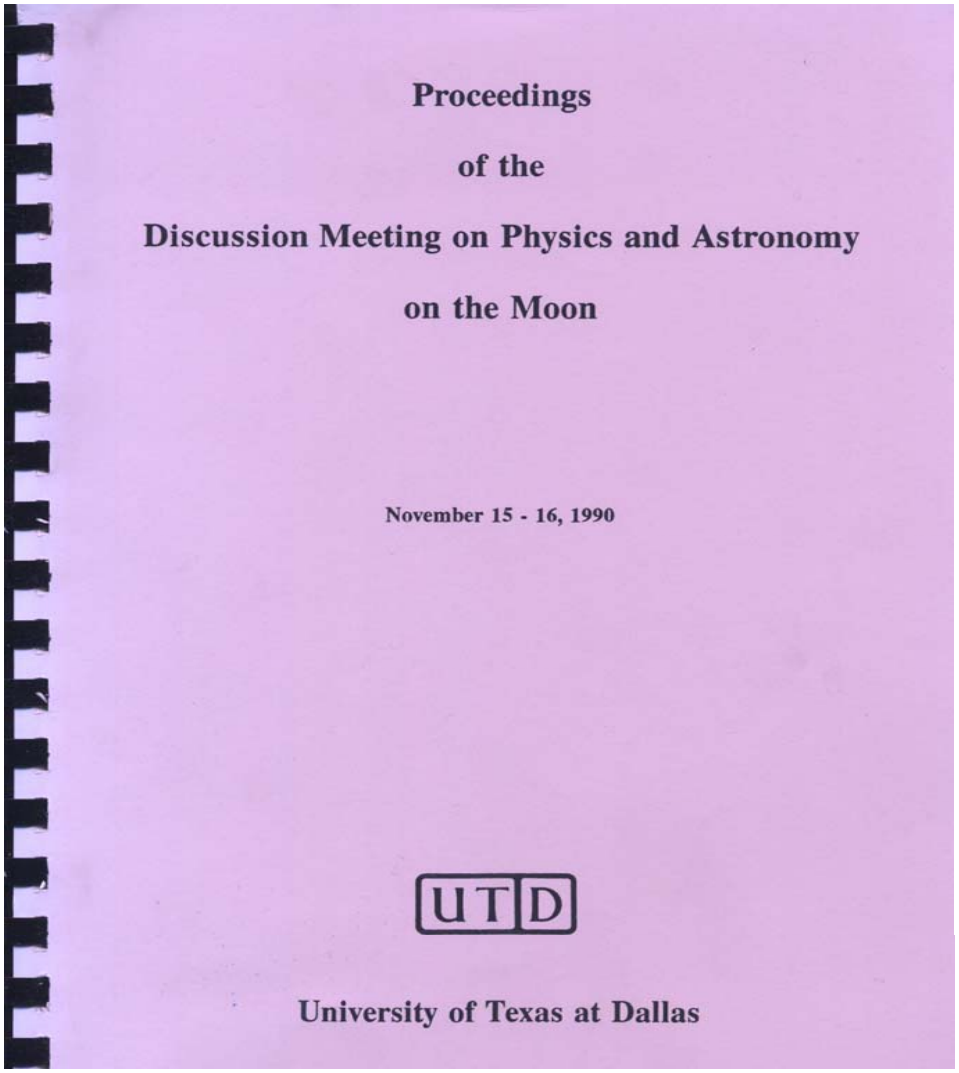
Institution: The Regents of the University of California
Department of Physics
University of California, Los Angeles
405 Hilgard Avenue
Los Angeles, California 90024-1547

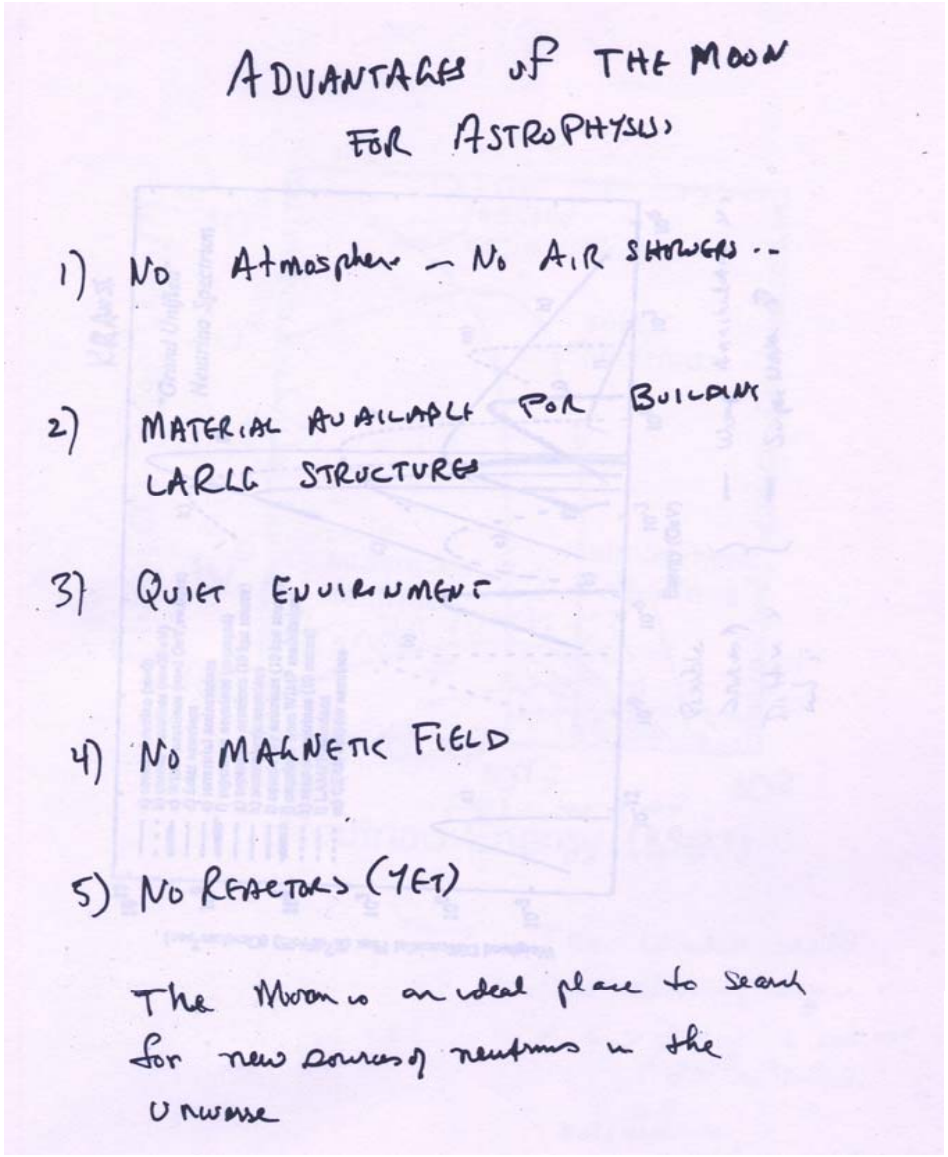
Thomas Müller Task Manager	William Slater, Vice-Chairman Department of Physics
Elisabeth Johnson ~~Assistant Director~~ Contract & Grant Officer	Date

MONACO

A LUNAR(TIC) IDEA

NEUTRINO PHYSICS ON THE MOON





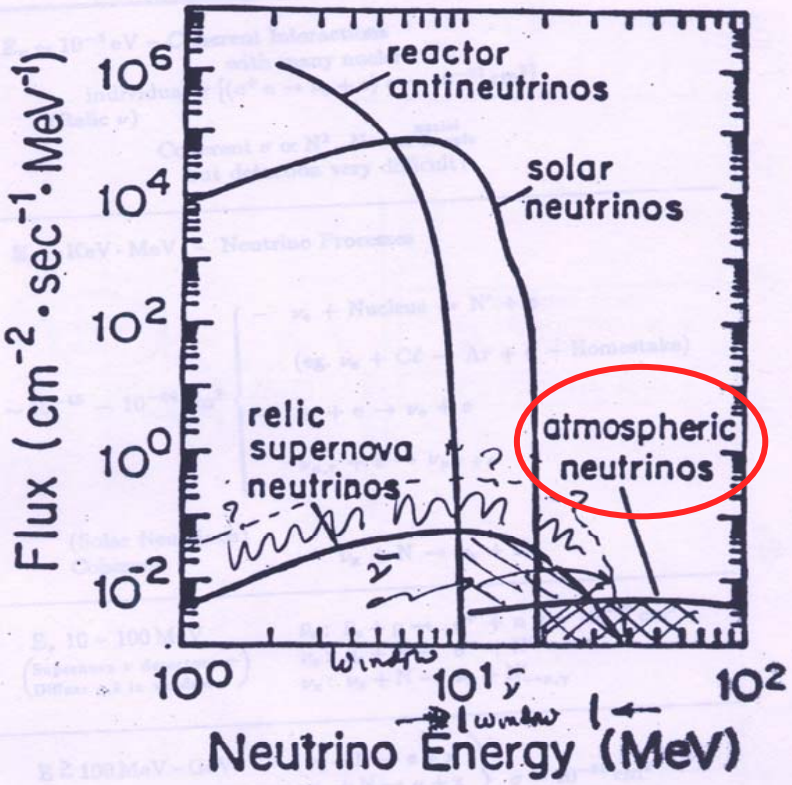


Fig. 2a

The Window would allow detection of diffuse ν with $E_\nu > 1.8$ MeV < 100 ν
F ~~$\times 10^{-3}$~~ $cm^{-2}\,sec^{-1}\,MeV^{-1}$
and
Anti neutrinos
$E_\nu > 10$ MeV < 10
$E > 5 \times 10^{-3}$

DETECTION OF NEUTRINO EMISSION FROM A PRIMORDIAL BLACK HOLE EVAPORATION

(DRAFT)

DAVID CLINE, W. P. HONG
Department of Physics, University of California at Los Angeles
405 Hilgard Avenue, Los Angeles, California 90024-1547

ABSTRACT

The diffuse number spectrum of neutrinos emmitted from primordial black holes is calculated. We calculate PBHs contribution to the closure density of the universe. A detection of neutrinos from the final stage of PBHs evaporation is discused.

THE DETECTOR ON THE MOON

Thomas Müller

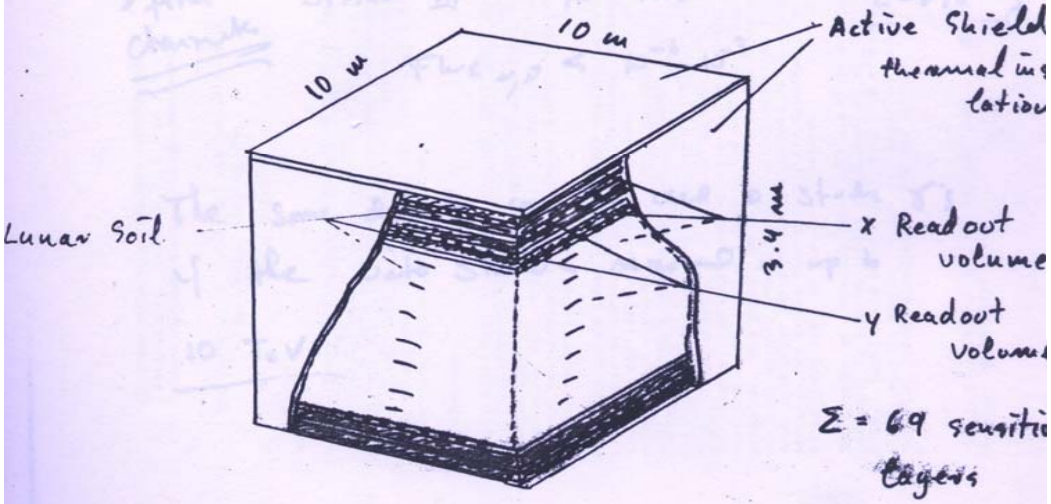
MONACO

Moon Observatory for Neutrinos And Cosmics

Speculations about the possible construction of a 1000 ton detector for ν, other cosmic rays with $E \gtrsim 500$ MeV on the Moon

Principle: Fine grained calorimeter using lunar soil as absorber, sandwiched with sensitive medium imported from Earth. → Nusex, Kolar

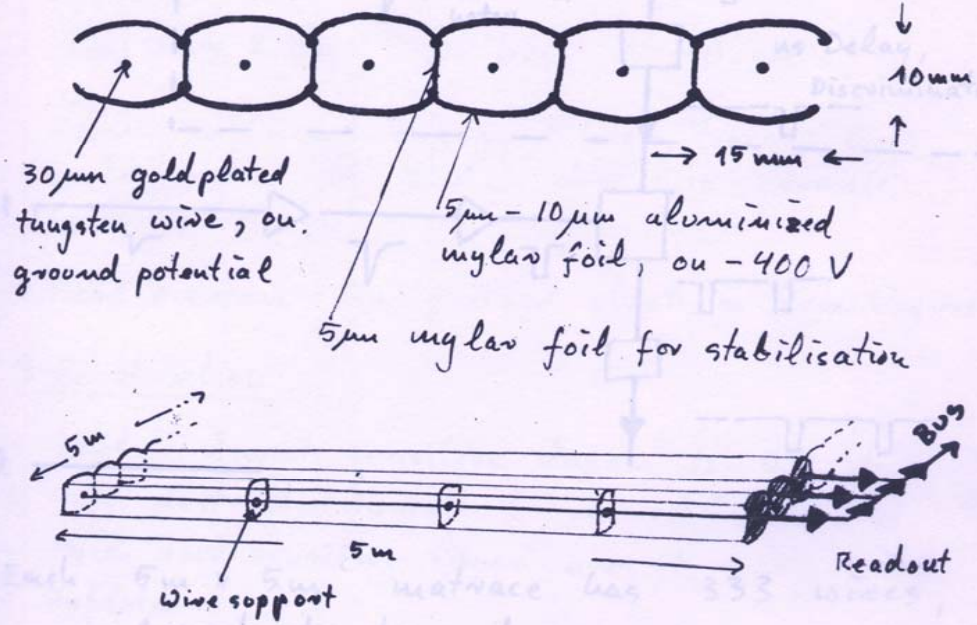
Schematic layout:



1 Sensitive Medium

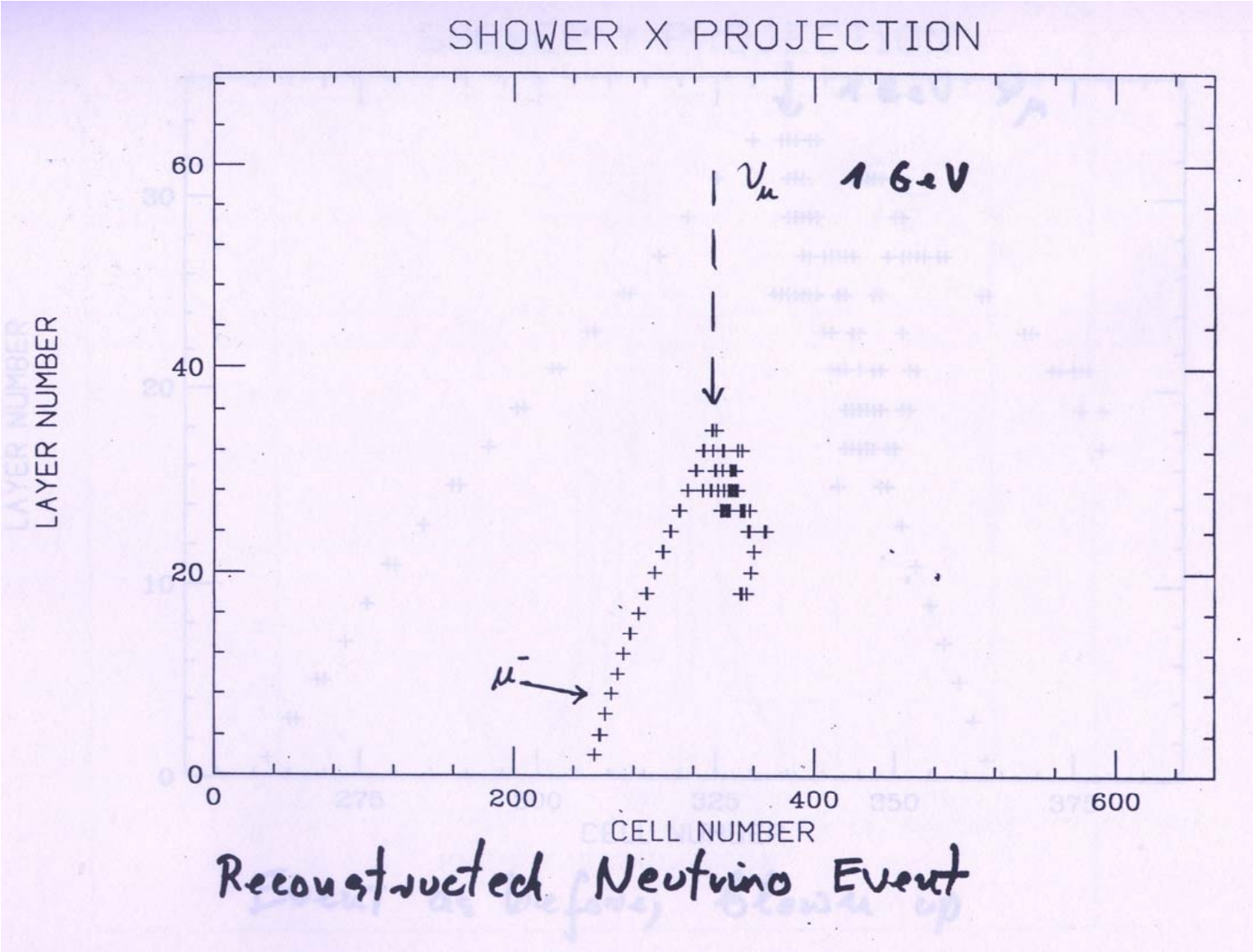
Proportional tubes made from aluminized mylar foil, arranged in 5m * 5m "matraces"

On the Moon: blown up with ~ 0.4 atm of gas



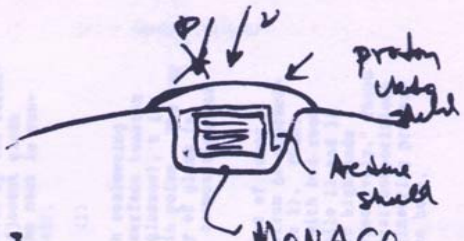
On the Earth: units fully prepared incl. wires, then folded up:

IT WOULD WORK!



DAVE CLINE'S OUTLOOK

SENSITIVITY



STAGE I 10^3 Tons

$F_{\nu,\bar{\nu}} \rightarrow 10^{-4}\ cm^{-2}\ sec^{-1}$

STAGE II 10^4 Tons

p DECAY DETECTOR

$\tau \rightarrow 10^{34}$ y

Require down ν to remove ν from channels

$(Flux)_{\nu,\bar{\nu}} < 10^{-5}$

STAGE III 10^5 Tons $\tau \rightarrow 10^{35}$ y

$Flux_{\nu,\bar{\nu}} < 10^{-6} - 10^{-7}$

The same detector can be used to study ν's if the veto shield is removed - up to 10 TeV

PHI FACTORY

AT UCLA

PHYSICS ISSUES OF THE PHI FACTORY

	PHYSICS:	WHY UNIQUE TO ϕ FACTORY:
1)	$K \to \pi\pi$ $\epsilon'/\epsilon \sim 10^{-4}$	Control of Systematics Large Number of $K_S K_L$ paris ($\sim 10^7$) Extremely Clean Environment Interference Effects
2)	$K^\pm \to 3\pi$, slope ($K^\circ \to 3\pi$ – use interference effects)	Creation of $\sim 10^9$ $K^\pm$ decays in vacuum Reverse Magnetic Field, etc.
3)	ϵ_S Measurement	Source of Pure K_S°
4)	$\Delta S = -\Delta Q$	Tag every event Compare $\pi^+ \ell^- \nu$ to $\bar{\pi} \ell^+ \nu$ (Similar to the $K^\pm$ slope experiment)
5)	CPT Test	Several channels can be used $\pi\pi$ (Imϵ' test) Mixture of Semileptonic and $\pi\pi$, etc. Inclusive CPT Test, Absolute ϕ_{+-}
6)	Exotic K_S°	Search for vacuum regeneration of $K_S^\circ \sim$, e.g. $K_S^\circ + \nu \to K_L^\circ + \nu$ ($K_L \to K_S$ can't be detected) pure K_S – tagged by K_L
7)	EPR in New Way Symmetric Regeneration Paradox	Test Quantum Mechanics with CP amplitudes in new way
8)	Gravitaional effects of K_S/K_L	Isotropic $K_S K_L$ production (long shot) can compare ↕ vs. ↔
9)	$K_L \to$new particles	Suppose $K_S \to$new types of particles Tag K_S Study large samples of K_L decay – detector dependent

DETECTOR REQUIREMENTS (UCLA ϕ FACTORY WORK SHOP - APPROX - WORKING GROUP)
- MAGNETIC FIELD (1-5) KG
- GOOD TRACKER
- EXCELLENT EM CAL
- π/e SEPERATION
- LARGE EVENT RECONSTRUCTION ($\sim 10^{10}$/year)

THE PROPOSAL CAME TO THE REVIEW PROCESS

A PROPOSAL TO DEVELOP

A ϕ FACTORY AT UCLA

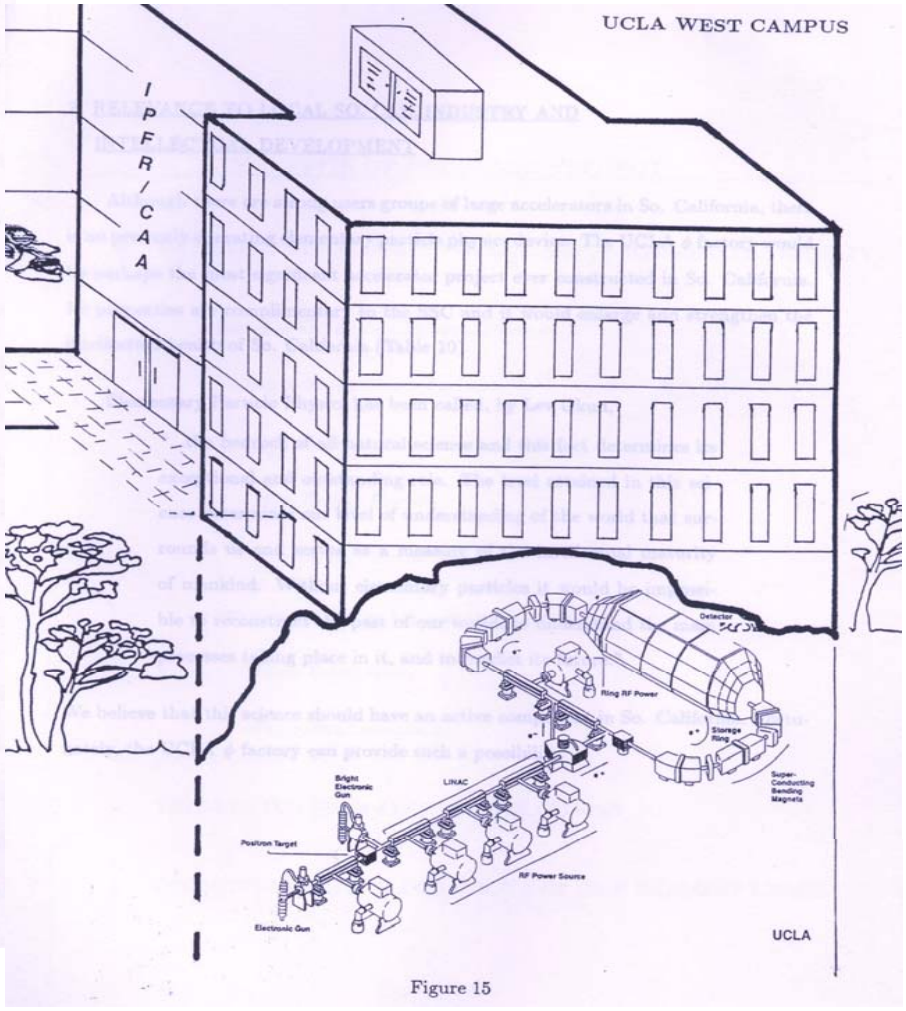


Figure 15

SSC

TO KILL IT WAS A DISASTER

Proceedings
of the
Miniworkshop on Novel Concepts for the SSC and LHC Detectors

September 25-29, 1989

UTD

University of Texas at Dallas
Conference Center

PHYSICS ISSUES OF THE SSC

THE IMPACT OF PRECISION MEASUREMENTS OF ELECTROWEAK PARAMETERS ON PHYSICS BACKGROUNDS FOR THE LHC/SSC

D. CLINE
UCLA

(1) THE WEAK NEUTRAL CURRENT PARAMETERS AND RADIATIVE CORRECTIONS

(2) M_{SUSY} VALUES AND $\sin^2\theta_W$

(3) BACKGROUNDS TO NEW PROCESSES DUE TO $\bar{t}t$ PRODUCTION AND $b'\bar{b}'$ PRODUCTION

(4) LHC DETECTION OF HIGGS BY $H \to ZZ \to$ Lepton Lepton
- POSSIBLE LHC DETECTOR FROM UA1

(5) SUMMARY

THE WEAK NEUTRAL CURRENT PARAMETERS ARE A KEY TO MANY TYPES OF NEW PHYSICS

1) m_t - [redacted] Gives a Radiative correction to the Tree Diagram

A ½% measure of $\sin^2\theta_W \Rightarrow \delta(m_t) \sim 25$ GeV

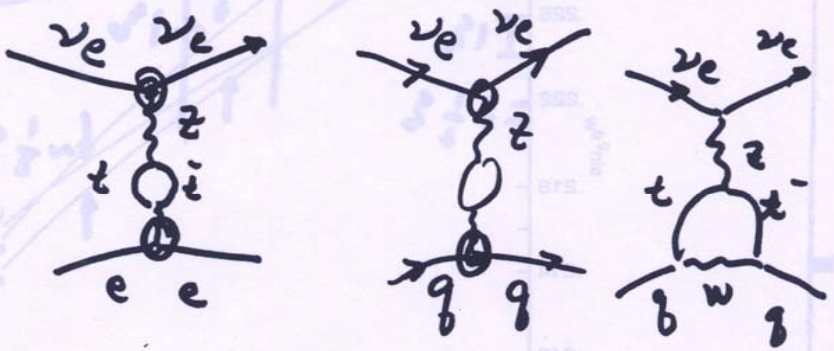
2) m_{Higgs} - Gives an correction to $\sin^2\theta_W$ - a 1% measure of $\sin^2\theta_W$ can distinguish between $m_H < 100$ GeV or $m_H > 100$ GeV

3) m_{SUSY} IN SUSY GUTS

$$\sin^2\theta_W = 0.237 - \frac{4}{15}\frac{\alpha}{\pi}\ln\left(\frac{M_{SUSY}}{M_W}\right)$$

$M_Z = 91.2 \pm 0.2$ GeV - SLC $\Rightarrow M_{SUSY} \sim 130$ GeV

DUE TO THE LARGE RADIATIVE CORRECTIONS THE VALUE OF $\sin^2\theta_W$ DEPENDS ON NEUTRAL CURRENT CHANNEL



We should label

$\sin^2\theta_W\Big]^{\nu e}$ $\sin^2\theta_W\Big]^{\nu q}$

$\sin^2\theta_W\Big]^{eq}$ $\sin^2\theta_W\Big]^{IVB}$

A precise measurement of any two can determine the radiative correction term!

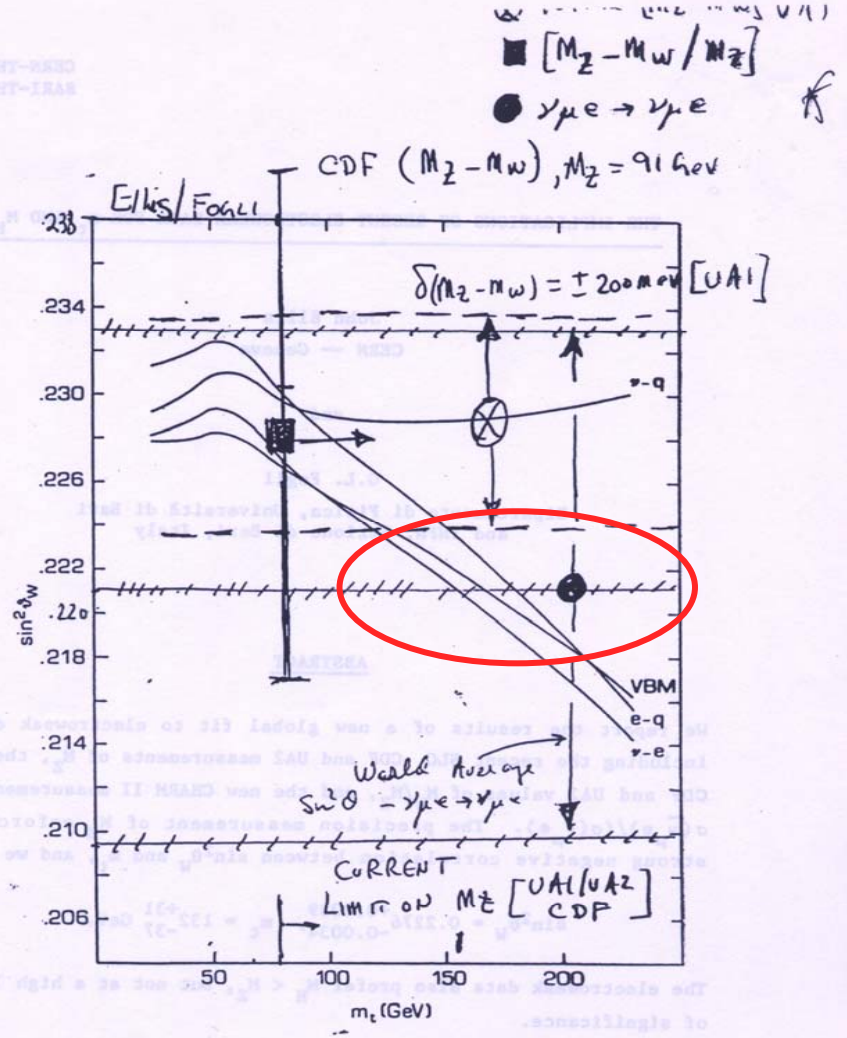
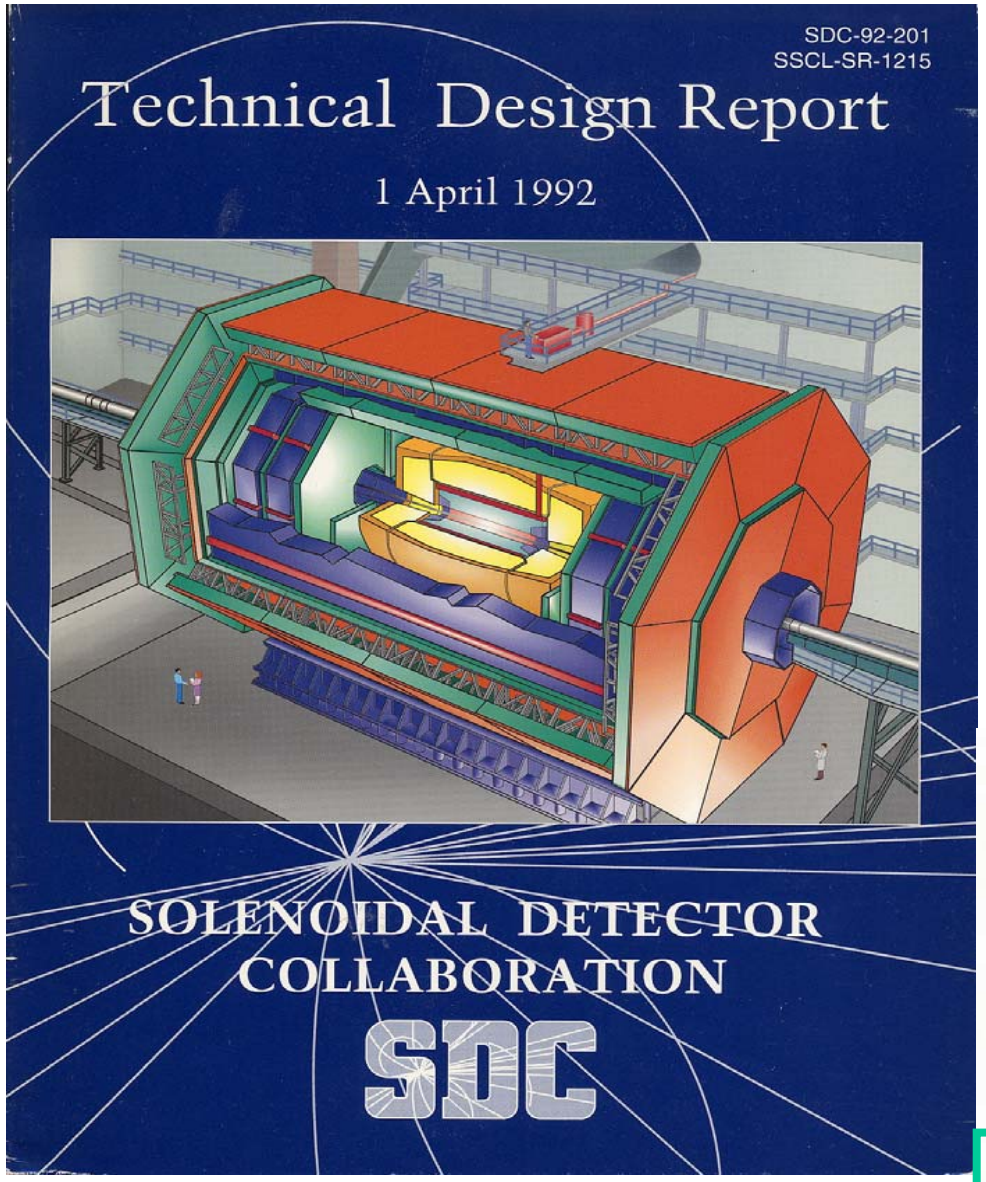


Fig. 1 — The dependence on m_t of the central value of $\sin^2\theta_W$ extracted from present data in the different sectors considered: ν–q, ν–e, e–q and the vector boson masses (VBM). Note the differences at large m_t. The curves are obtained assuming $m_c = 1.45$ GeV and $M_H = M_Z$. This figure updates Fig. 1 of ref. [10].

SDC AT THE SSC (BEFORE 10/1993)



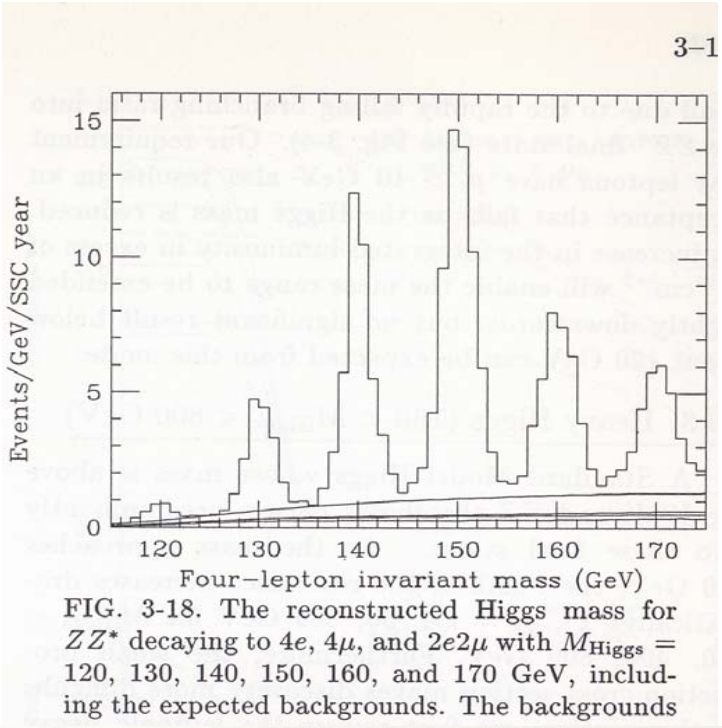


FIG. 3-18. The reconstructed Higgs mass for ZZ^* decaying to $4e$, 4μ, and $2e2\mu$ with $M_{\text{Higgs}} =$ 120, 130, 140, 150, 160, and 170 GeV, including the expected backgrounds. The backgrounds

Table 15-1
Major SDC milestones.

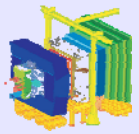
Milestone	Date
Submit technical design report	April 92
Stage I approval complete	August 92
Stage II approval complete	December 92
Detector construction begins	December 92
Earliest surface building beneficial occupancy	January 94
Beneficial occupancy of underground hall	January 96
Commissioning begins	March 99
Ready for operations	October 99

LHC

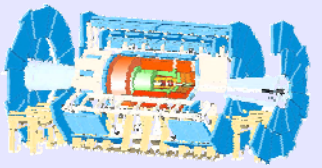
DISCOVERING THE HIGGS

1984 First ideas for LHC – workshop in Lausanne
1987 Rubbia's Long Range Planning recommended LHC in competition to SSC
1988 Start planning for general purpose detectors:
Iron Ball (Rubbia, Kienzle);
EAGLE, ASCOT, CMS, L3P (Evian 1992) → ATLAS, CMS
1989 First plans of UC groups to build the muon endcaps
1993 Demise of the SSC
1994 Approval of LHC Project by CERN council
1995 Negotiations CERN/US-LHC/CMS

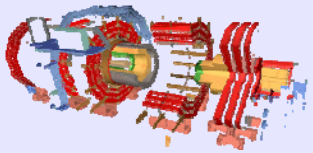
LHCb



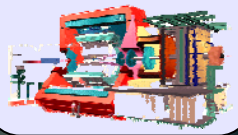
ATLAS



CMS



ALICE



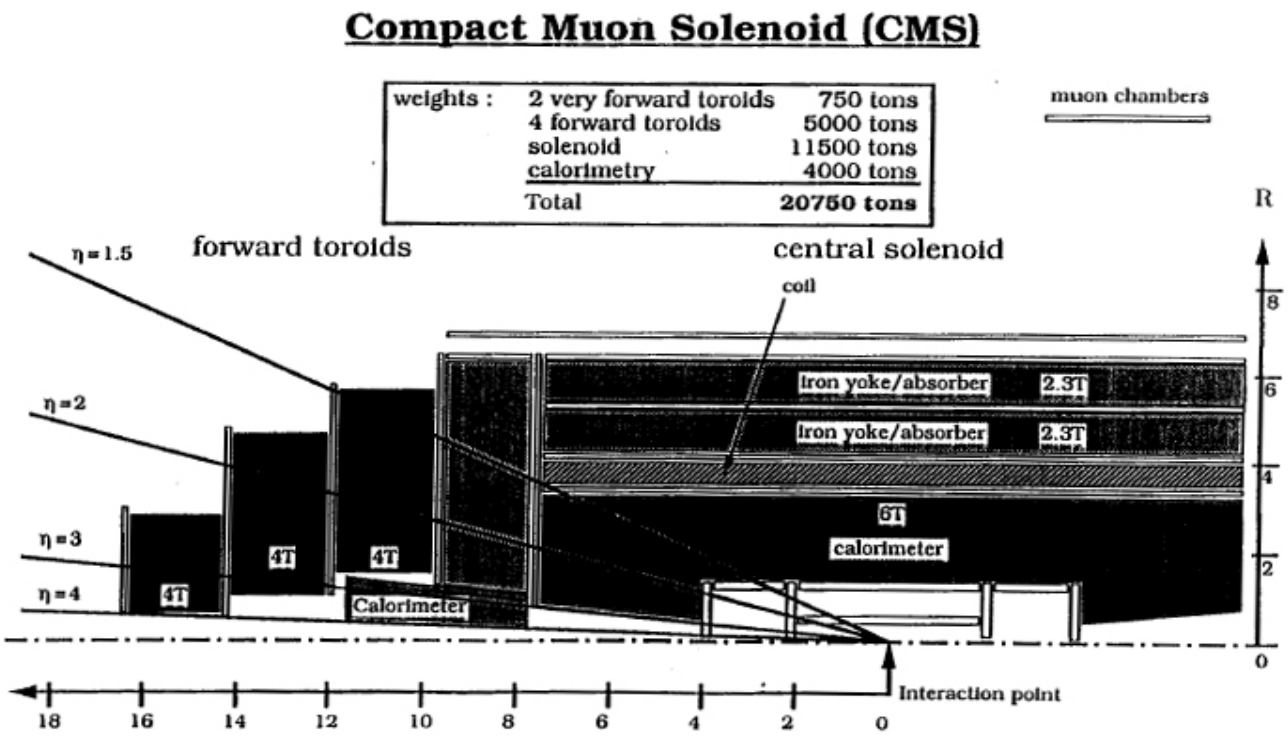
2007 Final assembly, commissioning
2009 Start data taking
2011 First hints for the Higgs-Boson
2012 Discovery
2013 Nobel prize
2014 Upgrade 1 and 2 in the making

FIRST PLANS OF CMS

1987 Rubbia, Kienzle: „Iron Ball“

1988 Della Negra, Eggert: „CMS“

Dave Cline Charter Member



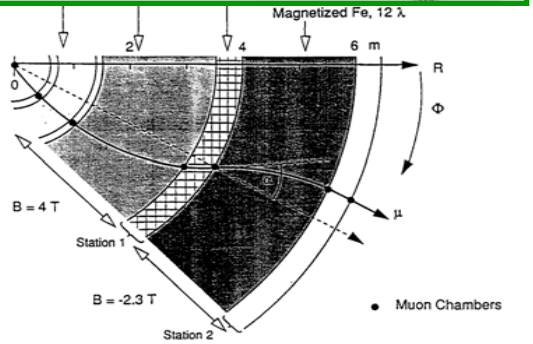


Fig. 7 Transversal view of the Compact Muon Solenoid detector.

SWIFT ACTIONS

11/12/93

Letter of Intent

of the

American CMS Collaborators

R.E. Breedon, W. Ko, R.L. Lander

University of California, Davis

M. Atac†, D. Chrisman, D.B. Cline, J. Hauser, M. Lindgren,
S. Lammel, Th. Muller, J. Park, S. Otwinowski

University of California, Los Angeles

J.W. Gary, P. Giacomelli, W. Gorn, C.C.H. Jui, J.G. Layter,
J. Letts, B.C. Shen, C.W. Wilson, G.J. VanDalen

University of California, Riverside

R.C. Chaney, E.J. Fenyves, D.J. Suson‡, H.D. Hammack

University of Texas at Dallas

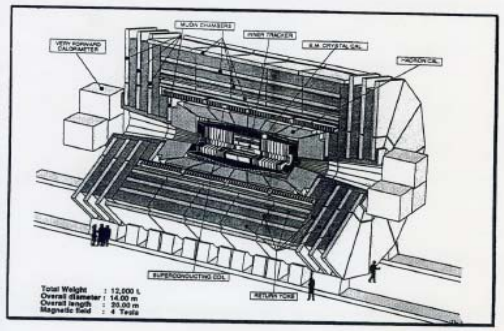
Submitted to O'Fallon on Nov. 12, 1993

CMS MEETING AT UCLA FEB. 2-4, 1994

CMS

A Compact Selenoidal Detector for LHC

COLLABORATION MEETING



UCLA

Feb 2-4, 1994

2 Weeks after Northridge Earthquake!

UCLA Meeting, Feb 2-4

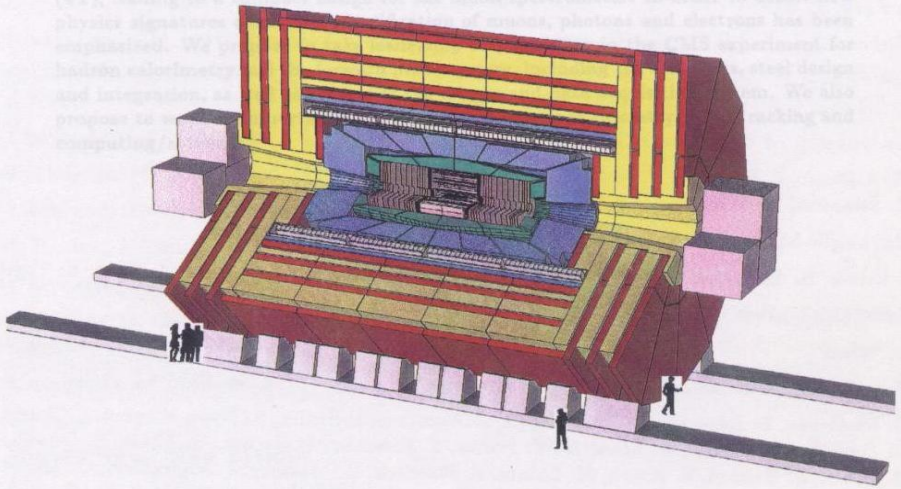
- Aim of the meeting
  - Inform about CMS and its physics
  - Present areas where help is needed
  - Collect relevant experience from SSC
  - Attract new groups
- Nearly 140 participants
  - 35 from Europe
  - 10 from US groups in CMS
  - 90 from 37 interested US groups
  - 2 from DOE
- Over 70 presentations

LOI of USCMS

Compact Muon Solenoid
(CMS)
Detector

US COLLABORATION

Letter of Intent
April 22, 1994



Chair of the US
Collaboration Board

Thomas Müller
UCLA

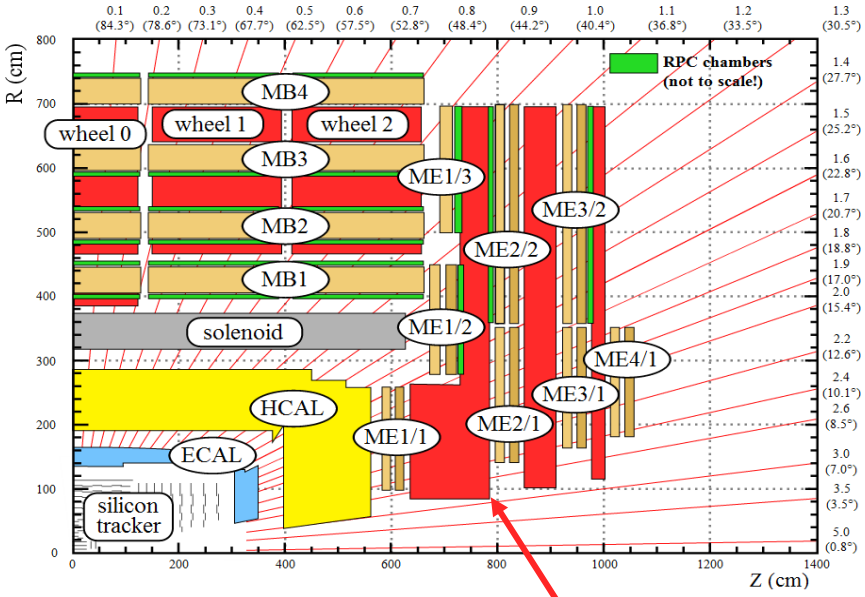
Spokesperson
to DOE

Dan Green
Fermilab

Table 1.1: US Institutions in the CMS Collaboration.

Institution	*contact person*
University of Alabama	L. Baksay
Boston University	L. Sulak
Brookhaven National Laboratory	C. Woody
California Institute of Technology	H. Newman
University of California, Davis	W. Ko
University of California, Los Angeles	Th. Müller
University of California, Riverside	J. Layter
University of California, San Diego	J. Branson
Carnegie Mellon University	A. Engler
Fairfield University	D. Winn
Fermi National Accelerator Laboratory	D. Green
Florida State University	V. Hagopian
Florida State University (SCRI)	M. Corden
University of Iowa	Y. Onel
Iowa State University	E.W. Anderson
Lawrence Livermore National Laboratory	C. Wuest
Los Alamos National Laboratory	H. Ziock
University of Maryland	A. Skuja
Massachusetts Institute of Technology	P. Sphicas
University of Michigan	J. Chapman / R. Gustafson
Michigan State University	J. Huston
University of Minnesota	R. Rusack
University of Mississippi	J. Reidy
University of Nebraska	G. Snow
University of New Mexico	J. Matthews
Northeastern University	S. Reucroft
Northwestern University	B. Gobbi
University of Notre Dame	R. Ruchti
Ohio State University	T.Y. Ling
Princeton University	P. Piroue
Purdue University	V. Barnes / L. Gutay
Rice University	D. Adams
University of Rochester	A. Bodek
State University of New York at Stony Brook	M. Mohammadi
Texas Tech University	R. Wigmans
University of Texas at Dallas	E.J. Fenyves
Virginia Polytechnic Institute and State University	L. Mo
University of Wisconsin	W.H. Smith

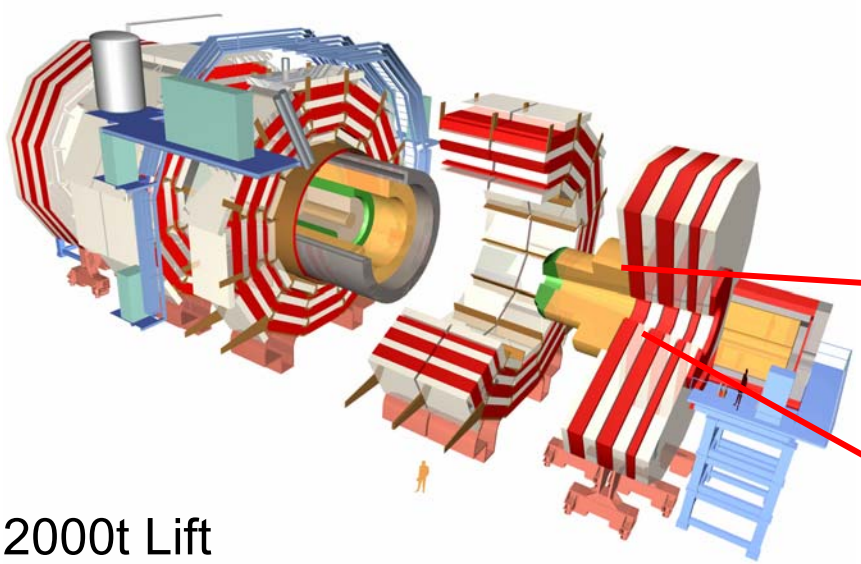
CMS MUON SYSTEM



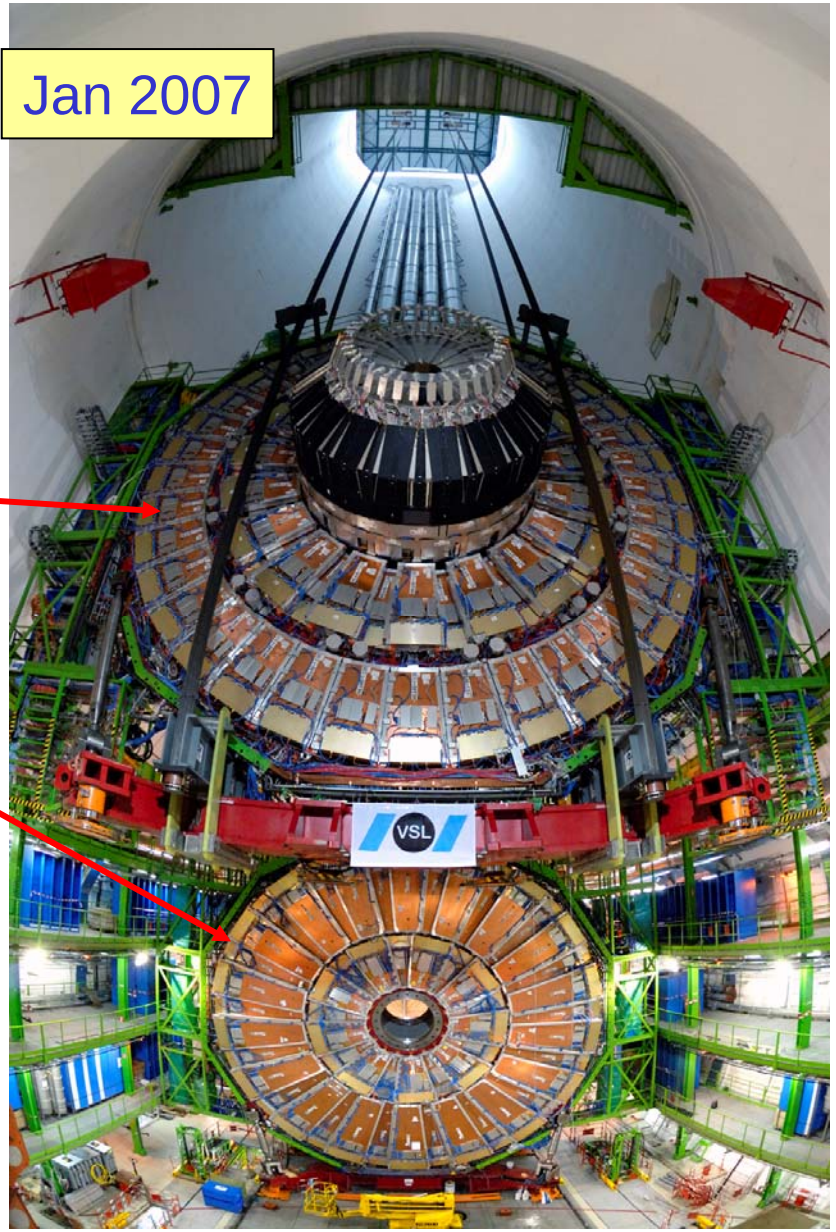
ME

FINAL ASSEMBLY

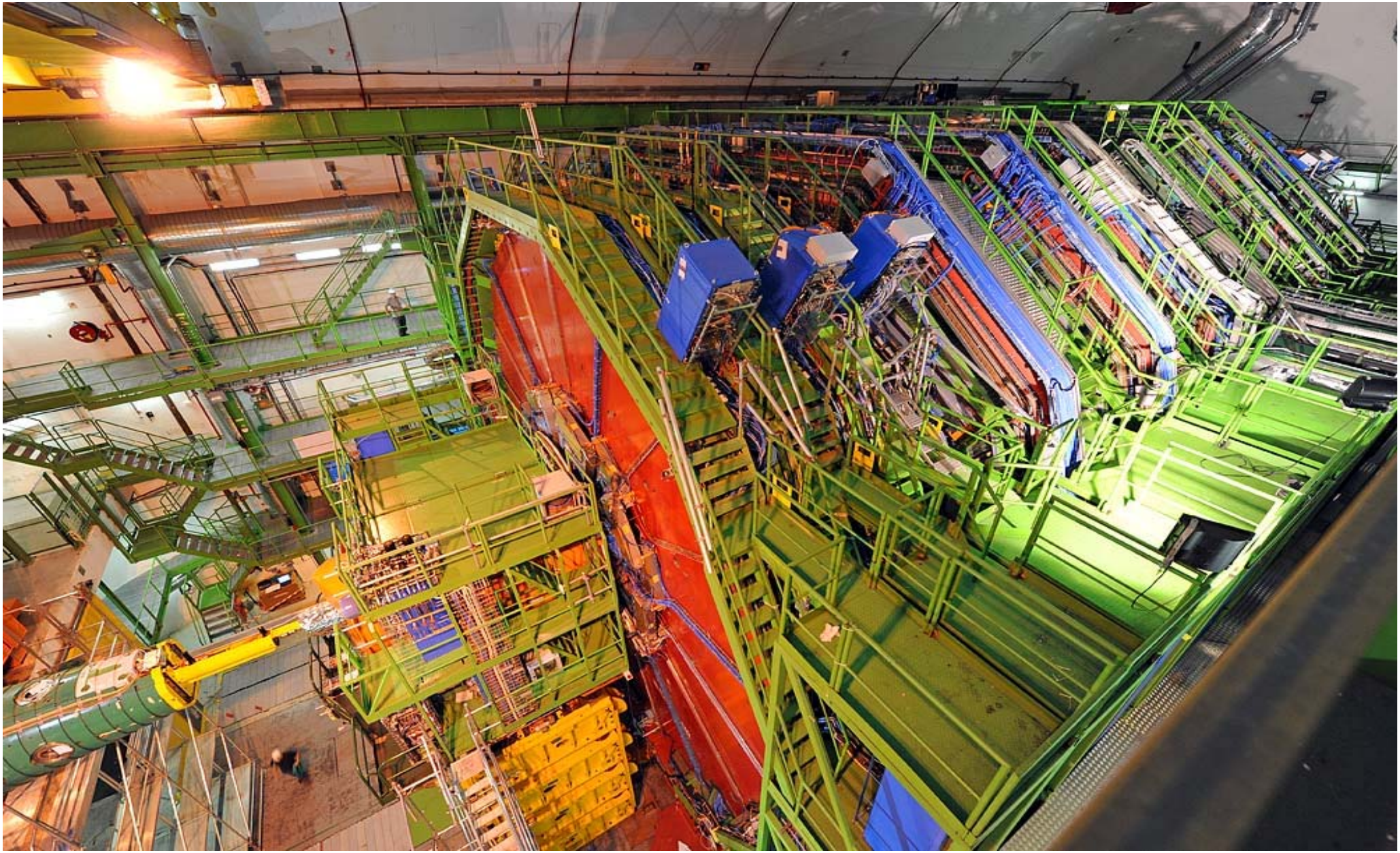
Lowering of an endcap



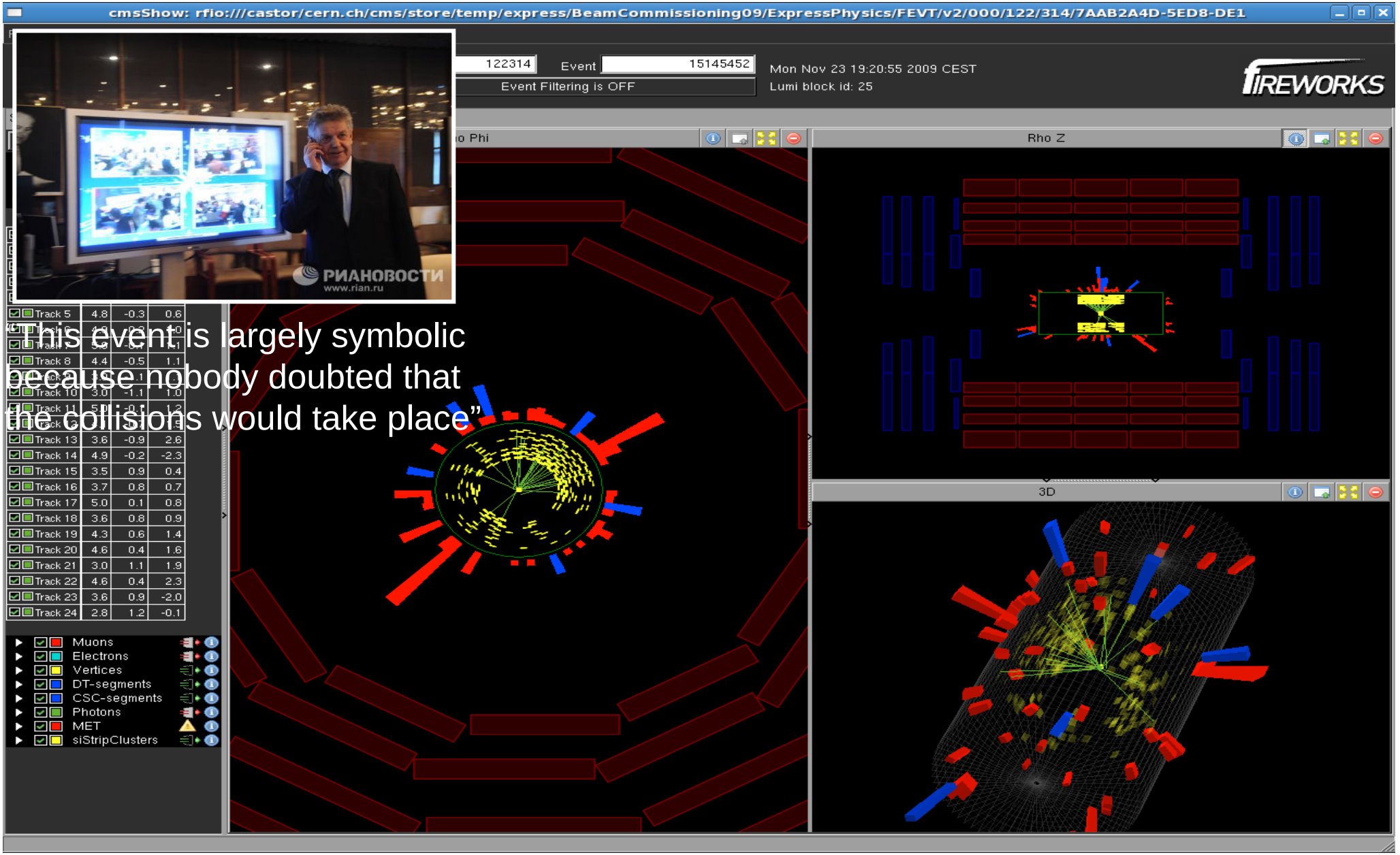
2000t Lift



CMS IS READY !

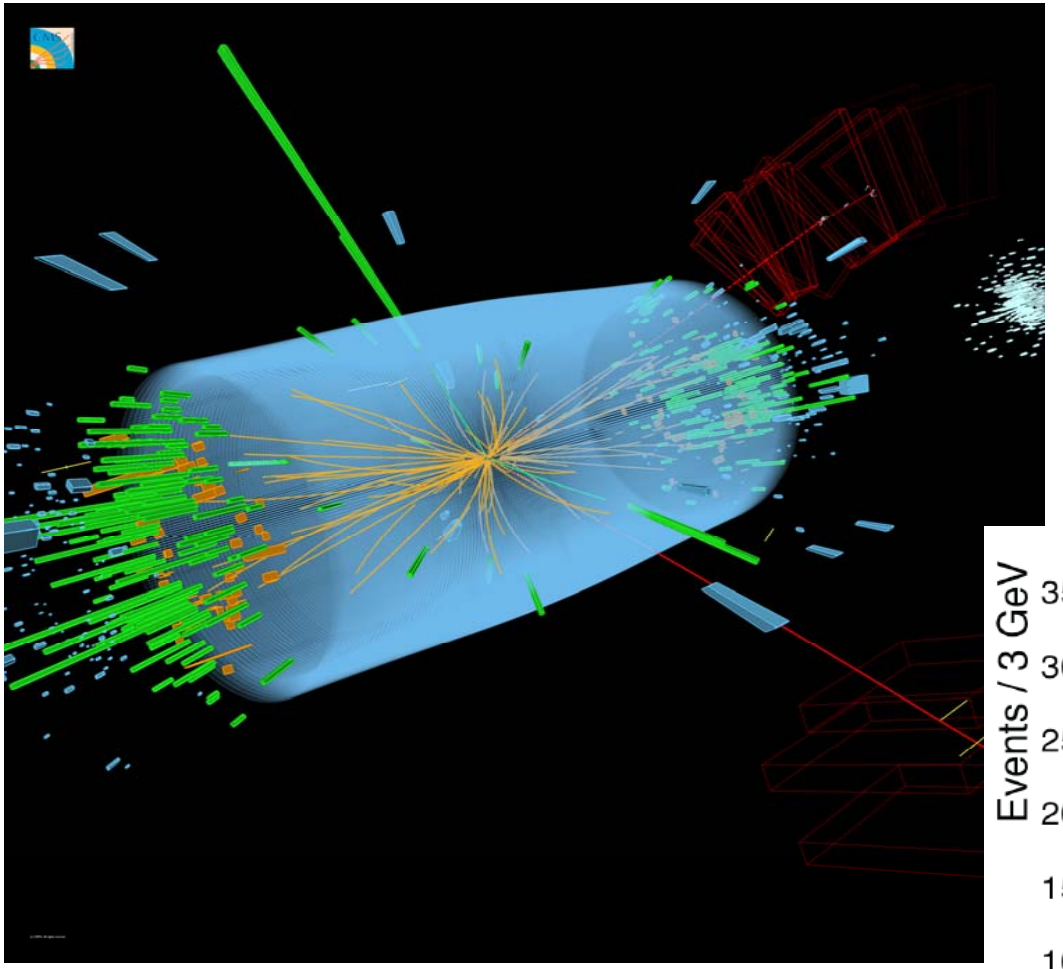


FIRST COLLISION ON 23. 11. 09



This event is largely symbolic because nobody doubted that the collisions would take place”

HIGGS !

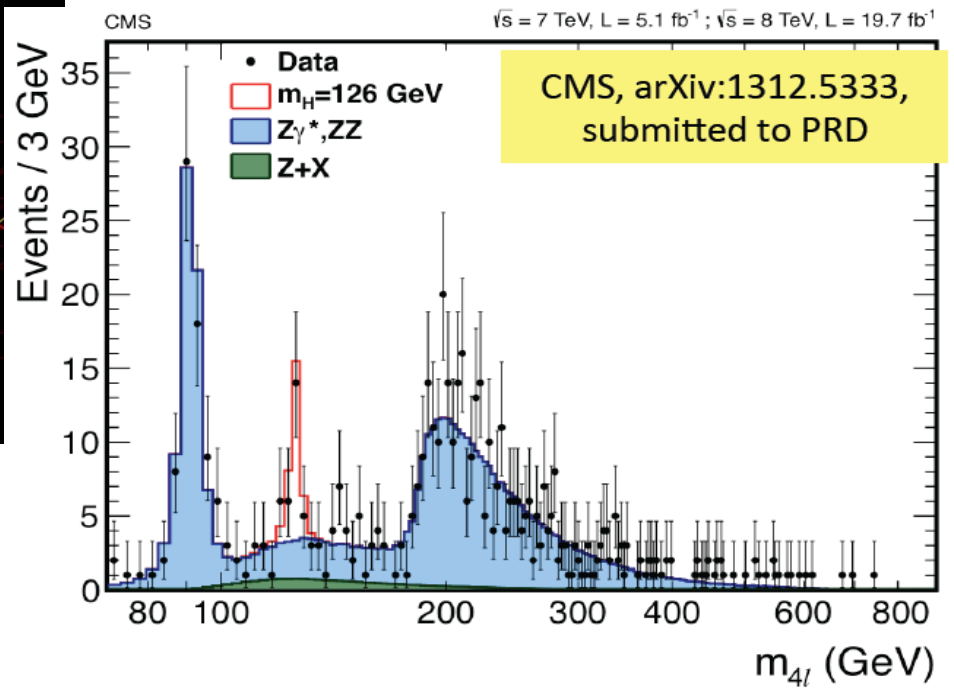


Candidate for

$pp \rightarrow H + X$; $H \rightarrow ZZ^*$,

$Z \rightarrow e^- e^+$

$Z^* \rightarrow \mu^- \mu^+$



DAVE‘S MEMOS

UCLA

MEMORANDUM

Department of Physics and Astronomy
154705

Date: August 30, 1995

To: DOE -HEP Group

From: D. Cline

REF: DOE Review Oct 2-3

(1) I'm pleased to report that I have convinced P.K. Williams to attend our review Oct 2-3. Only he and Rol will be there - no outside committee!

(2) He reports that the budget now looks bad due to the Senate cuts which can't be resolved soon. I believe we may be cut next year.

(3) He supports (our) CMS work and will come to part of the Tahoe CMS meeting. (I can only be there the first 2 days). He also believes COSMOS has a strong future. This is all I could get from him.

(4) The Zeplin WIMP proposal has been sent out for review and should be presented at the meeting. One review is in already.

(5) The situation with T. Muller needs to be resolved.

(6) So far, I have heard nothing from you concerning the agenda proposed for the review. I assume all is OK for now.

UCLA

TO: J. Hauser
Th. Muller

FROM: D. Cline (by

Since you are not i
I've replaced it by one by C
You will someday s

cc:D. Sanders

Break

FOR ME DAVE IS STILL AROUND

HE IS JUST TRAVELING