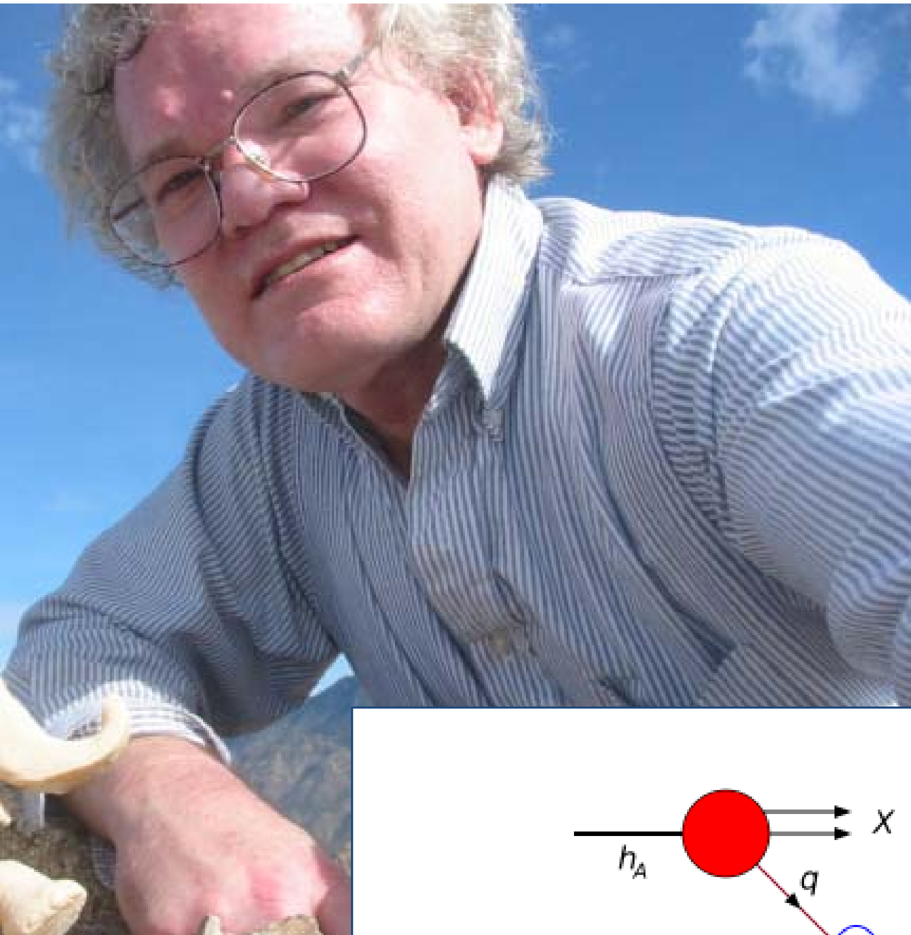
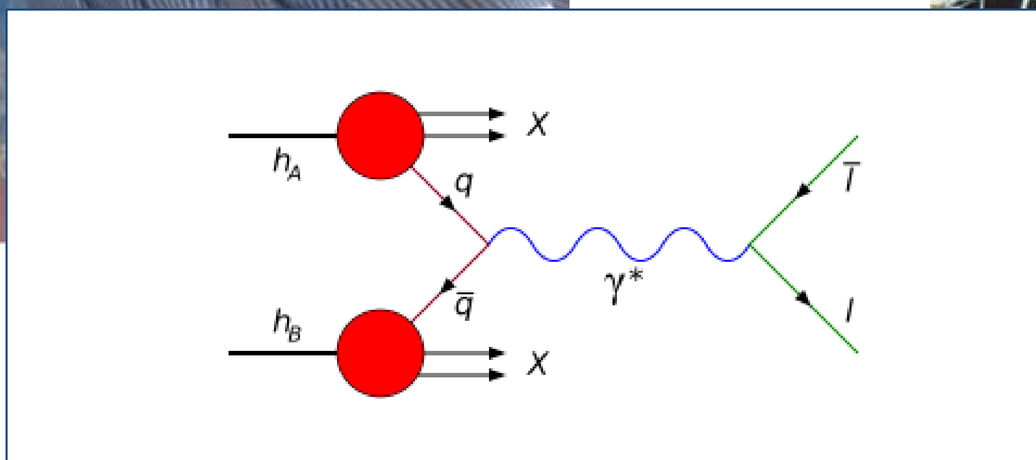
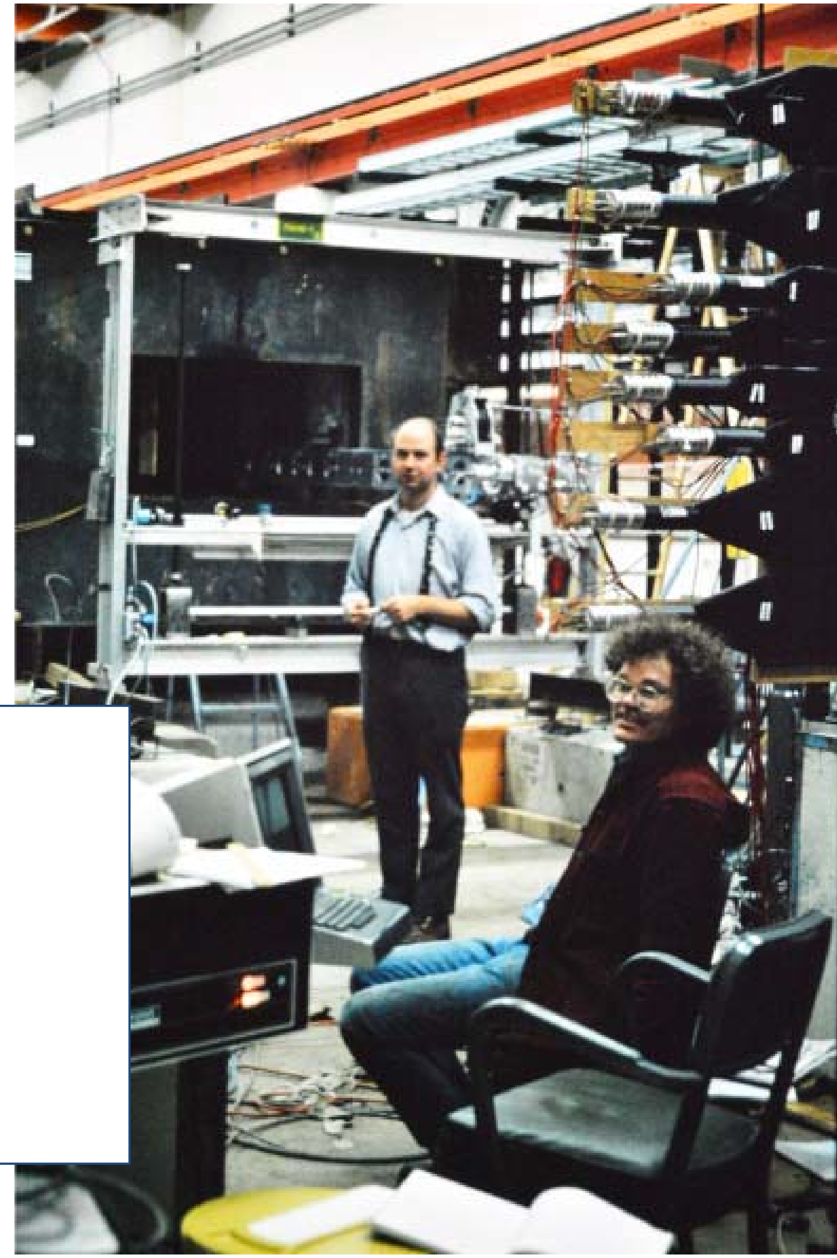






Physics with Pair of Particles

from muons, to pions, to photons

NAL Proposal No. 615
Correspondent: J. E. Pilcher
Enrico Fermi Institute
University of Chicago
Chicago, IL 60637
Telephone: 312-753-8747

A Study of the Forward Production of
Massive Particles

C. Adolphsen, K. J. Anderson, K. Karhi, J. E. Pilcher, E.I. Rosenberg
Enrico Fermi Institute, University of Chicago

and

K. T. McDonald, A. J. S. Smith
Princeton University

November 8, 1978

ADDENDUM TO PROPOSAL 615

A First Phase to Study Forward Produced μ-pairs

C. Adolphsen, J. Alexander, K.J. Anderson, K. Karhi,
J. E. Pilcher, E. I. Rosenberg
Enrico Fermi Institute, University of Chicago

and

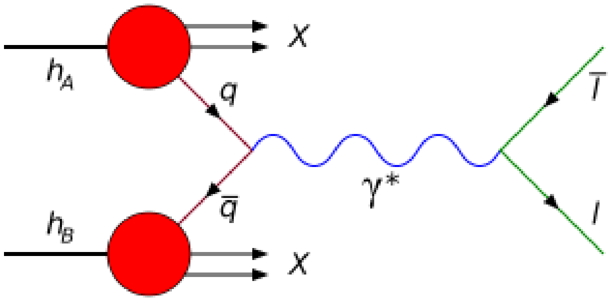
J. Elias
Fermi National Accelerator Laboratory, Batavia, Illinois 60510

and

K. T. McDonald, A.J.S. Smith
Joseph Henry Laboratories, Princeton University, Princeton, NJ 08540

May 4, 1979

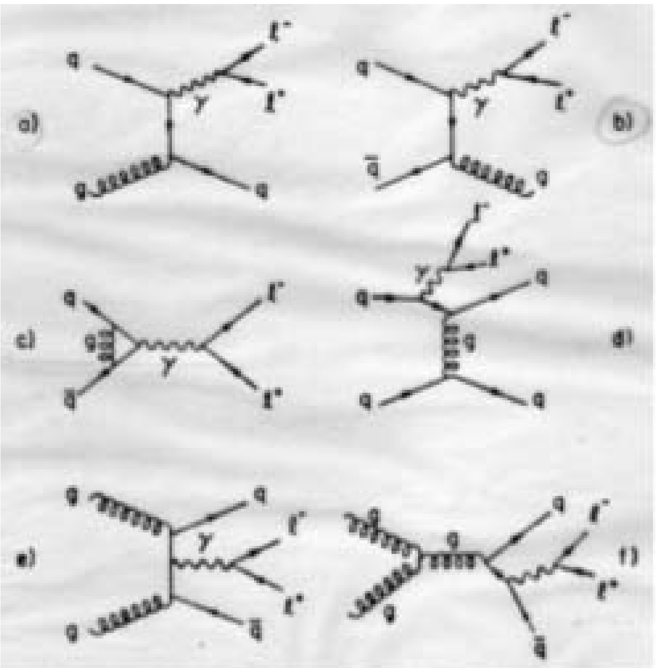
(Proposed: 1978-05-04, Approved: 1979-07-01, Completed: 1984-07-15)
Ran for 2260 hours



- Naïve picture confirmed by early Drell-Yan experiments

$$M^4 \frac{d^2\sigma}{dx_1 dx_2} = \frac{4\pi\alpha^2 s}{9} f^{\pi}(x_1) g^{N}(x_2) \qquad \frac{d\sigma}{d\cos\theta} \propto 1+\cos^2\theta$$

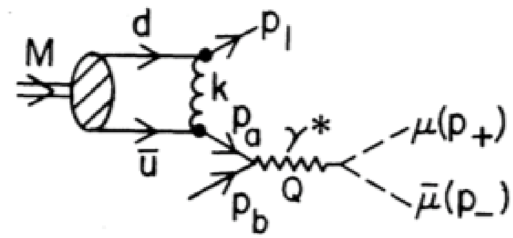
- Start including QCD higher order corrections

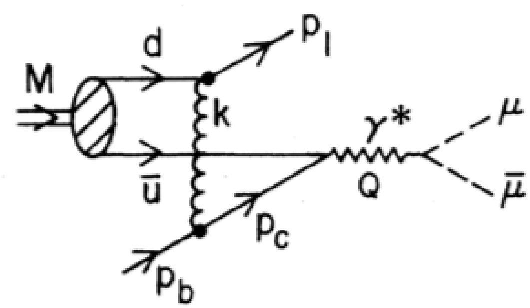


- Internal gluon exchanges – effects of the *pion bound state* – should have observable effects ➔ "Higher Twist" contributions

A large x_F quark with p_T>0 must be far off-shell ➔ can couple to longitudinal photons.

where x_F is the momentum fraction of the quark in the pion





Berger & Brodsky
PRL 42, 940 (1979)

$$d\sigma \propto (1-x)^2(1+\cos^2\theta) + \tfrac{4}{9}(\langle k_T^2\rangle/Q^2)\sin^2\theta,$$

E615: Search for departures from the simple DY model and test QCD predictions

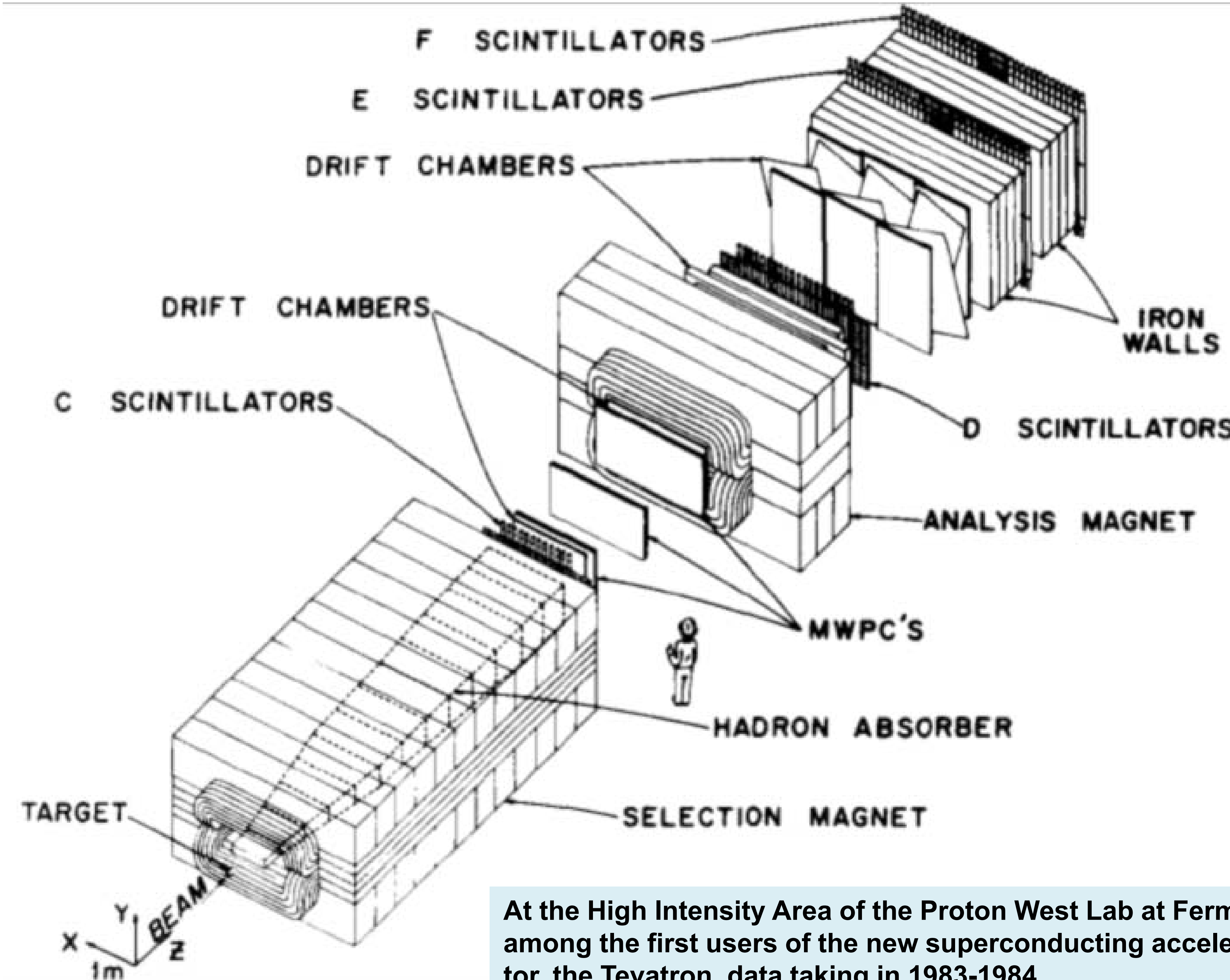
$\pi W \longrightarrow \mu^+\mu^- X$ (in the continuum region $M_{\mu+\mu-}$, from 4 to 9 GeV/c^2)

E615 Physics Goal:

- Study pion structure functions
- High statistics measurement of the muon pair angular distribution as a function of x_F using a 255 GeV/c beam
- Search for scale breaking effects in the pion structure function by comparing measu-rements at 255 Gev/c with ones at 80 GeV/c
- Perform π^+/π^- test at high x_F with 255 GeV/c beams to check that the production does proceed through $q\bar{q}$ annihilation.

E615 Detector design:

- Cross section for the production of lepton pairs at $x_F > 0$, $M_{\ell\ell} > 4$ GeV/c^2, s=10-20 GeV is of the order of 100 pb per Nucleon ➔ high intensity beam
- Muon pairs in the final state ➔ beam dump experiment
- Should maintain good acceptance in the angular variables at large x_F
- The detectors acceptance is peaked at large x_F where logarithmic and higher twist scale dependence are predicted.
- Reduce low mass acceptance
- Ready identification of Drell-Yan events



At the High Intensity Area of the Proton West Lab at Fermilab, among the first users of the new superconducting accelerator, the Tevatron, data taking in 1983-1984.

Nuclear Instruments and Methods in Physics Research A243 (1986) 323–347
North-Holland, Amsterdam

AN APPARATUS TO MEASURE THE STRUCTURE OF THE PION

C. BIINO, J.F. GREENHALGH, W.C. LOUIS, K.T. McDONALD, S. PALESTINI *, F.C. SHOEMAKER and A.J.S. SMITH

Joseph Henry Laboratories, Department of Physics, Princeton University, Princeton, New Jersey 08544, USA

C.E. ADOLPHSEN, J.P. ALEXANDER **, K.J. ANDERSON, J.S. CONWAY, J.G. HEINRICH, K.W. MERRITT + and J.E. PILCHER

Enrico Fermi Institute and Department of Physics, The University of Chicago, Chicago, Illinois 60637, USA

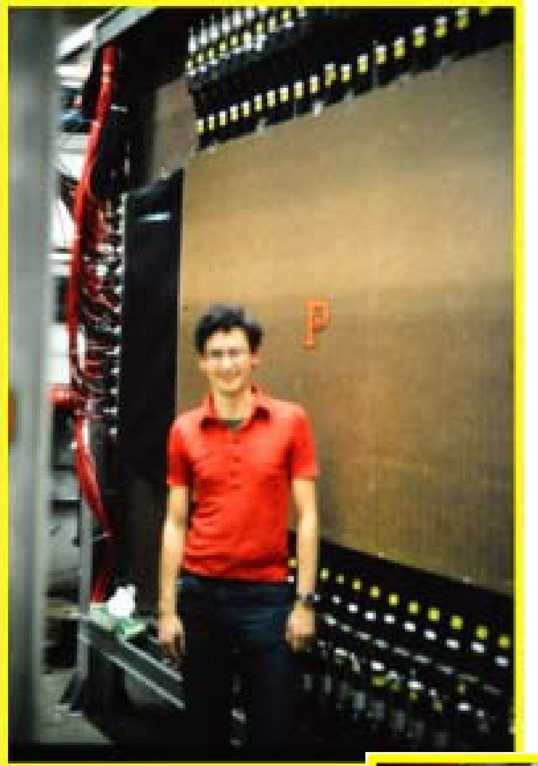
E.I. ROSENBERG and D.T. SIMPSON ++

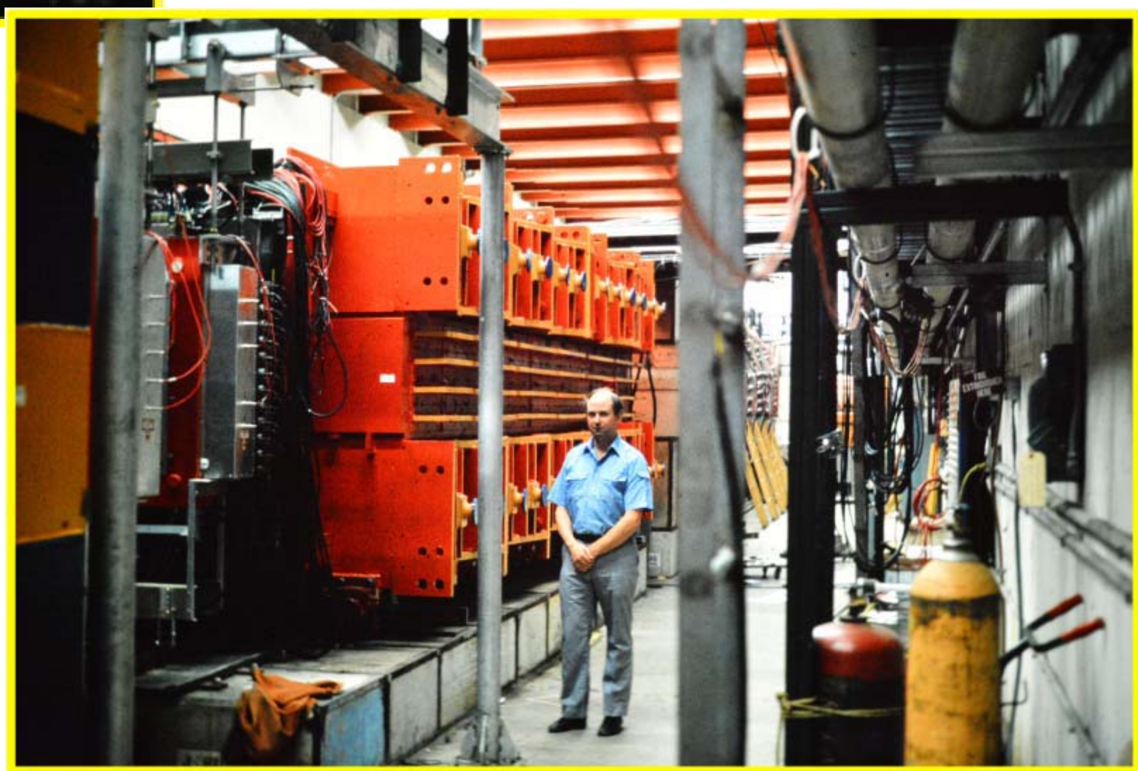
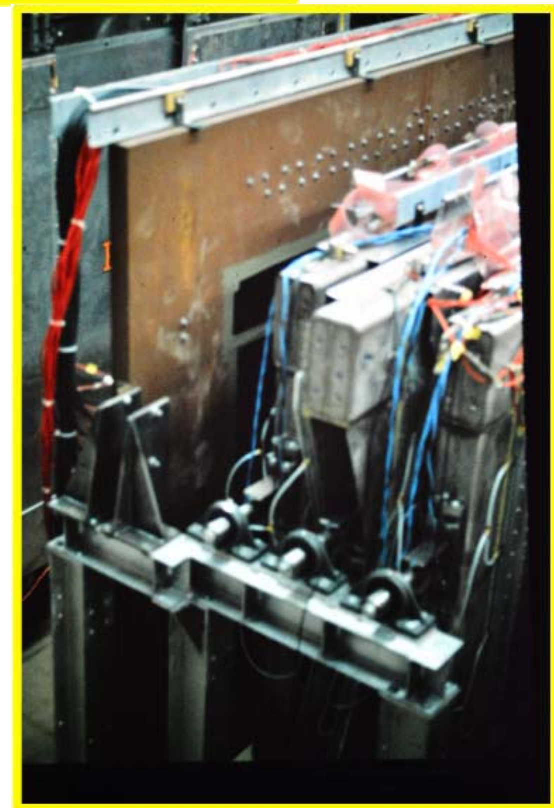
Ames Laboratory and Department of Physics, Iowa State University, Ames, Iowa 50011, USA

Received 27 September 1985

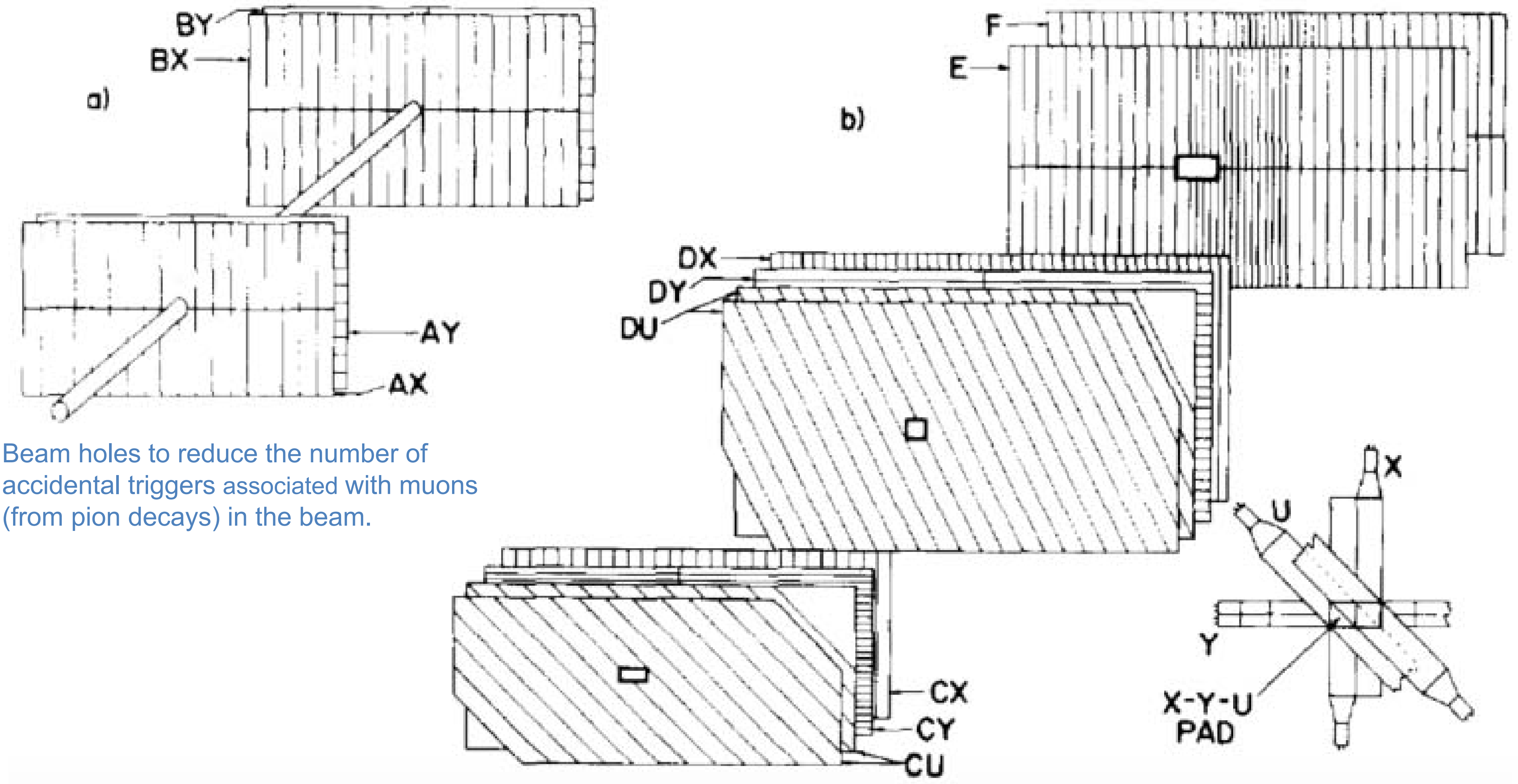
We discuss the design and performance of
apparatus was used to measure the properti
tungsten target in order to infer the distribut
emphasis was on interactions in which a si
momentum. A hardware trigger processor en
environment.

Kirk McDonald, Stew Smith, Frank Shoemaker,
Jim Pilcher, Kelby Anderson, Bill Louis,
John Greenhalgh, Eli Rosenberg,
Jim Alexander, Chris Adolphsen, John Conway,
Joel Heinrich, Sandro Palestini, Cristina Biino


P

Scintillation counters



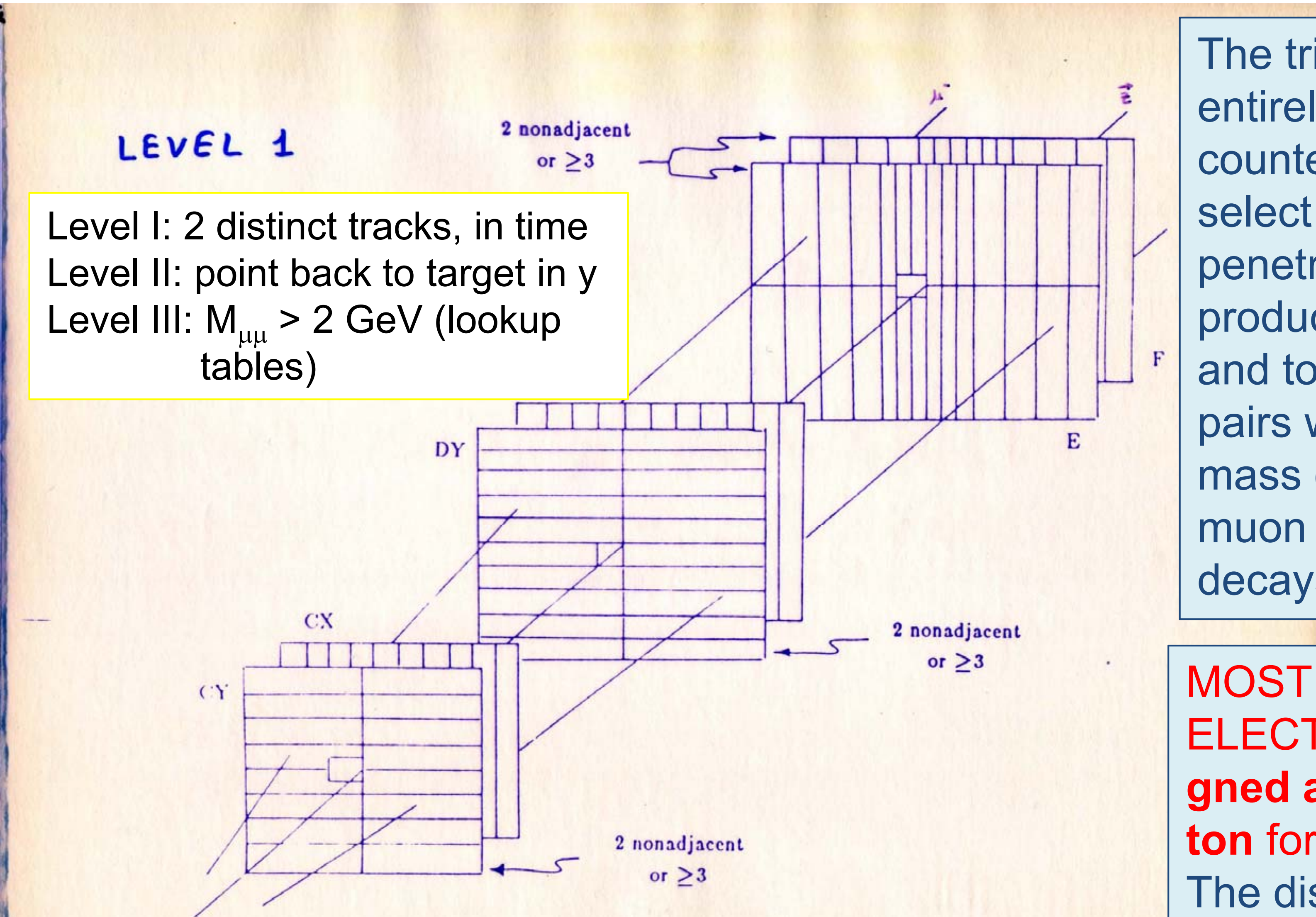
Beam holes to reduce the number of accidental triggers associated with muons (from pion decays) in the beam.

A&B(x,y) hodo to veto events associated with an incident muon outside the beam pipe
C&D(x,y,u,u,) provide detailed informations on the candidate muon pair positions for the trigger selection
E&F banks to confirm muon identification

Black scotch tape

QVT

Scintillator Timing

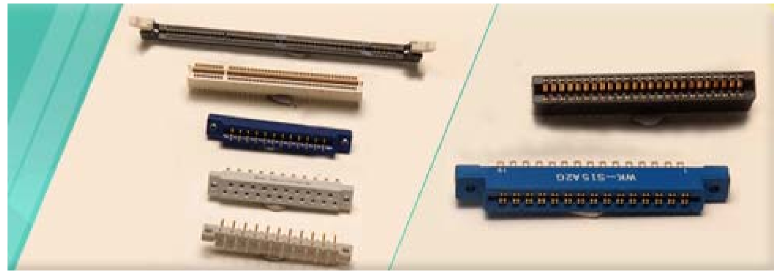


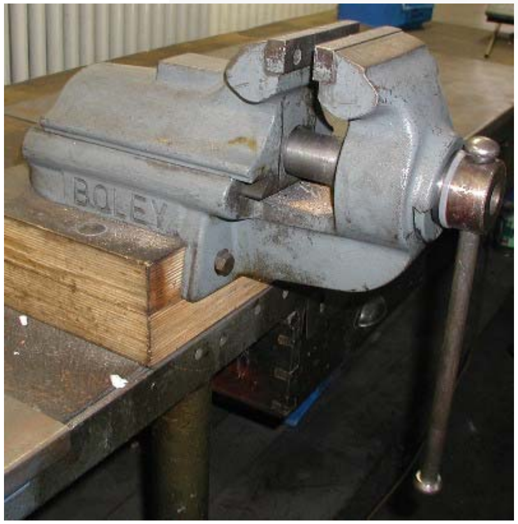
Level I: 2 distinct tracks, in time
Level II: point back to target in y
Level III: $M_{\mu\mu}$ > 2 GeV (lookup tables)

The trigger was based entirely on scintillator counter informations, to select events with 2 penetrating particles produced in the Be target and to discriminate against pairs with low invariant mass or containing a halo muon from beam pion decays.

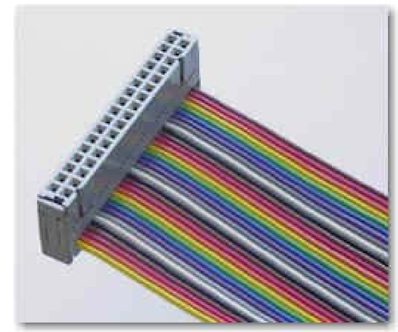
The Level-1 decision was reached about **40 ns** after the signals emerged from the scintillator discriminators.
The Level-2 decision was available 10 ns after the Level-1.
Strong limits coming from signal cables length of the drift chambers …

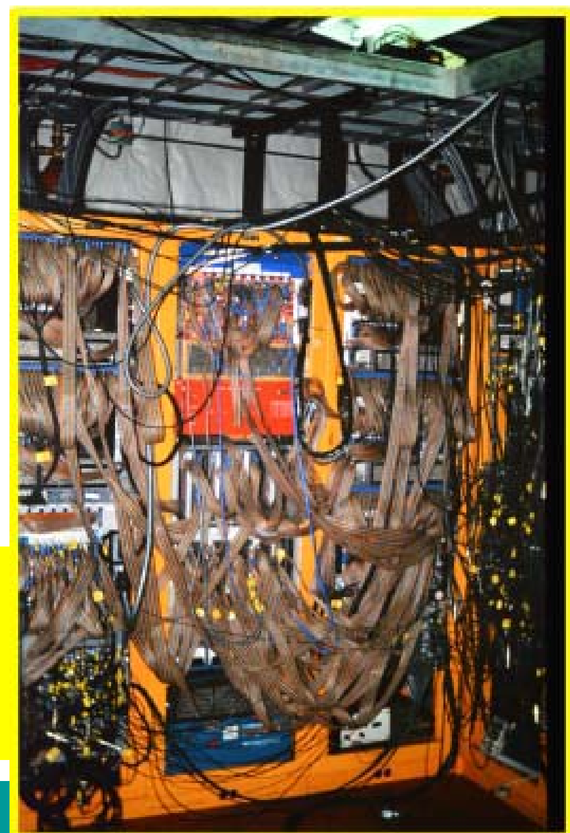
MOST of the TRIGGER ELECTRONICS was **designed and built in Princeton** for this experiment.
The discriminators, latches, and trigger processors used ECL integrated circuits while a few standard NIM modules were used in forming final coincidences at each trigger level.

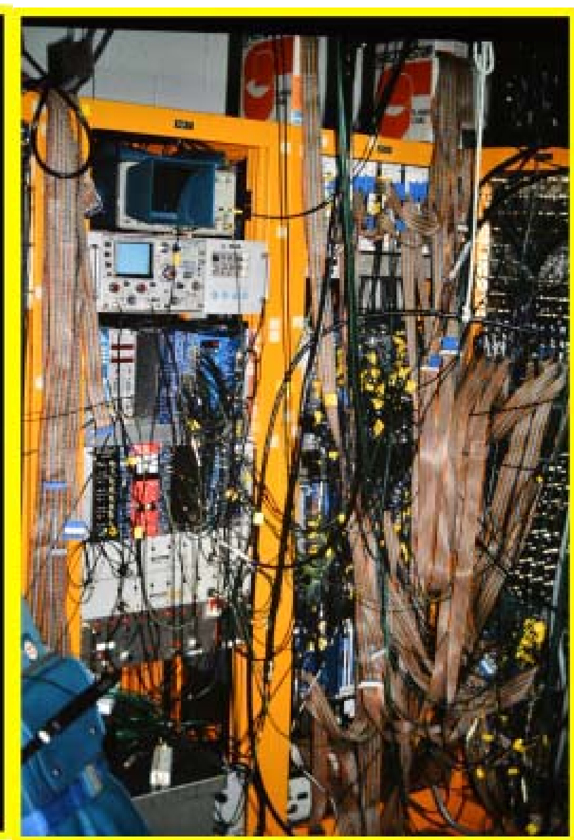


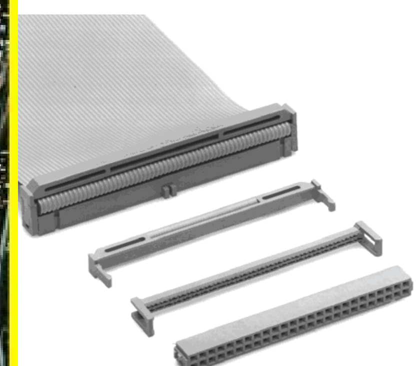


Twist & flat

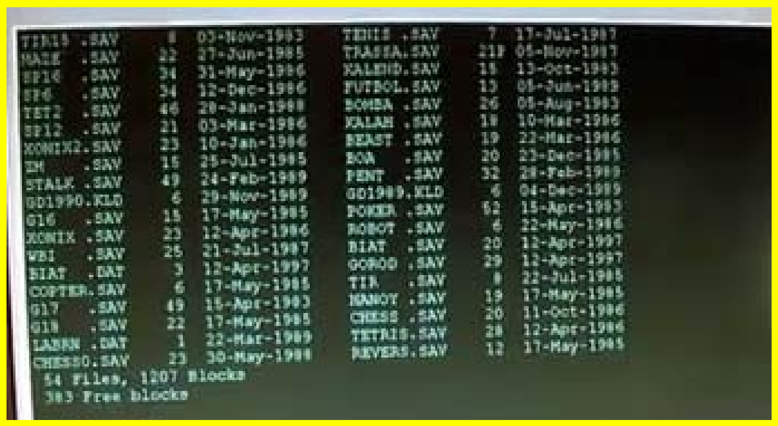


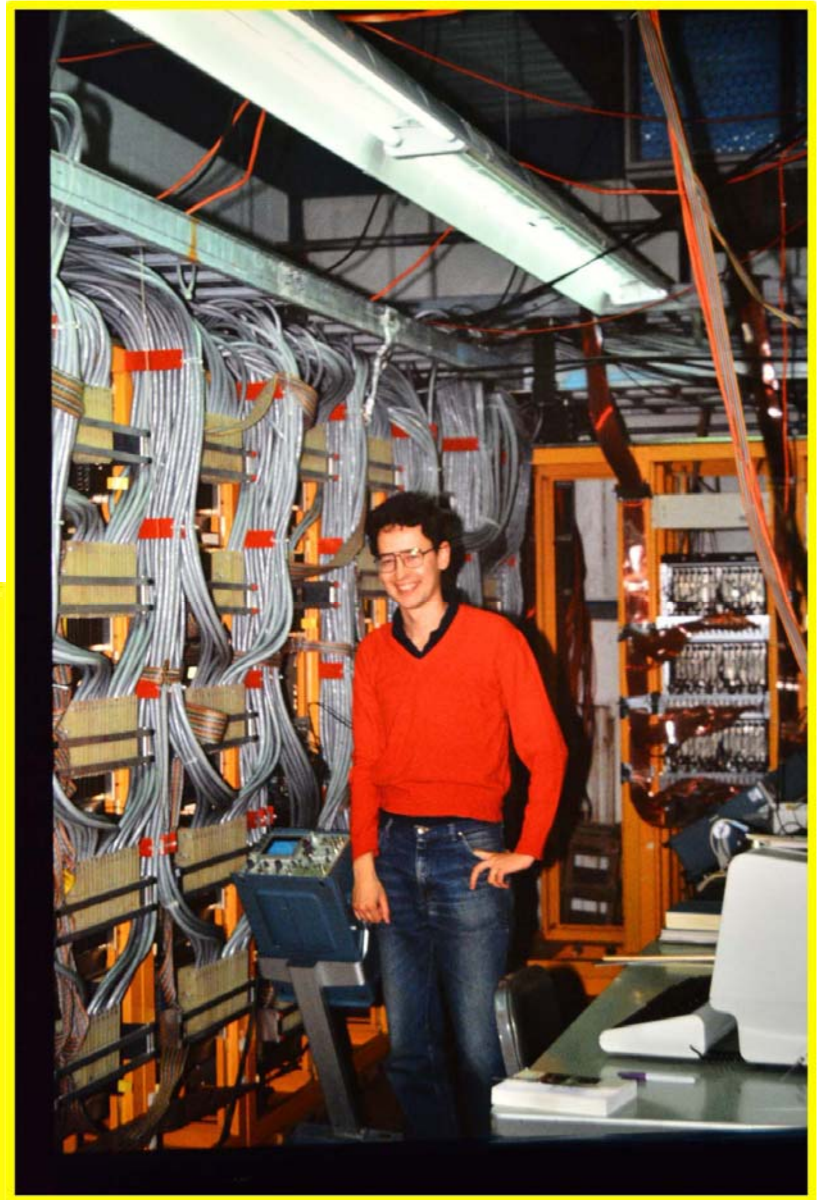




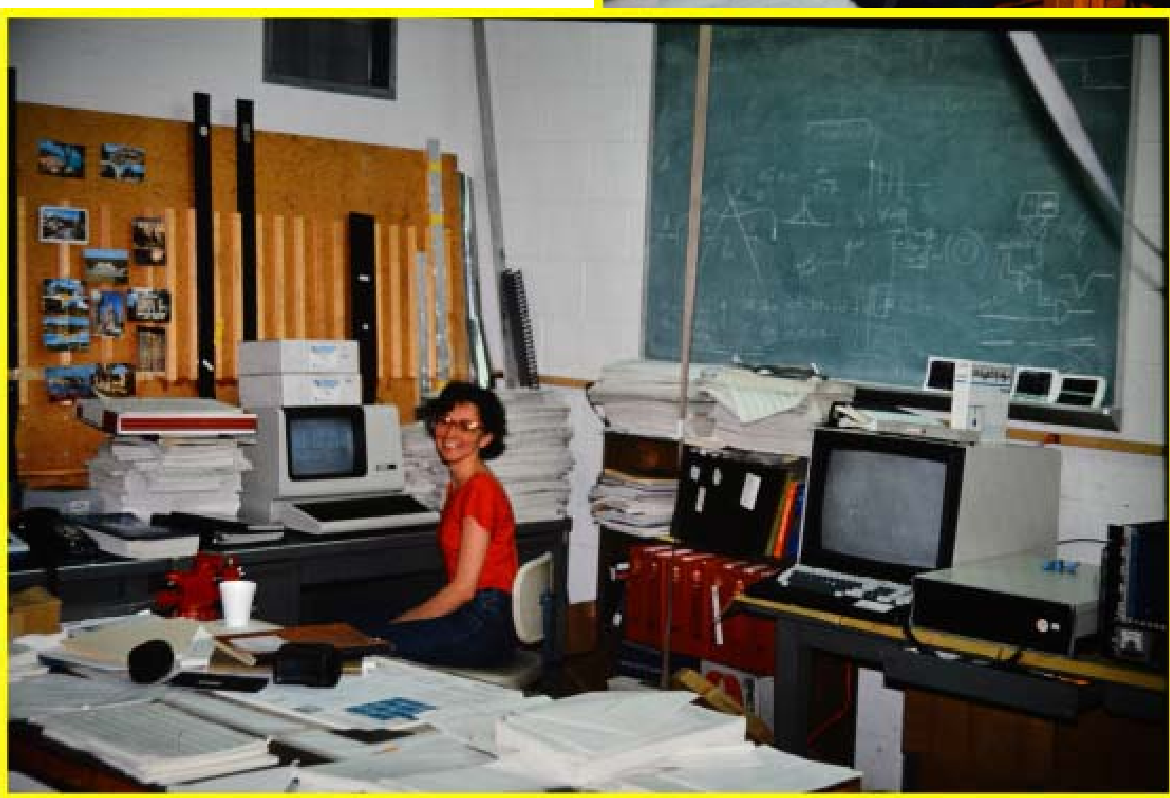


"...you are in a twisty maze of passageways, all alike"


MAZE .SAV 22 27-Jun-1985
XONIX2.SAV 23 10-Jan-1986
STALK .SAV 49 24-Feb-1989
GD1990.KLD 6 29-Nov-1989
XONIX .SAV 23 12-Apr-1986
BIAT .DAT 3 12-Apr-1997
COPTER.SAV 6 17-May-1985
CHESS0.SAV 23 30-May-1988
TENIS .SAV 7 17-Jul-1987
TRASSA.SAV 219 05-Nov-1987
KALEND.SAV 15 13-Oct-1983
FUTBOL.SAV 13 05-Jun-1989
BOMBA .SAV 26 05-Aug-1983
KALAH .SAV 18 10-Mar-1986
BEAST .SAV 19 22-Mar-1986
BOA .SAV 20 23-Dec-1985
PENT .SAV 32 28-Feb-1989
GD1989.KLD 6 04-Dec-1989
POKER .SAV 52 15-Apr-1983
ROBOT .SAV 6 22-May-1986
BIAT .SAV 20 12-Apr-1997
GOROD .SAV 29 12-Apr-1997
TIR .SAV 8 22-Jul-1985
HANOY .SAV 19 17-May-1985
CHESS .SAV 20 11-Oct-1986
TETRIS.SAV 28 12-Apr-1986
REVERS.SAV 12 17-May-1985
54 Files, 1207 Blocks
383 Free blocks



Anybody remembers what was THIS ?







Fermilab Village

“Princeton House”
in Sauk circle

Maybe E615 the first collaboration to get a terminal in the village to profit of the night….

… to push E615 tapes through the reconstruction program running at the computer center - 7th flloor of the Hi-Rise.

~40 M events written on tape.
A final sample of 103K events with $M > 2.5 GeV/c^2$ and $x_F > 0.3$

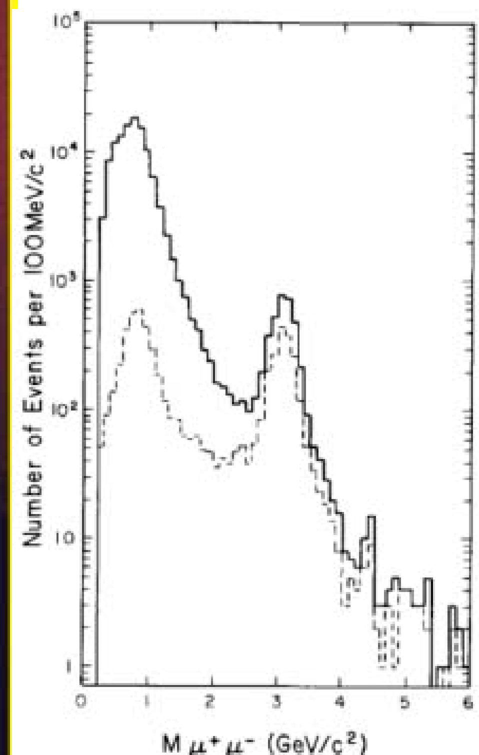
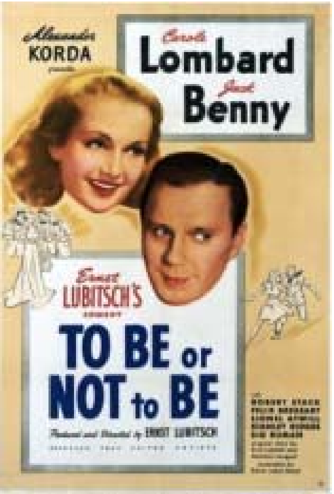


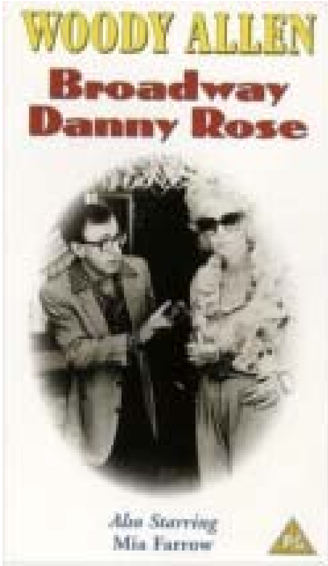
Fig. 17. The $\mu^+\mu^-$ pair invariant-mass spectrum for the entire sample of Level-1 triggers collected during the 255 GeV/c π^- run (solid curve) compared to the subsample of Level-1 triggers that also satisfied the second- and third-level trigger requirements (dashed curve).

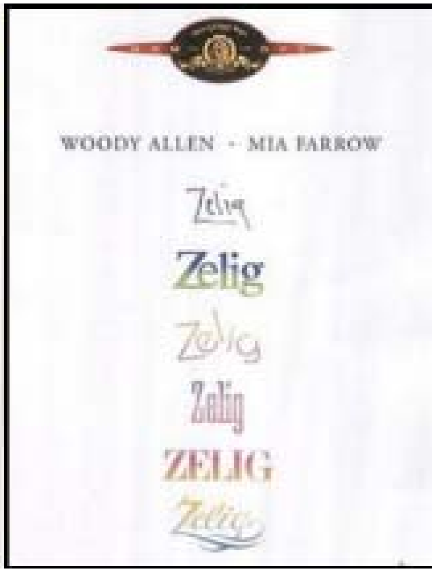


E615 FUN

E615-Cineforum of **screwball comedies** in the "Chicago house" at FNAL village with the help of **Kelby Anderson**

From Woody Allen movies to … a galaxy far far away ...





…more E615 FUN

White Hen

Pal Joey's - BATAVIA

Chez Leon

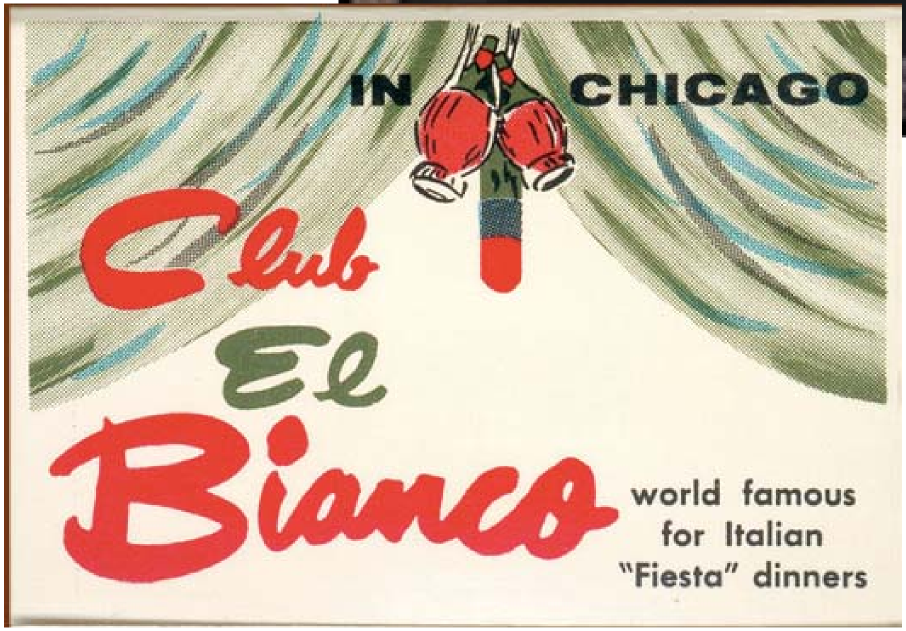
Little Owl Restaurant

ON THE FOX

Ho:

More About
Geneva, IL

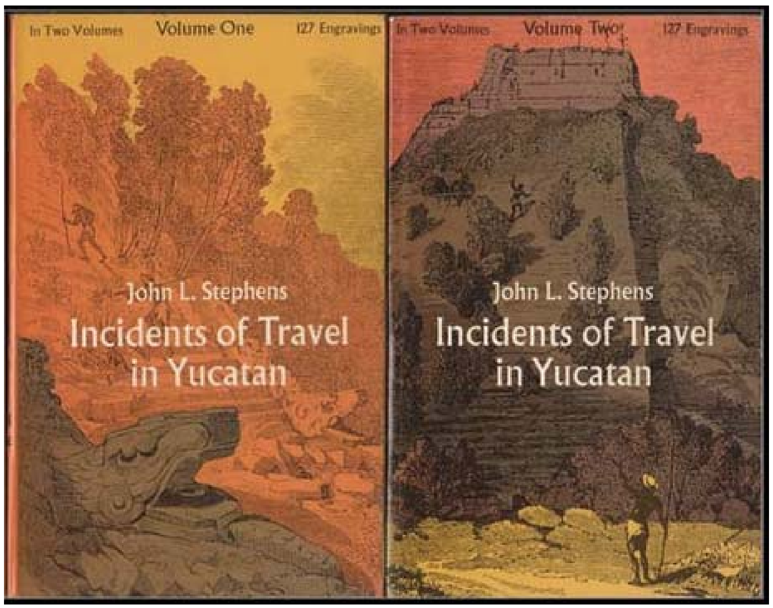
GENEVA DINING

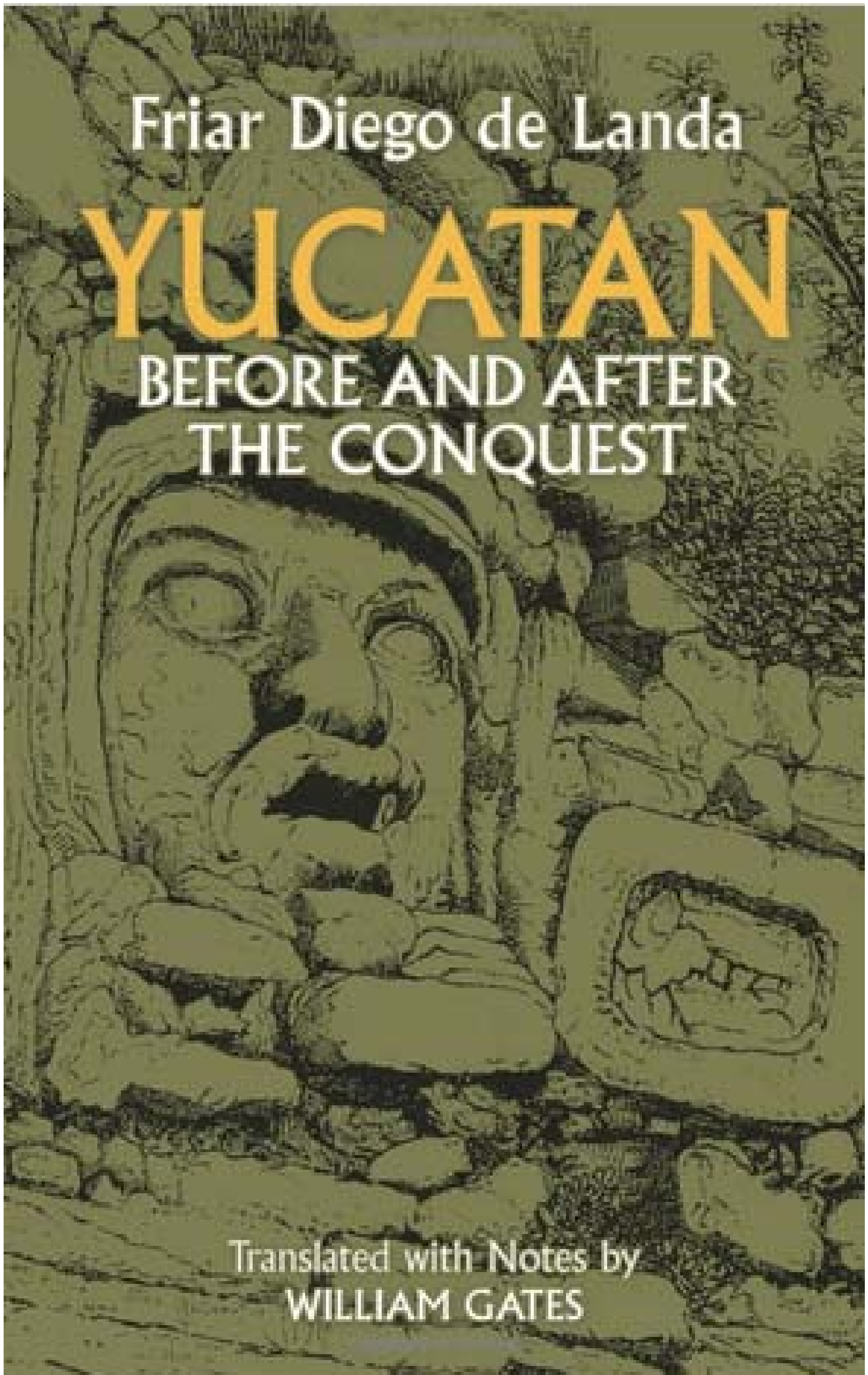


E615 - time for far away FUN

"Rosie" magnet incident…

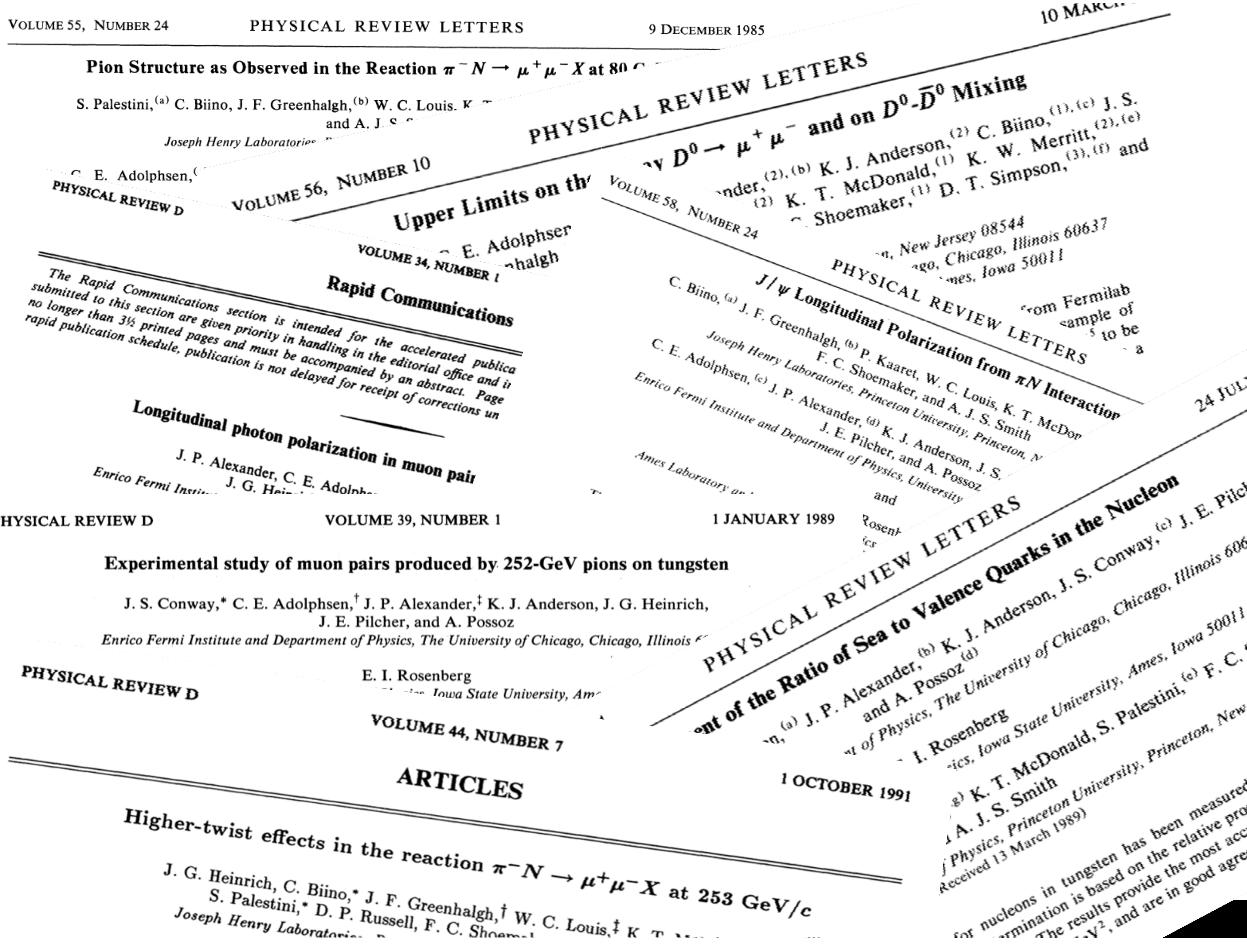
Kirk suggesting the
best vacation destination!





Summers
in
Princeton !

Happily
house
and
dog sitting


VOLUME 55, NUMBER 24
PHYSICAL REVIEW LETTERS
9 DECEMBER 1985
Pion Structure as Observed in the Reaction π⁻N → μ⁺μ⁻X at 80
S. Palestini,(a) C. Biino, J. F. Greenhalgh,(b) W. C. Louis.
Joseph Henry Laboratories
PHYSICAL REVIEW LETTERS
VOLUME 56, NUMBER 10
10 MARCH
D⁰ → μ⁺μ⁻ and on D⁰-D̄⁰ Mixing
Upper Limits on th
K. J. Anderson,(2) C. Biino,(1),(c) J. S.
K. T. McDonald,(1) K. W. Merritt,(2),(e)
D. T. Simpson,(3),(f) and
Shoemaker,(1)
New Jersey 08544
Chicago, Illinois 60637
Ames, Iowa 50011
PHYSICAL REVIEW D
VOLUME 34, NUMBER 1
Rapid Communications
The Rapid Communications section is intended for the accelerated publica
submitted to this section are given priority in handling in the editorial office and i
no longer than 3½ printed pages and must be accompanied by an abstract. Page
rapid publication schedule, publication is not delayed for receipt of corrections un
Longitudinal photon polarization in muon pair
J. P. Alexander, C. E. Adolph
Enrico Fermi Insti
VOLUME 58, NUMBER 24
PHYSICAL REVIEW LETTERS
J/ψ Longitudinal Polarization from πN Interaction
C. Biino,(a) J. F. Greenhalgh,(b) P. Kaaret, W. C. Louis, K. T. McDon
F. C. Shoemaker, and A. J. S. Smith
Joseph Henry Laboratories, Princeton University, Princeton, N
C. E. Adolphsen,(c) J. P. Alexander,(d) K. J. Anderson, J. S.
J. E. Pilcher, and A. Possoz
Enrico Fermi Institute and Department of Physics, University
Ames Laboratory
PHYSICAL REVIEW D
VOLUME 39, NUMBER 1
1 JANUARY 1989
Experimental study of muon pairs produced by 252-GeV pions on tungsten
J. S. Conway,* C. E. Adolphsen,† J. P. Alexander,‡ K. J. Anderson, J. G. Heinrich,
J. E. Pilcher, and A. Possoz
Enrico Fermi Institute and Department of Physics, The University of Chicago, Chicago, Illinois
E. I. Rosenberg
Iowa State University,
PHYSICAL REVIEW LETTERS
of the Ratio of Sea to Valence Quarks in the Nucleon
J. P. Alexander,(b) K. J. Anderson, J. S. Conway,(c) J. E. Pilc
and A. Possoz(d)
of Physics, The University of Chicago, Chicago, Illinois
I. Rosenberg
Iowa State University, Ames, Iowa 50011
K. T. McDonald, S. Palestini,(e) F. C.
A. J. S. Smith
Physics, Princeton University, Princeton, New
Received 13 March 1989)
24 JUL
PHYSICAL REVIEW D
VOLUME 44, NUMBER 7
1 OCTOBER 1991
ARTICLES
Higher-twist effects in the reaction π⁻N → μ⁺μ⁻X at 253 GeV/c
J. G. Heinrich, C. Biino,* J. F. Greenhalgh,† W. C. Louis,‡
S. Palestini,* D. P. Russell, F. C. Shoem
Joseph Henry Laborator

Direct CP Violation in the neutral Kaon system

Experimental situation on ε/ε' from previous generation experiments (early 90's):

- **NA31 (CERN)** **$(23.0 \pm 6.5) \times 10^{-4}$**
- **E731 (Fermilab)** **$(7.4 \pm 5.9) \times 10^{-4}$**

$(\varepsilon'/\varepsilon) \neq 0$? $\Rightarrow$ Second generation of experiments:

- **KTEV (Fermilab)**
- **NA48 (CERN)**

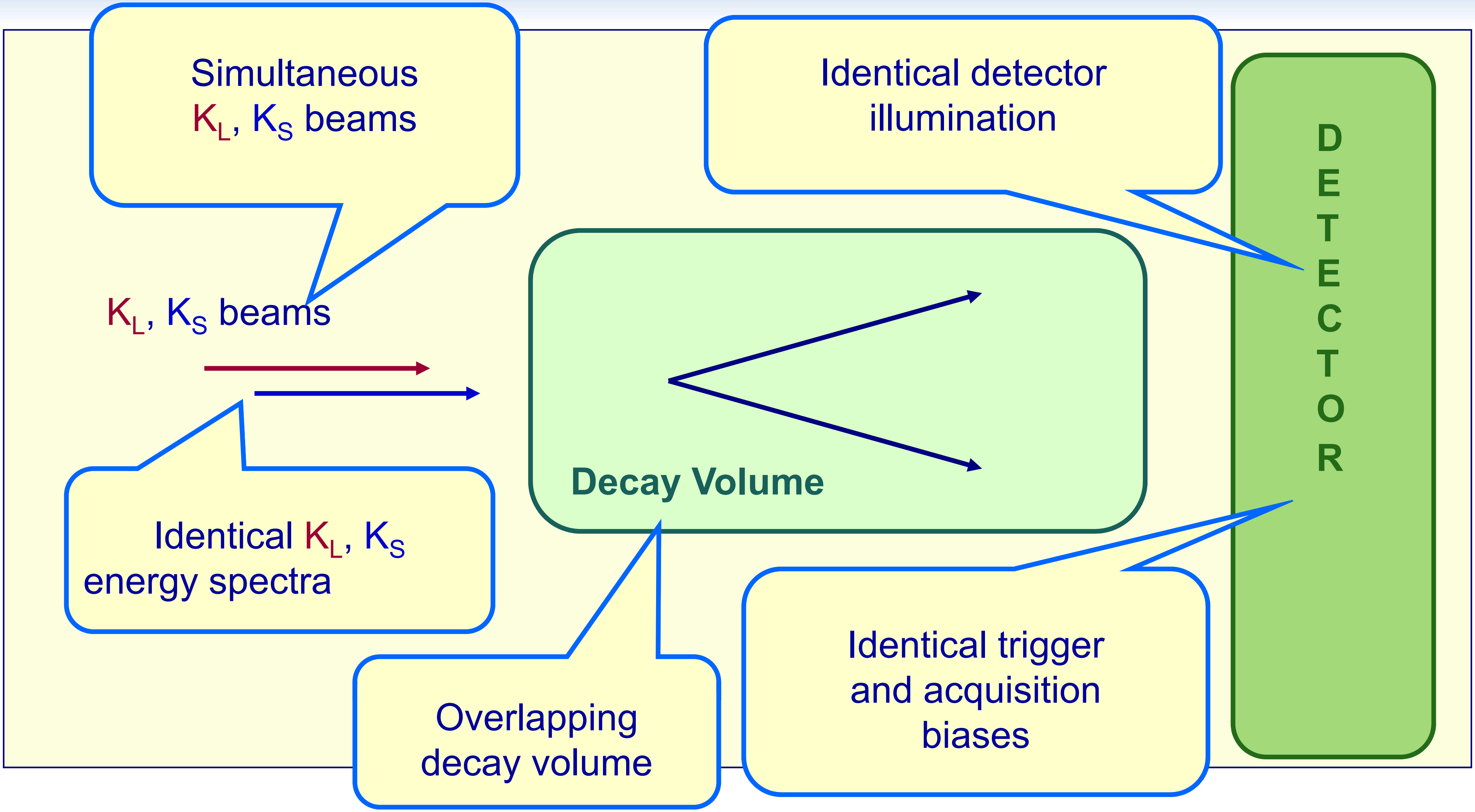
Measure the double ratio:

$$R = \frac{BR(K_L \to \pi^0\pi^0)\, BR(K_S \to \pi^+\pi^-)}{BR(K_S \to \pi^0\pi^0)\, BR(K_L \to \pi^+\pi^-)} = 1 - 6\, Re(\varepsilon'/\varepsilon)$$

by counting the number of decays in two beams of K_L and K_S

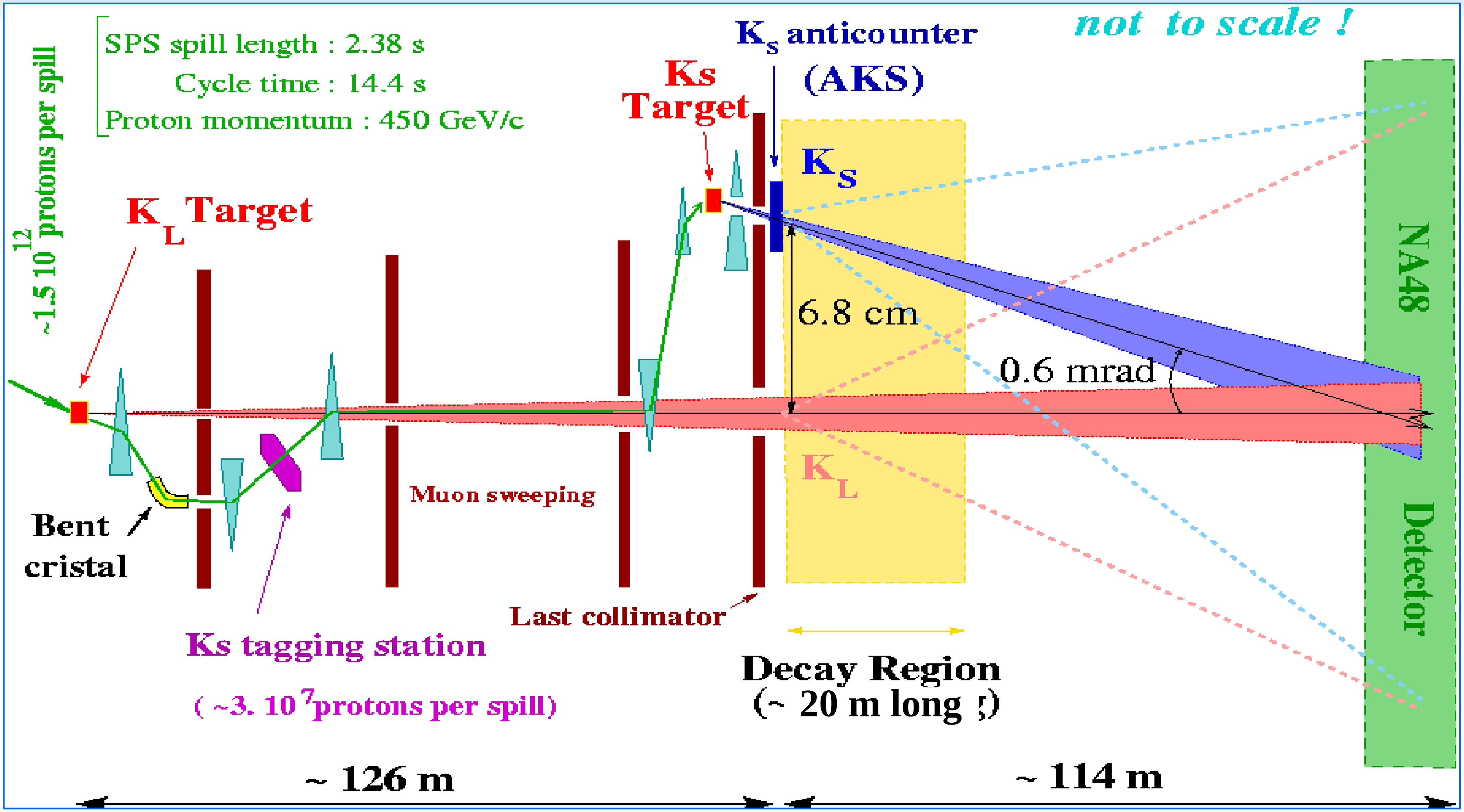
Need $> 3.\ 10^6$ $K_L \to \pi^0\pi^0$ for stat. error on $R < 0.1\%$
and look for cancellation of systematic effects related to differences in acceptance, efficiency, backgrounds

The ideal experiment…



Exploit cancellations of the double beam method i.e. for perfectly overlapping and concurrent beams the corrections are minimized

NA48 simultaneous and collinear K_L & K_S beams



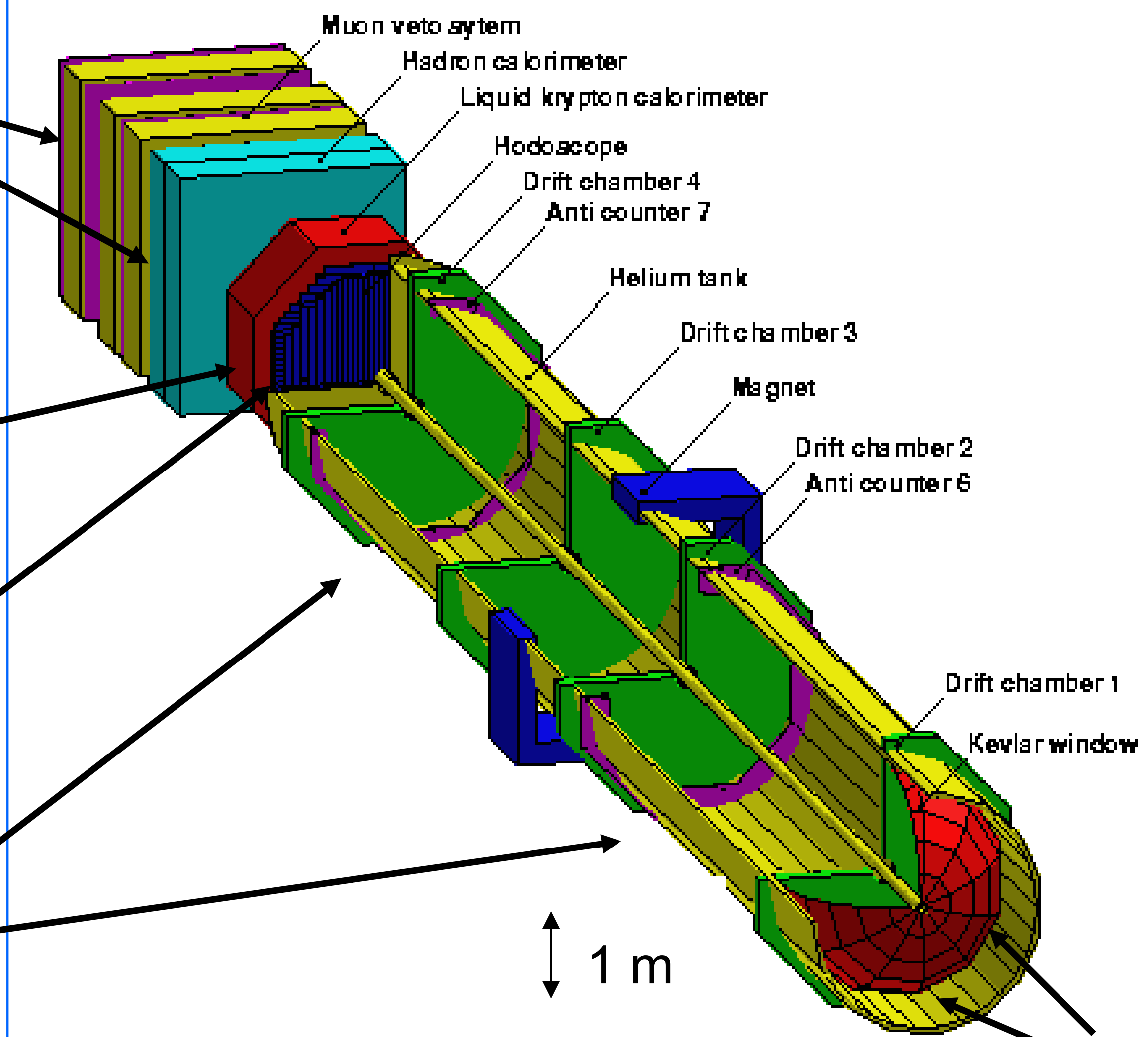
K_S from protons on target

K_S and K_L beams are distinguished by proton tagging upstream of the K_S target

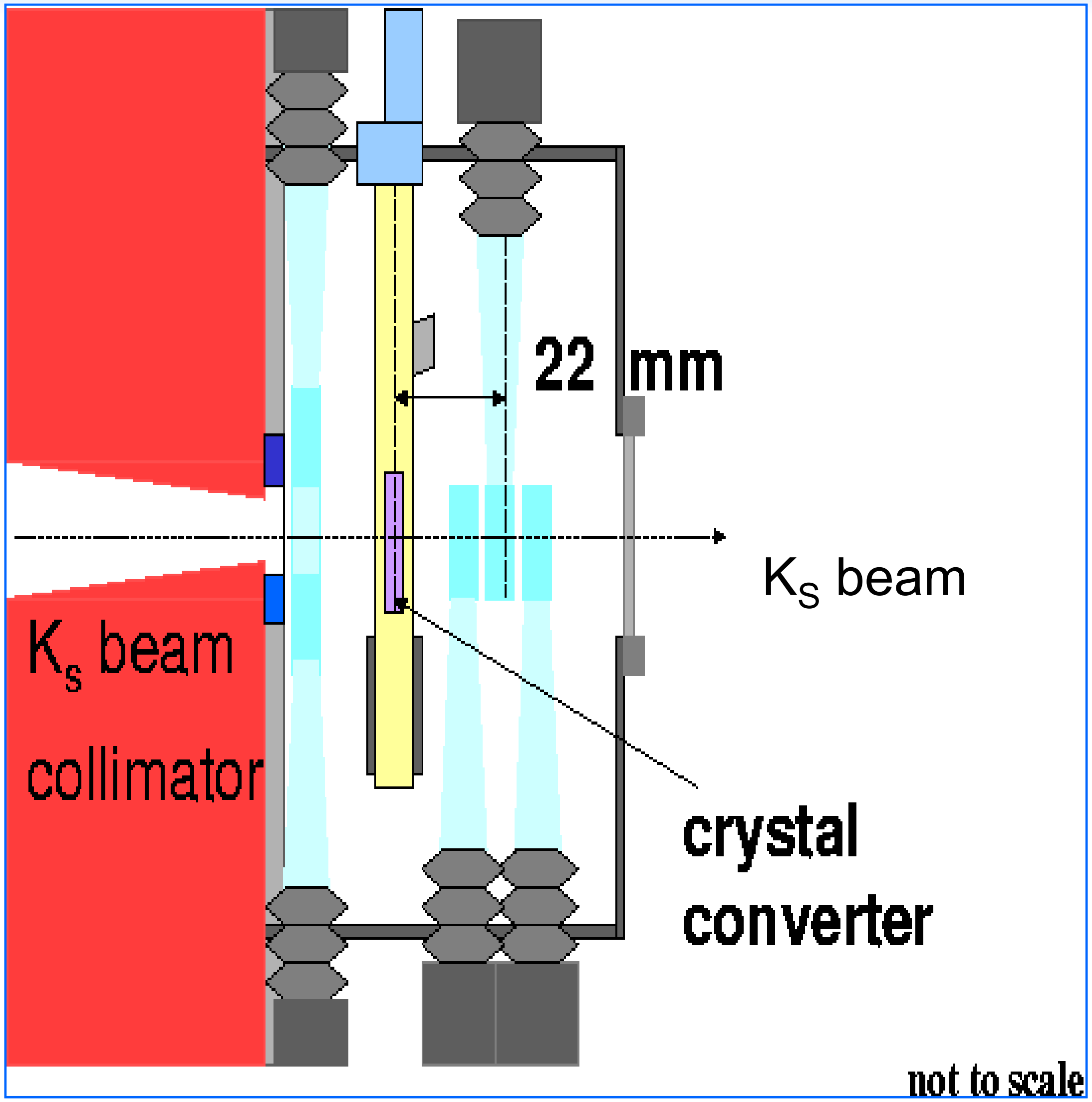
NA48 detector

- Muon veto and hadron calorimeter (background, trigger)
- Quasi homogeneous liquid krypton calorimeter to detect $\pi^0\pi^0$ events
- Scintillation hodoscope (trigger and timing $\pi^+\pi^-$)
- Magnetic spectrometer to detect $\pi^+\pi^-$ events
  $\sigma(P)/P \cong 0.5\,\% \oplus 0.009\,P(\mathrm{GeV}/c)\%$

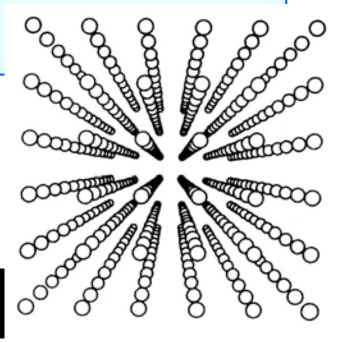
(≅ 1% for 100 GeV/c track momentum)



NA48: the AKS anticounter



- Defines beginning of decay region for $\pi^+\pi^-$ and $\pi^0\pi^0$ K_S decays
- Plastic scintillation counters following a
- Photon converter :
  - iridium crystal 3mm thick , 0.98 X_0 for amorphous iridium $\Rightarrow$ 1.79 X_0 for the **aligned crystal** and less scattering



Exploiting photon convertion enhancement in an aligned crystal

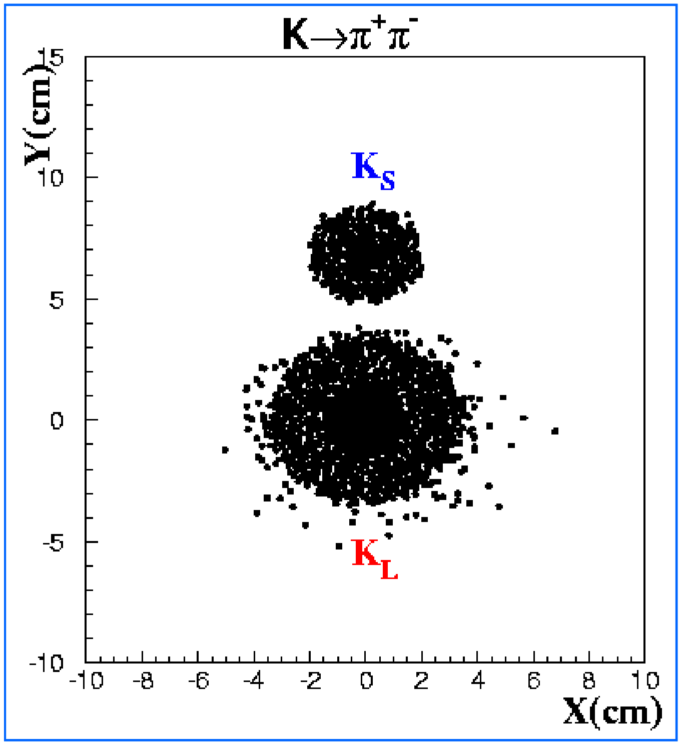
NA48 Tagging performance

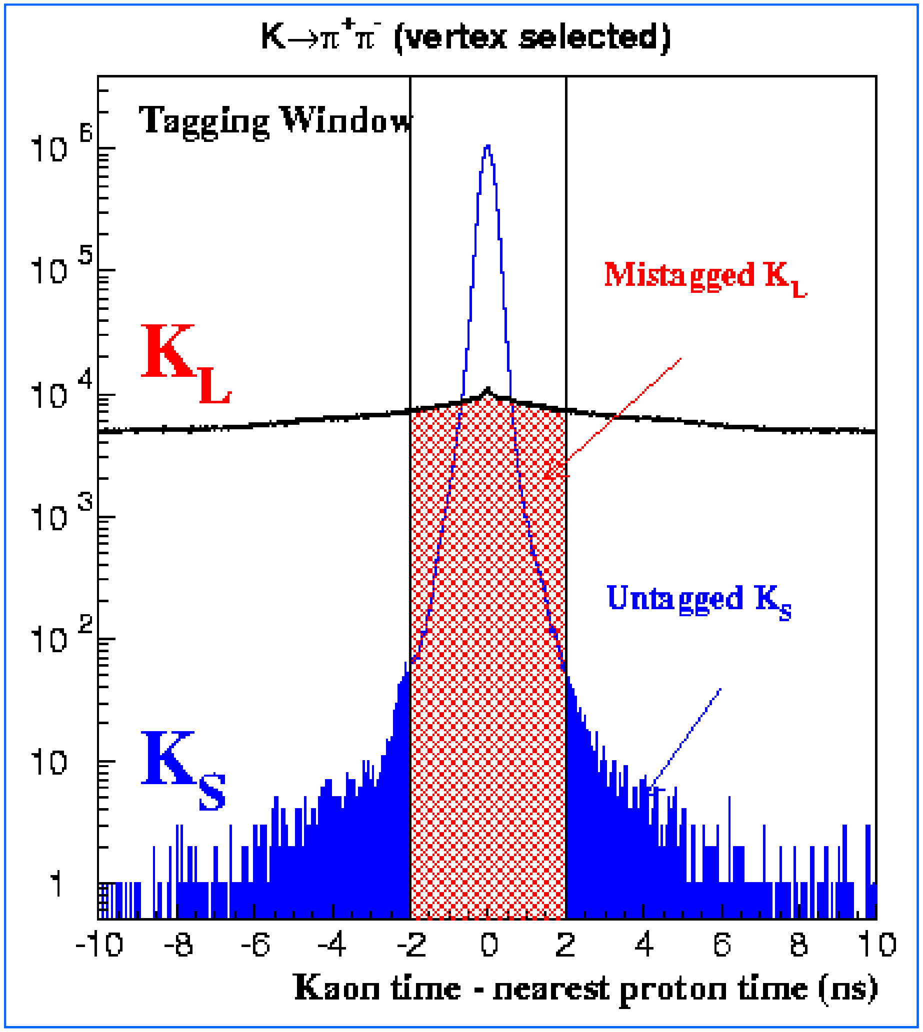
NA48: K_S are tagged using the difference between the event time and the nearest proton in the Tagger:

$$K_S = |t_{tag} - t_K| \leq 2ns$$

$$K_L = |t_{tag} - t_K| > 2ns$$

Done for both $\pi^+\pi^-$ and $\pi^0\pi^0$



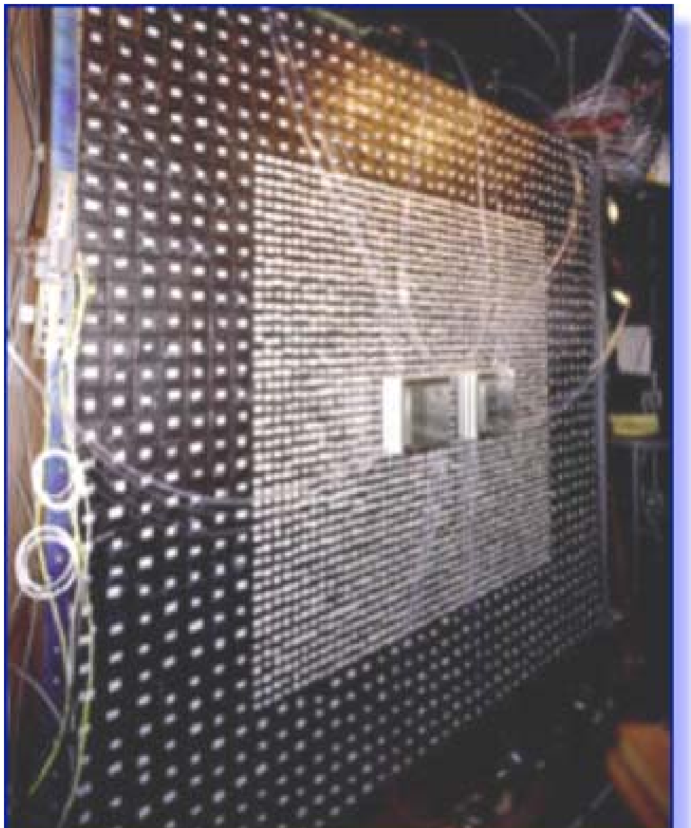


Identify K_S, K_L with decay vertex position in transverse plane

NA48 and KTeV: the art of calorimetry

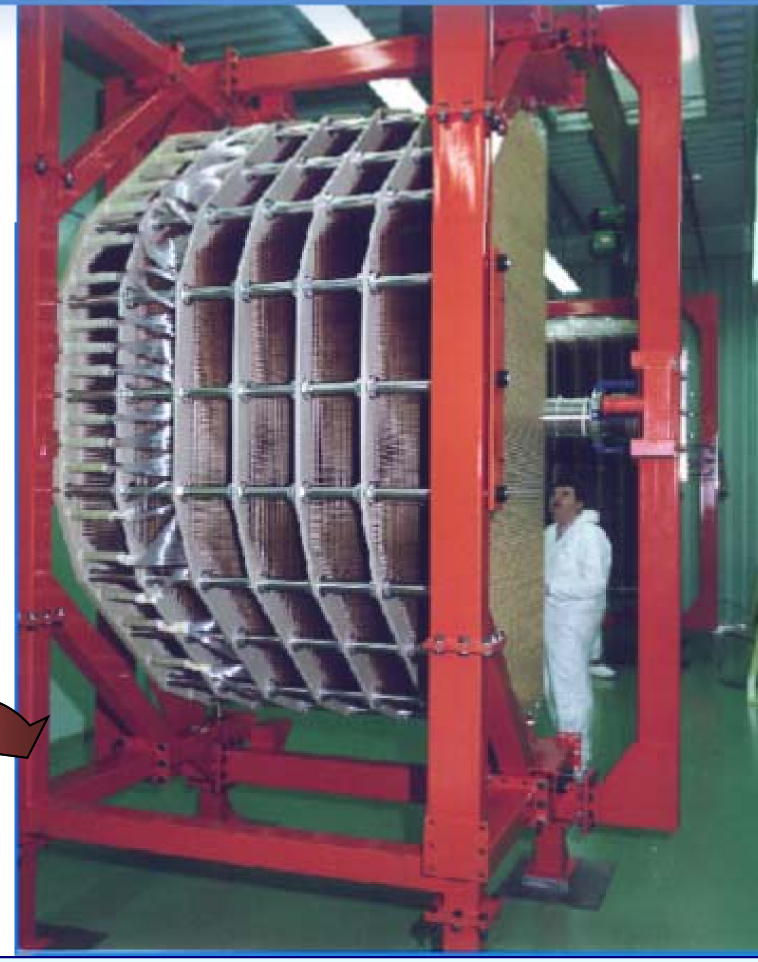
- **3100 CsI crystals**
- **0,5 m depth (~27 X_0)**
- **$\sigma(E)/E \cong$ 2.0 % / $\sqrt{E} \oplus$ 0.45%**

(E in GeV) ; **0.7% energy resolution for 19 GeV γ**



KTeV

NA48

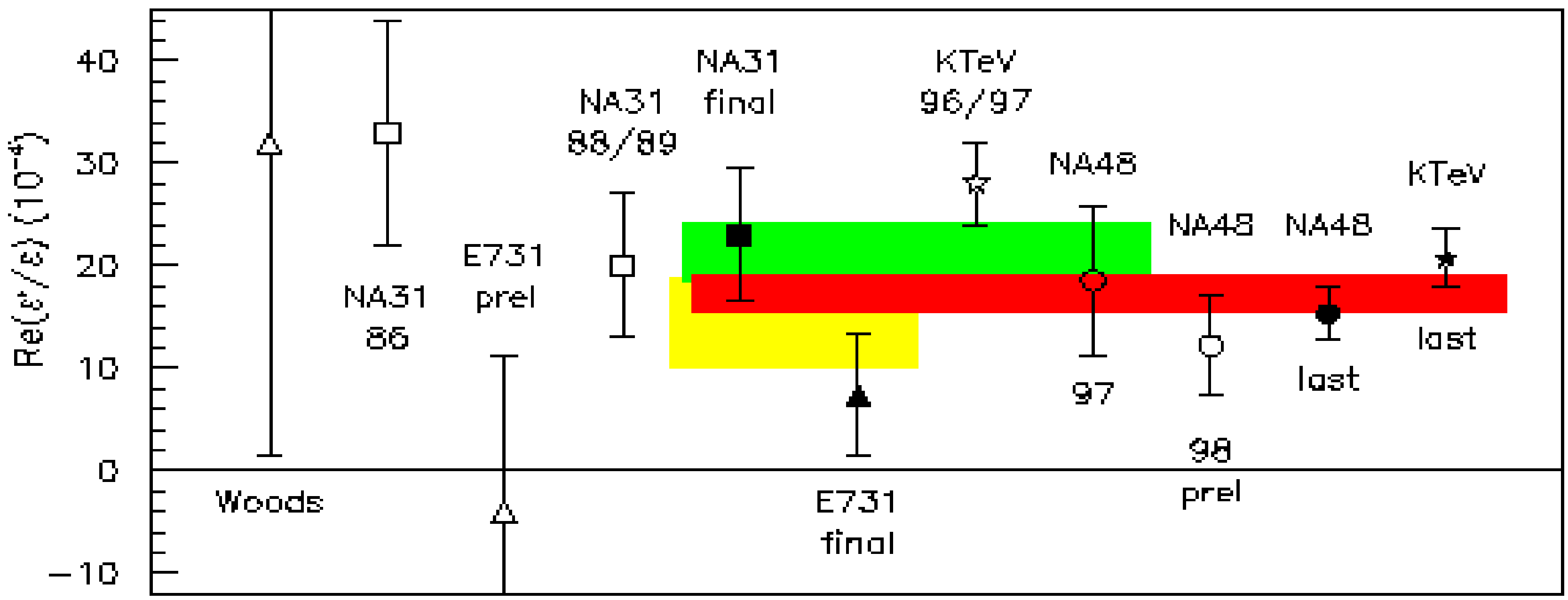


- **10 m^3 of LKr (13212 cells)**
- **1.25 m depth (~27 X_0)**
- **$\sigma(E)/E \cong$ 3.2 % / $\sqrt{E} \oplus$ 0.09 /E $\oplus$ 0.42%**

(E in GeV) ;**<1% energy resolution for 25GeV γ**

Unprecedented stability ; <0.1% corrections

Experimental results comparison

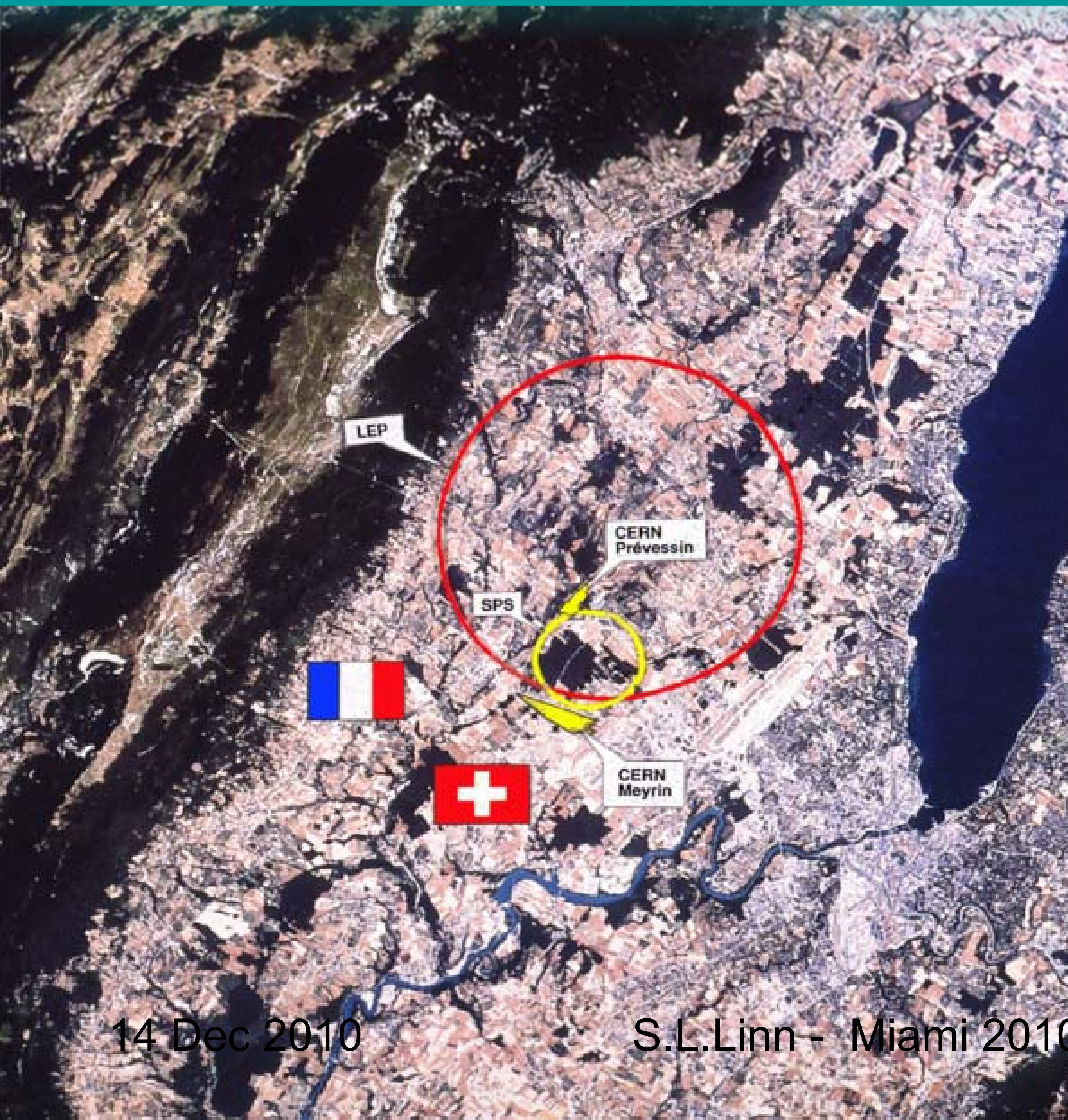


PDG average: Re(ε' / ε) = **(16.5 ± 2.3) 10⁻⁴**

Direct CP violation established

The Large Hadron Collider

The Large Hadron Collider is a 27 km long pp collider ring housed in a tunnel about 100 m underground near Geneva



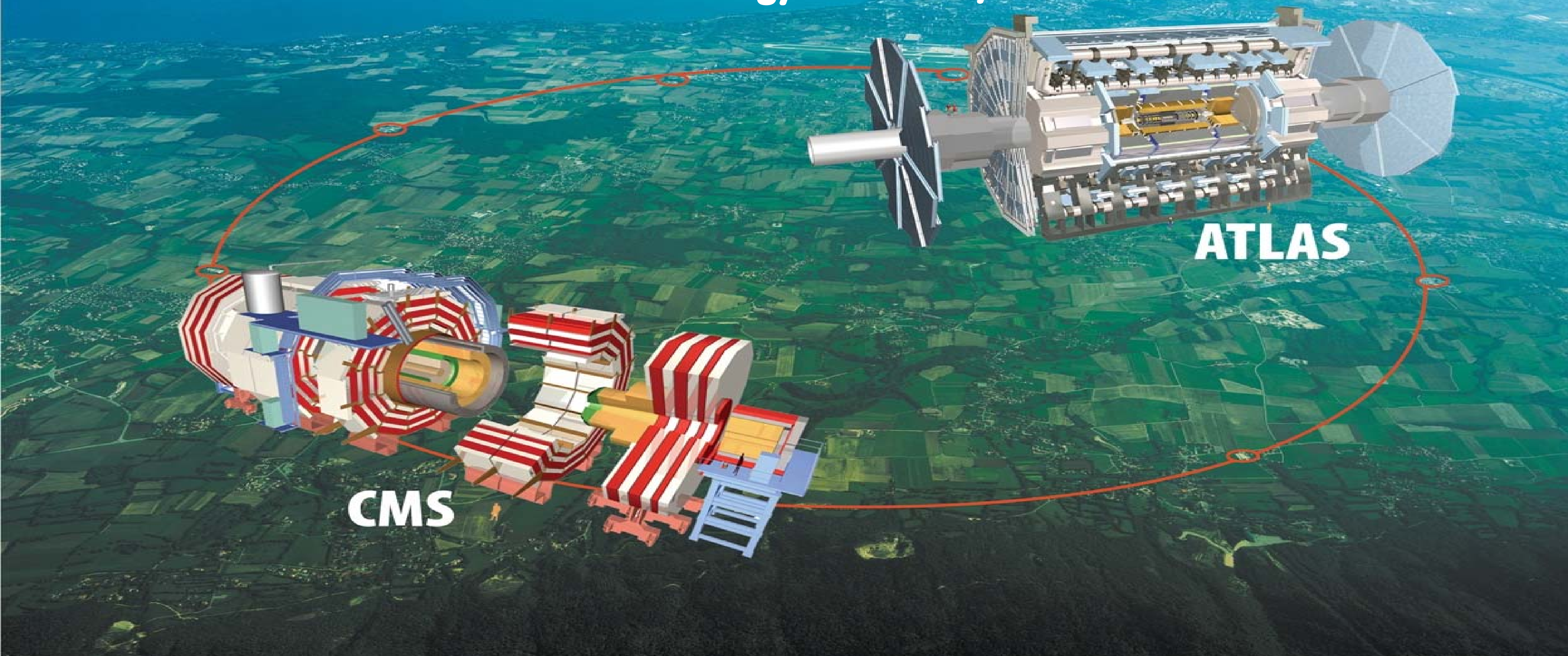
- Diameter 8.5 km
- Beam energy: 7 TeV
- Luminosity: 10^{34}
- Protons/bunch: 1.15×10^{11}
- Bunches: 2808
- Bunch spacing: 25 ns
- Machine current: 0.5 A
- Beam Stored energy: 362 MJ
- Operating temperature: 1.9 K
- Number of magnets: ~9300
- Magnet Stored Energy 8800 MJ
- Power consumption: ~120 MW
- Cost: 9.0×10^{9} $

The LHC collider

Two general purpose detectors, designed to search for the Higgs Boson

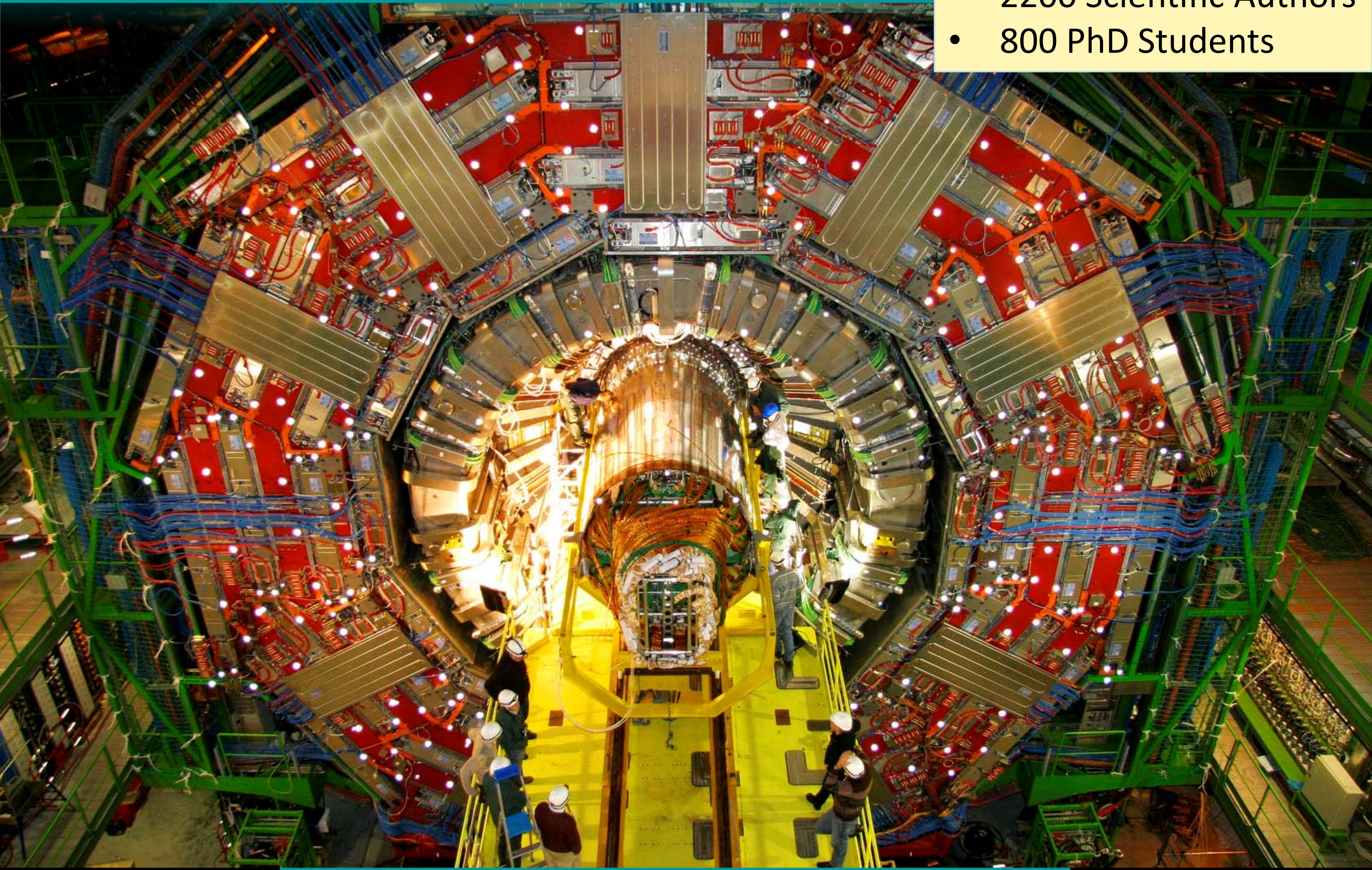
The Large Hadron Collider (LHC), one of the largest and truly global scientific projects ever

- **pp collisions at a centre of mass energy of 7, 8 and 13 TeV**
- **PbPb collisions at a centre of mass energy of 2.76 TeV/nucleon**



The CMS collaboration

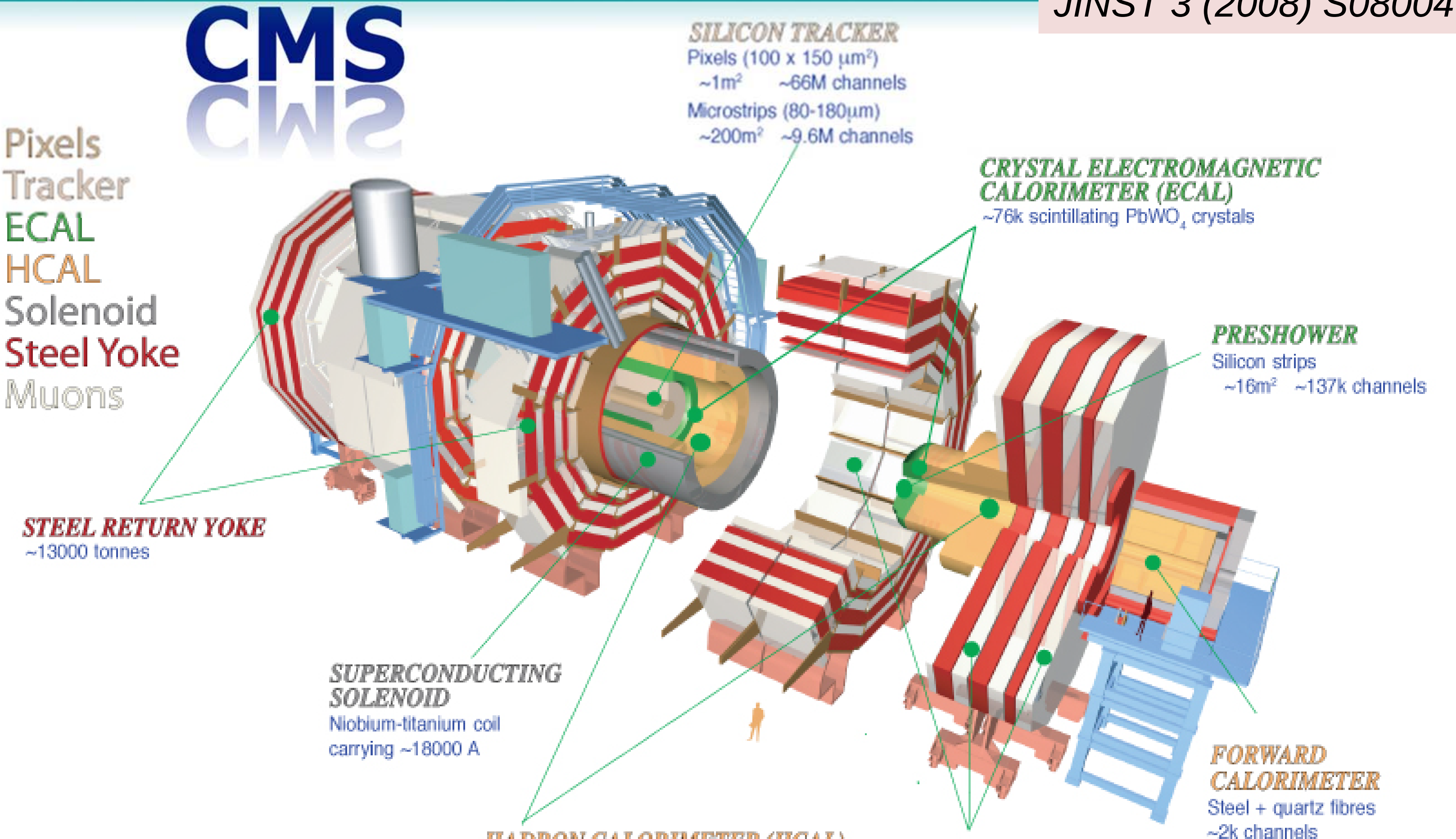
- 42 Countries
- 190 Institutions
- 2200 Scientific Authors
- 800 PhD Students



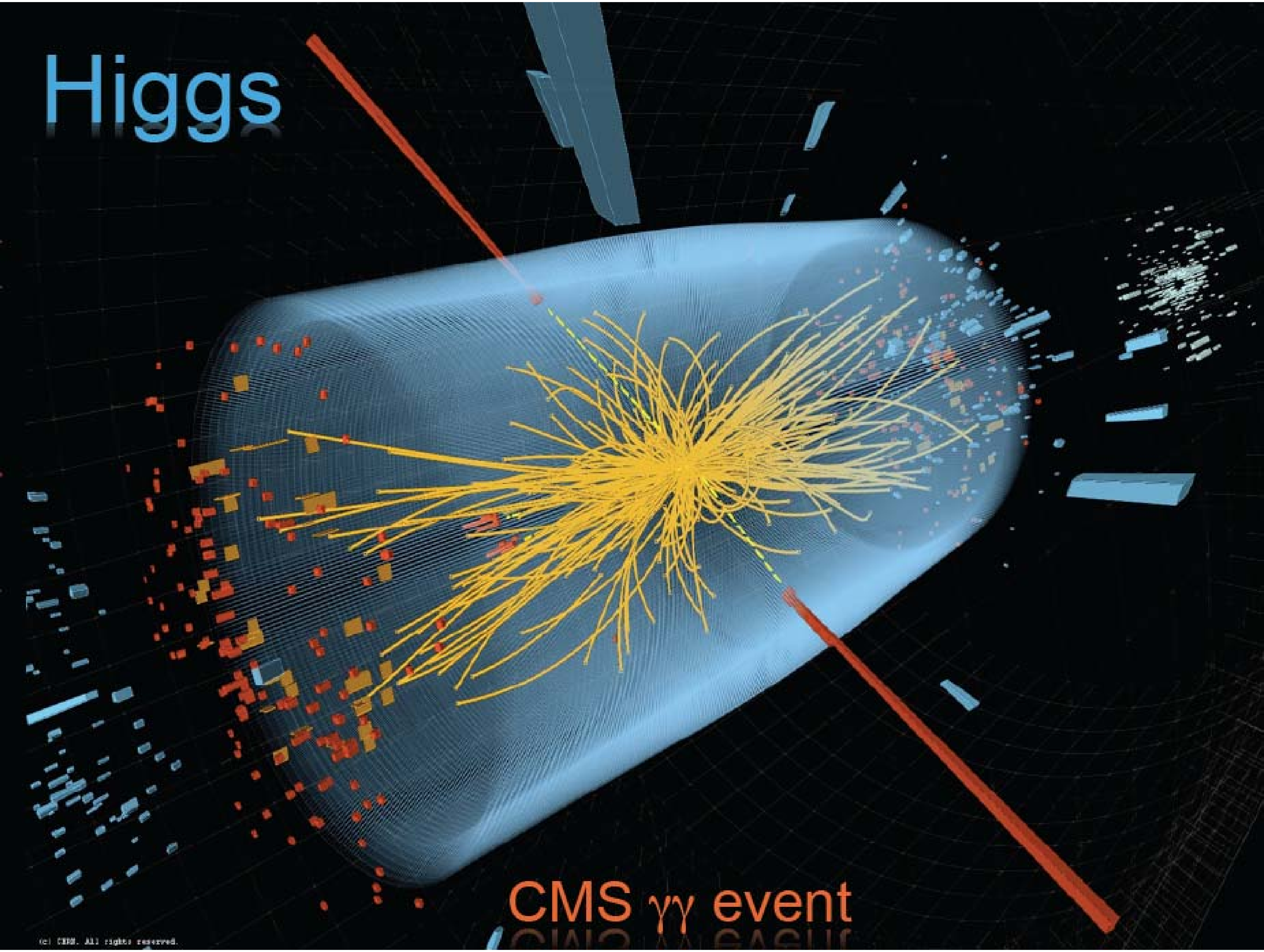
The CMS Detector

http://cms.web.cern.ch/

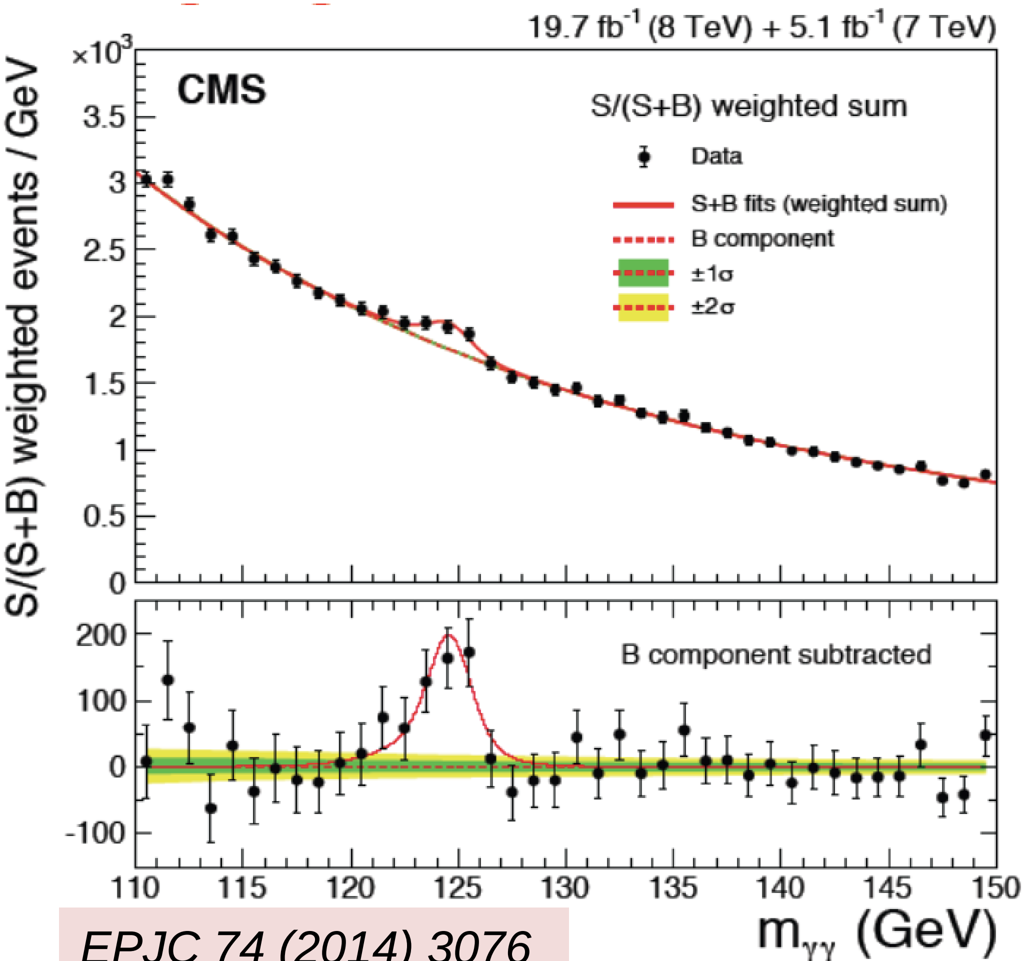
JINST 3 (2008) S08004



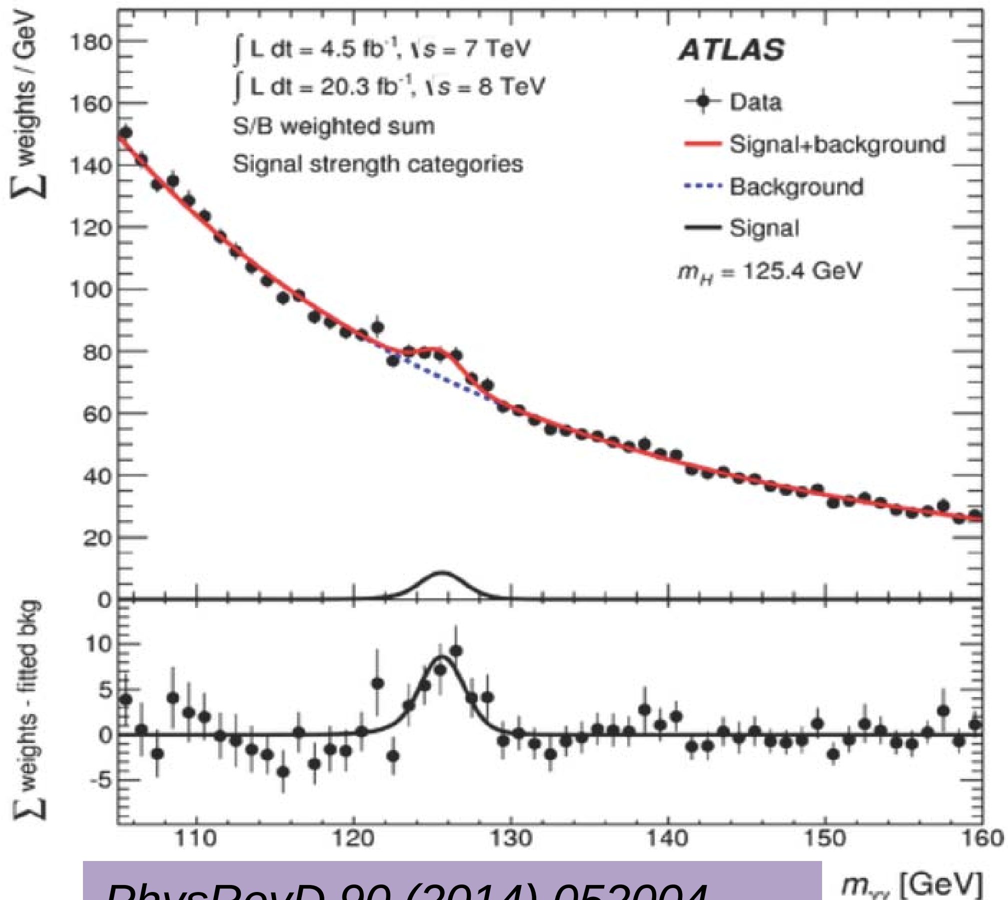
Total weight	**: 14000 tonnes**
Overall diameter	**: 15.0 m**
Overall length	**: 28.7 m**
Magnetic field	**: 3.8 T**


Higgs
CMS γγ event
(c) CERN. All rights reserved.

Higgs → γγ results



EPJC 74 (2014) 3076



PhysRevD 90 (2014) 052004

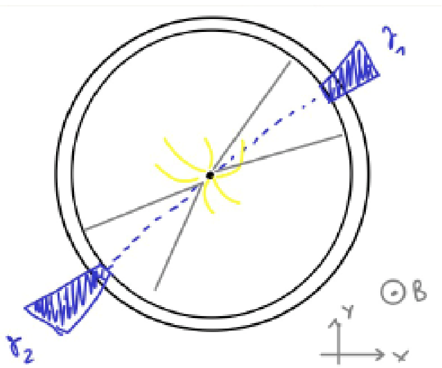
m_H = 124.7 ± 0.4 GeV
Significance = 5.7 (expected 5.2) σ
$\mu = \sigma BR/\sigma_{SM} BR_{SM}$ = 1.14 + 0.26 – 0.23
Γ_H < 3.4 GeV @ 95% CL

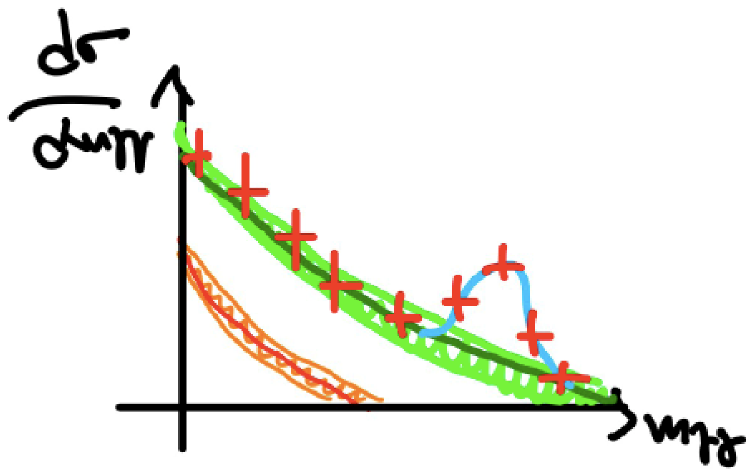
m_H = 126.0 ± 0.5 GeV
Significance = 5.2 (expected 4.6) σ
$\mu = \sigma BR/\sigma_{SM} BR_{SM}$ = 1.17 ± 0.27
Γ_H < 5.0 GeV @ 95% CL

…search for high mass diphoton resonances

Why diphoton searches?

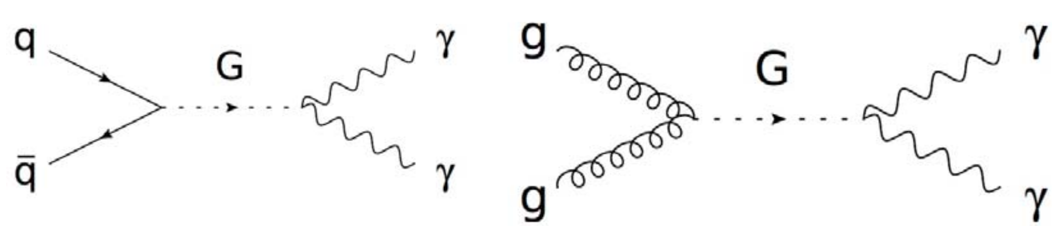
Clean signal over smooth and well known background (i.e. H(125) → γγ) :
two high p_T photon candidates





Several models of physics beyond SM.

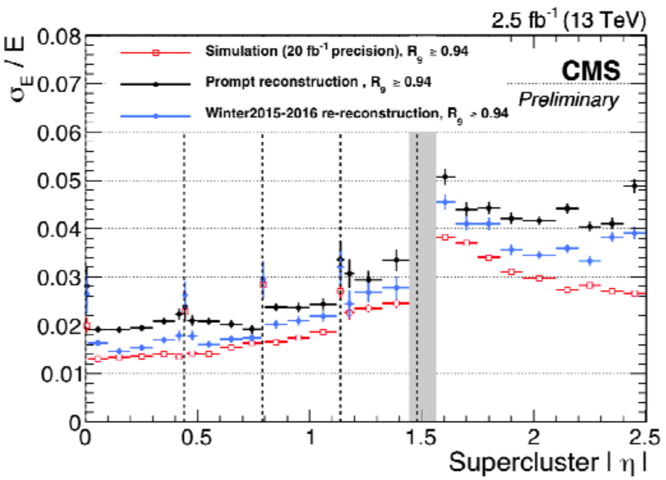
Models with extended Higgs sectors predict appearance of spin-0 resonances;
Extra-dimensional models predict appearance of spin-2 resonances.

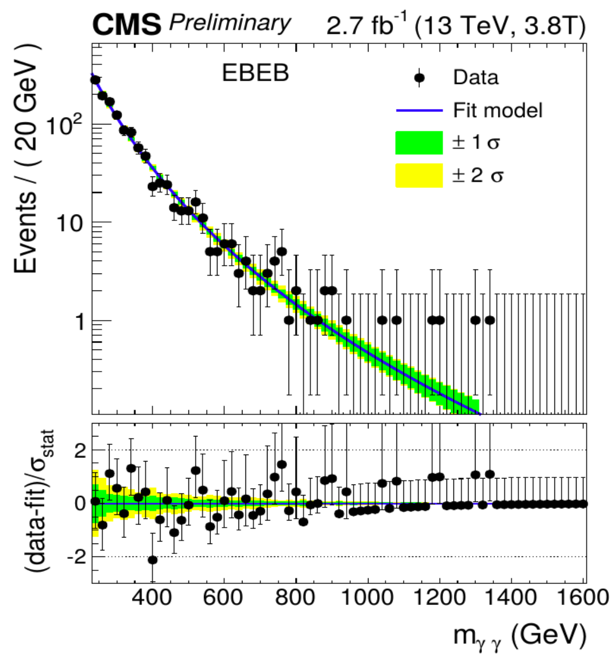


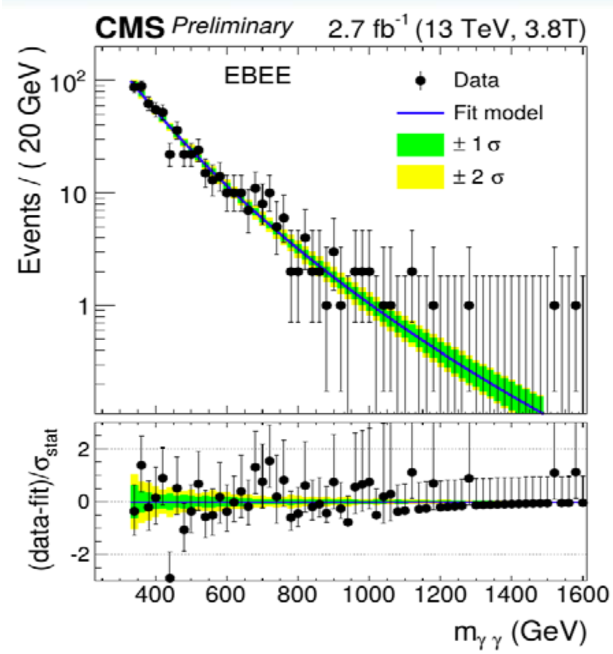
Mass spectra at 3.8 T and 0 T

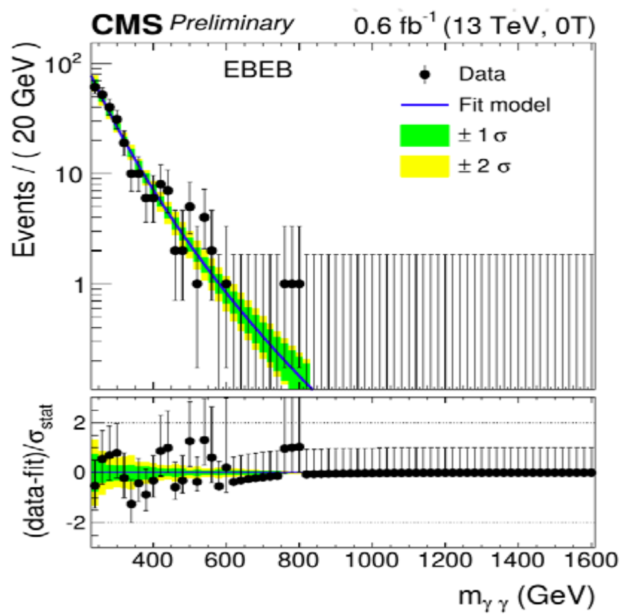
Data re-reconstructions during winter shut-down, using ECAL updated channel-to-channel calibration, crucial for energy resolution.

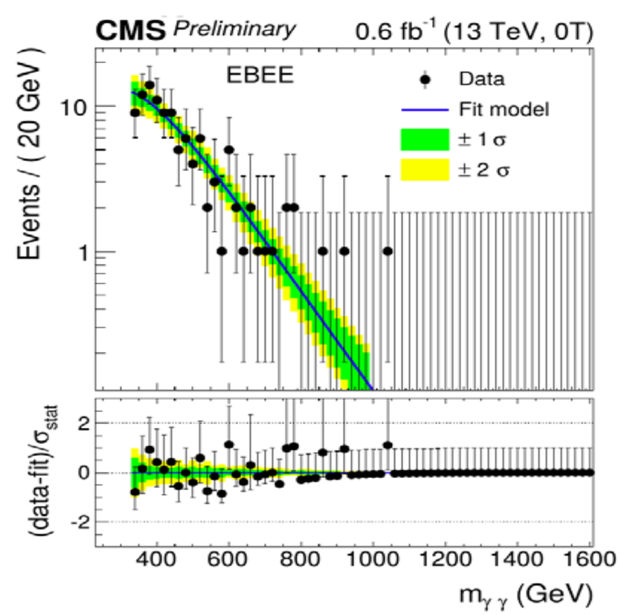
Additional 0.6 fb-1 dataset , recorded at B=0T.





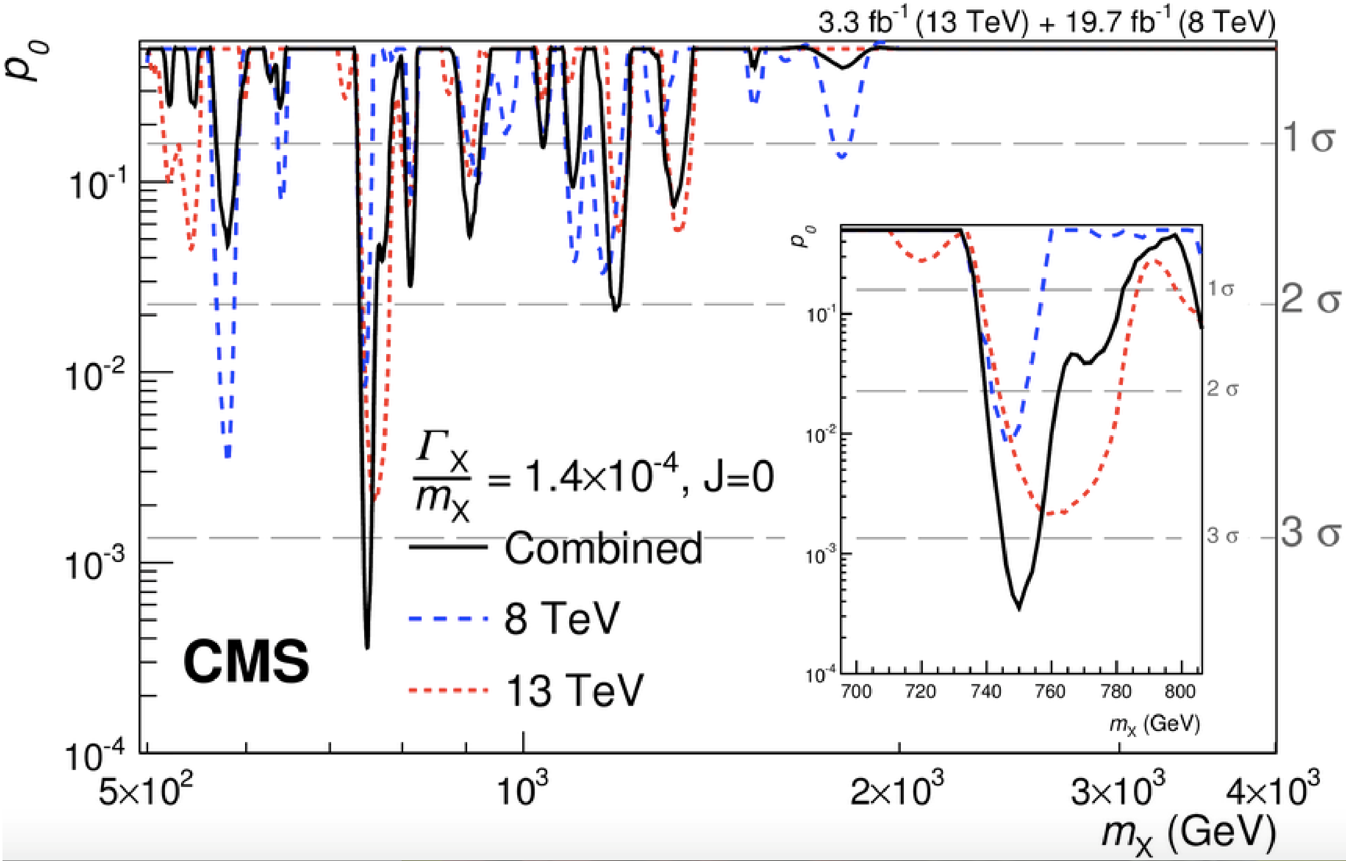






30% improvement in mass **resolution** above 500GeV.

Limits are set on scalar resonances produced through gluon-gluon fusion, and on Randall-Sundrum gravitons. A modest excess of events compatible with a narrow resonance with a mass of about 750 GeV is observed. The local significance of the excess is approximately 3.4 standard deviations. The significance is reduced to 1.6 standard deviations once the effect of searching under multiple signal hypotheses is considered.



Just a statistical fluctuation?

More data needed to verify excess origin: looking forward to results from 2016 LHC run

As a young physicist coming to Princeton to work on E615 was the best possible experience.
Working on building and commissioning an experiment, take data, do the analysis and write the papers in just a few years!

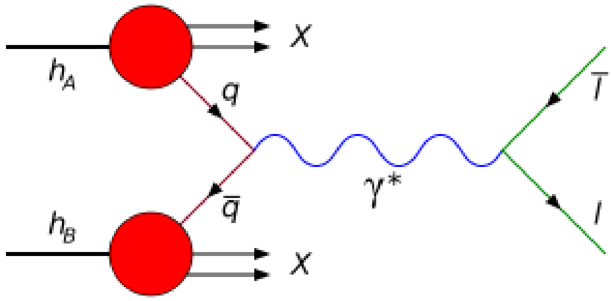
I want to celebrate Kirk work: a great school of physics.

But thanks to Kirk generosity it was much much more than a work experience!

Thank you!

…Rosanna Cester, at the origin of the Torino-Princeton connection that brought me here in 1982, is sending her congratulations to Kirk

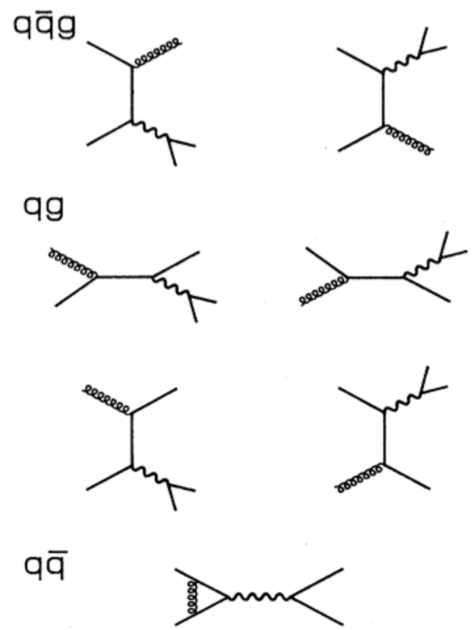
Spare Slides



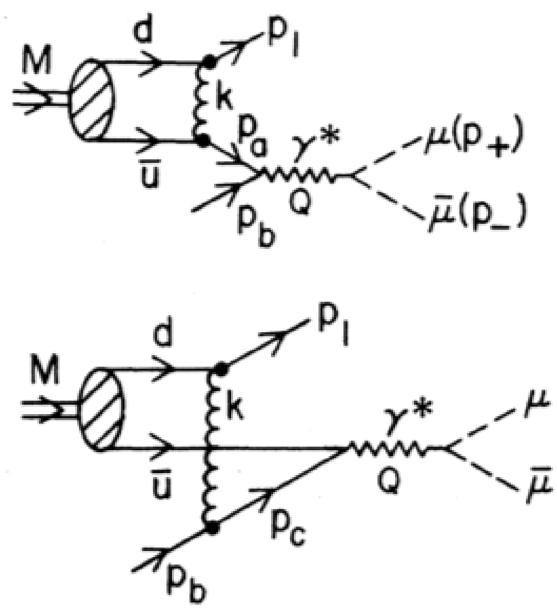
- Naïve picture confirmed by early Drell-Yan experiments

$$M^4 \frac{d^2\sigma}{dx_1 dx_2} = \frac{4\pi\alpha^2 s}{9} f^{\pi}(x_1) g^{N}(x_2) \qquad \frac{d\sigma}{d\cos\theta} \propto 1+\cos^2\theta$$

- Start including QCD corrections at first order



- Internal gluon exchanges – effects of the *pion bound state* – should have observable effects ➔ "Higher Twist" contributions



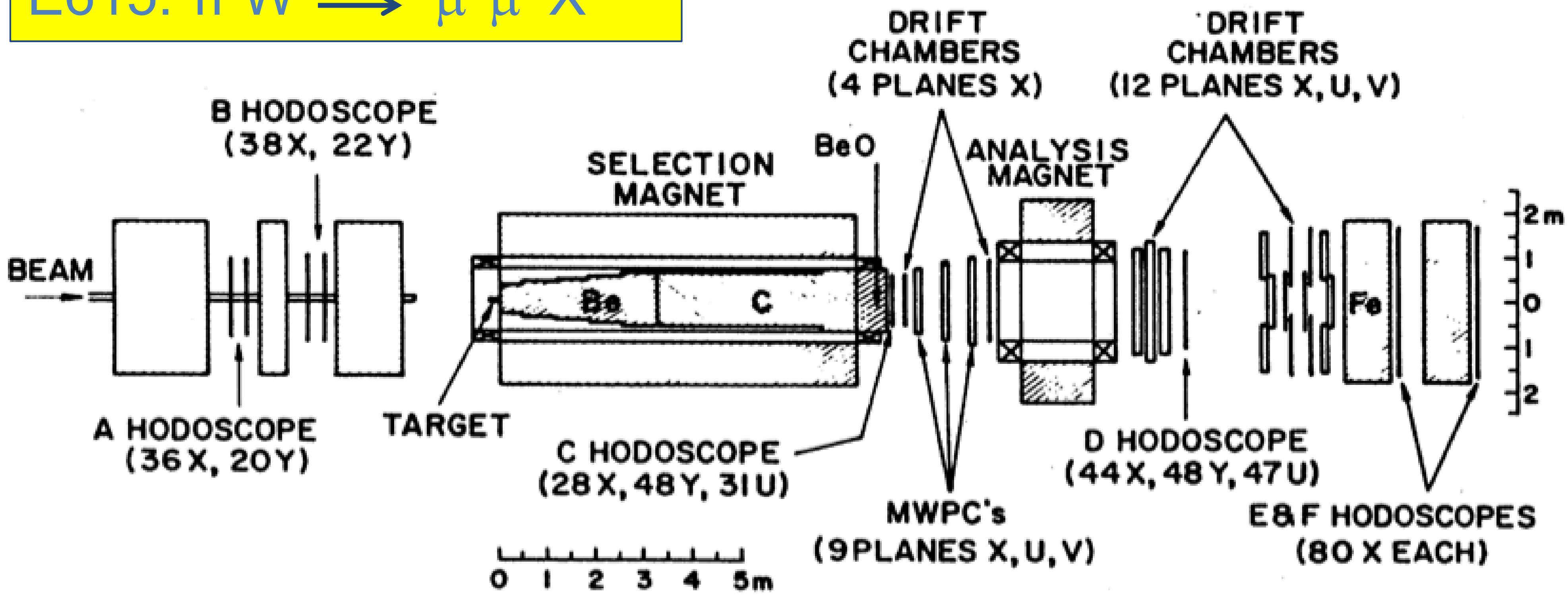
Berger & Brodsky:
pion at $x_F \rightarrow 1$
PRL 42, 940 (1979)

A large x_F quark with $p_T>0$ must be far off-shell ➔ can couple to longitudinal photons.

$$d\sigma \propto (1-x)^2(1+\cos^2\theta) + \tfrac{4}{9}(\langle k_T^2\rangle/Q^2)\sin^2\theta,$$

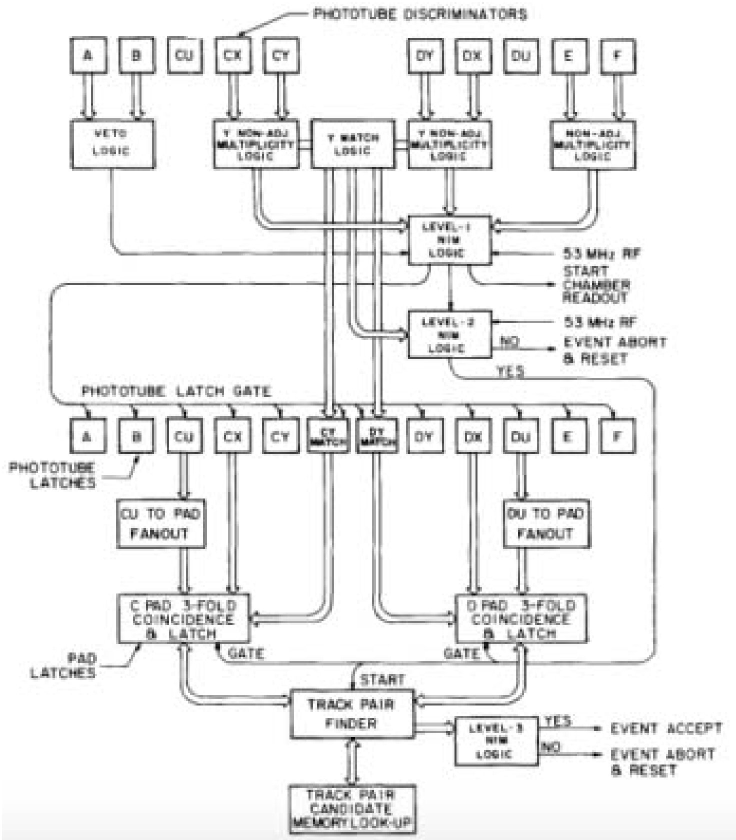
where x_F is the momentum fraction of the quark in the pion

E615: π W $\longrightarrow$ $\mu^+\mu^-$ X

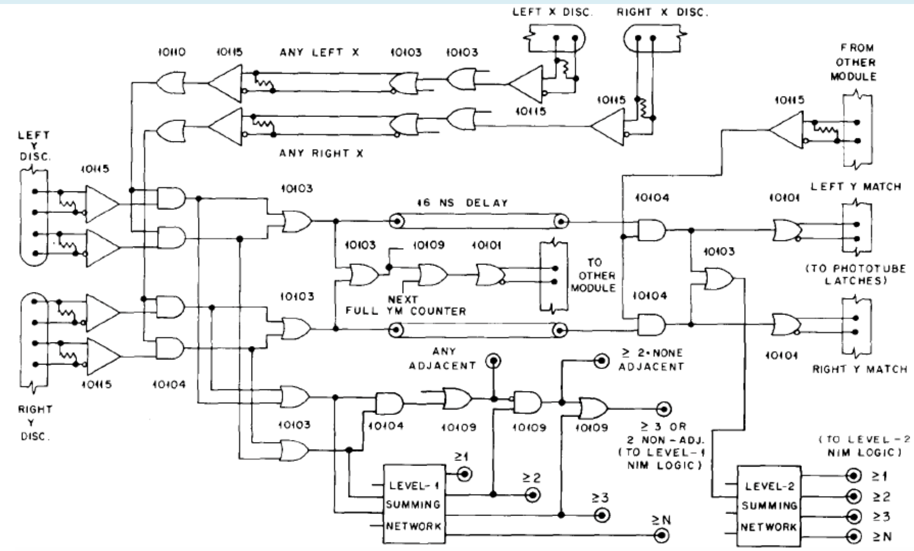


- Selma dipole magnet, momentum kick of 3.2 GeV/c
- Berillium absorber
- 25 planes of wire chambers upstream and downstream of the spectrometer magnet measuring position and time of the tracks
- 6 banks of plastic scintillators arranged in 14 planes.
- 2 iron walls

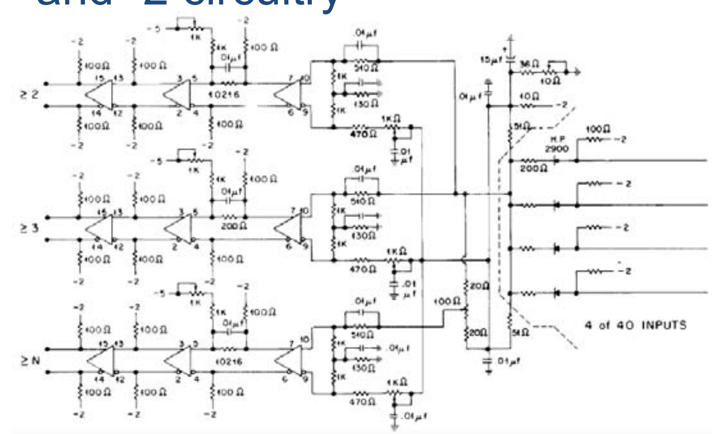
Flow chart of the PRINCETON three levels trigger logic.



Scheme of the ECL circuitry for the **Level-I and -2** C- and D-hodoscope logic. *The "top" and "bottom" E- and F-counter discriminator outputs passed through similar Level-1 non-adjacency logic similar to that shown for the "left" and "right" Cy- and Dy-counter signals.*



A detail of the analog summing network used in the Level-1 and -2 circuitry



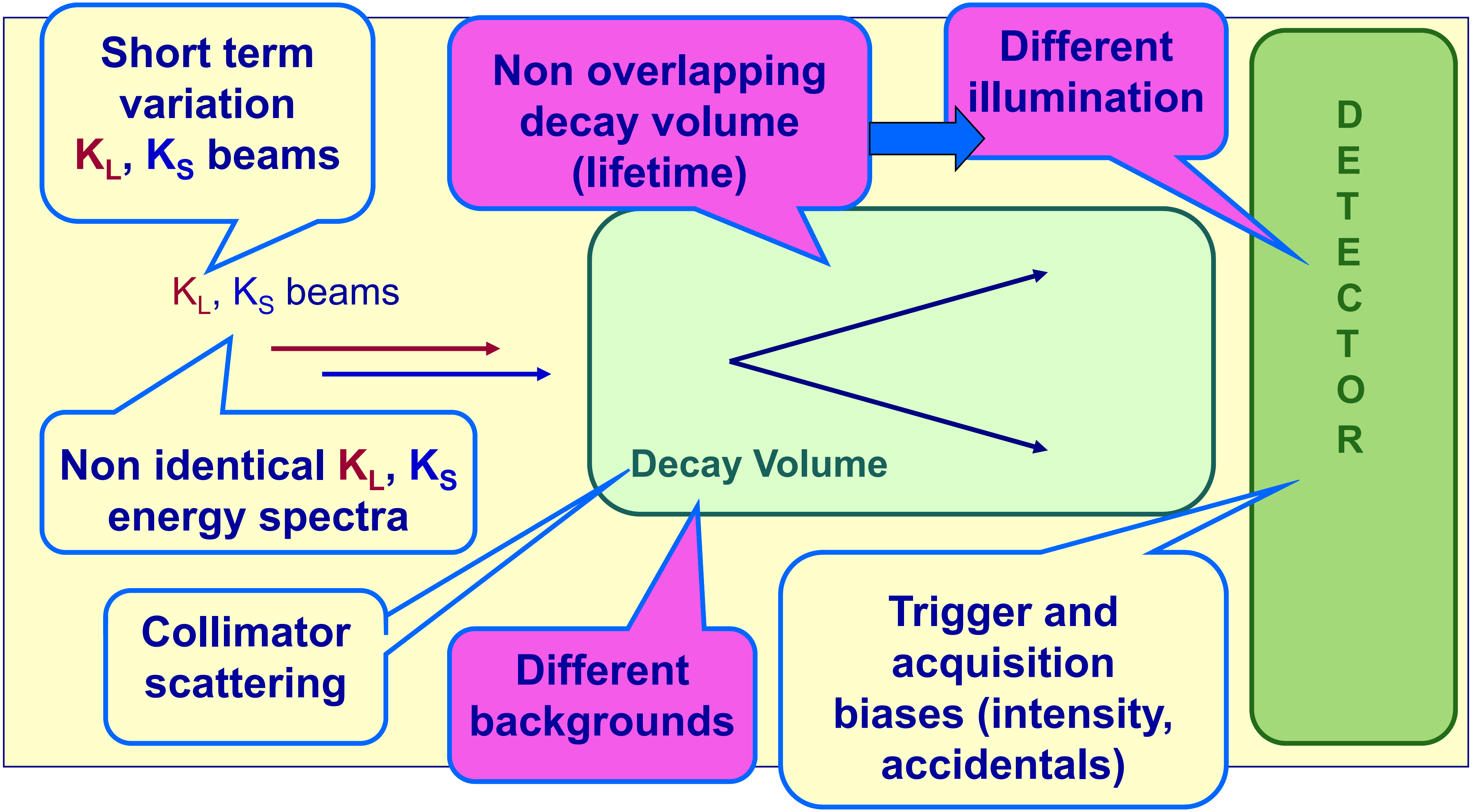
The Level-1 decision was reached about **40 ns** after the signals emerged from the scintillation-counter discriminators.

The Level-2 decision was available 10 ns after the Level-1.

Strong limits coming from signal cables length of the drift chambers …

… and the real case

Both KTeV and NA48 were almost ideal fixed target experiments measuring R using the double ratio method and recording the four modes concurrently.



NA48 method and set-up

Strategy to minimize systematic effects:

- the 4 modes are collected concurrently

$\Rightarrow$ cancellation of fluxes, dead times, inefficiencies, accidental rates

- use same decay regions for all modes, apply lifetime weighting to equalize distribution of K_S and K_L decay positions

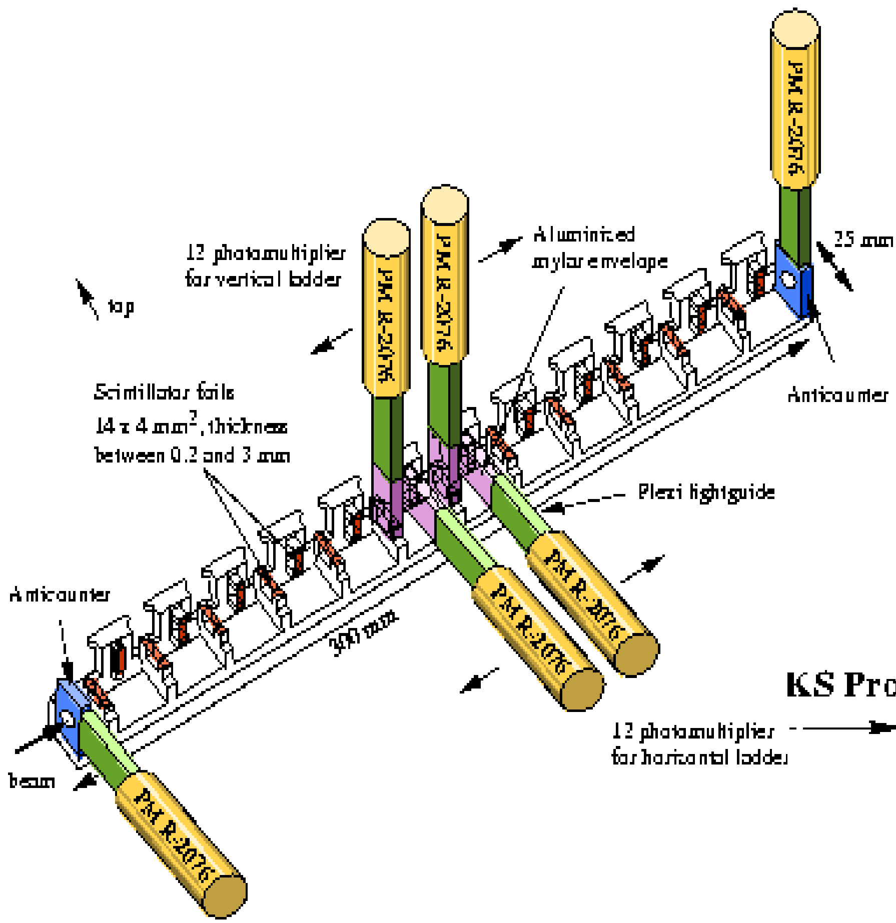
$\Rightarrow$ cancellation of detector acceptance effects

- use quasi-homogeneous liquid Krypton calorimeter to detect $\pi^0\pi^0$ and magnetic spectrometer for $\pi^+\pi^-$

$\Rightarrow$ optimize resolution, uniformity, linearity and stability

NA48: the Tagger

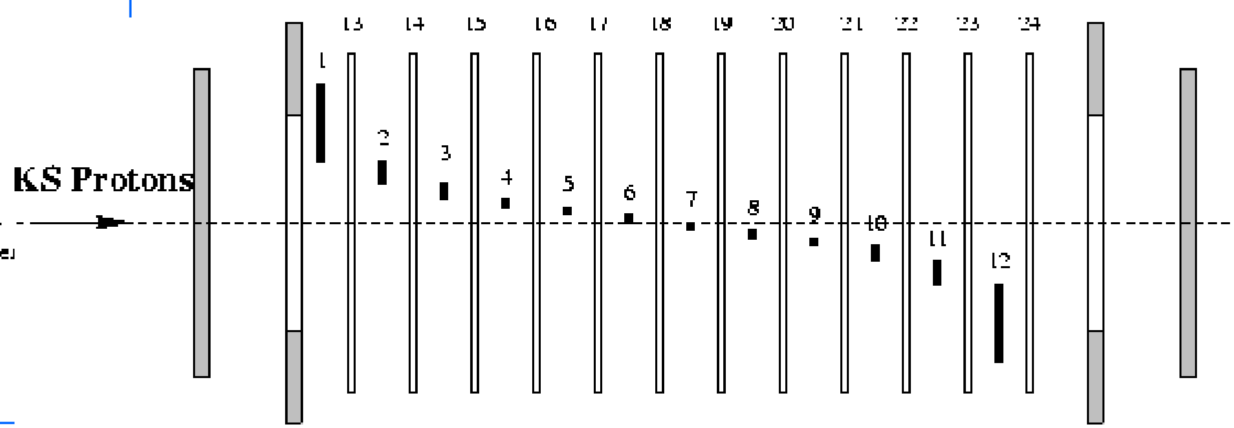
2x12 thin scintillator foils



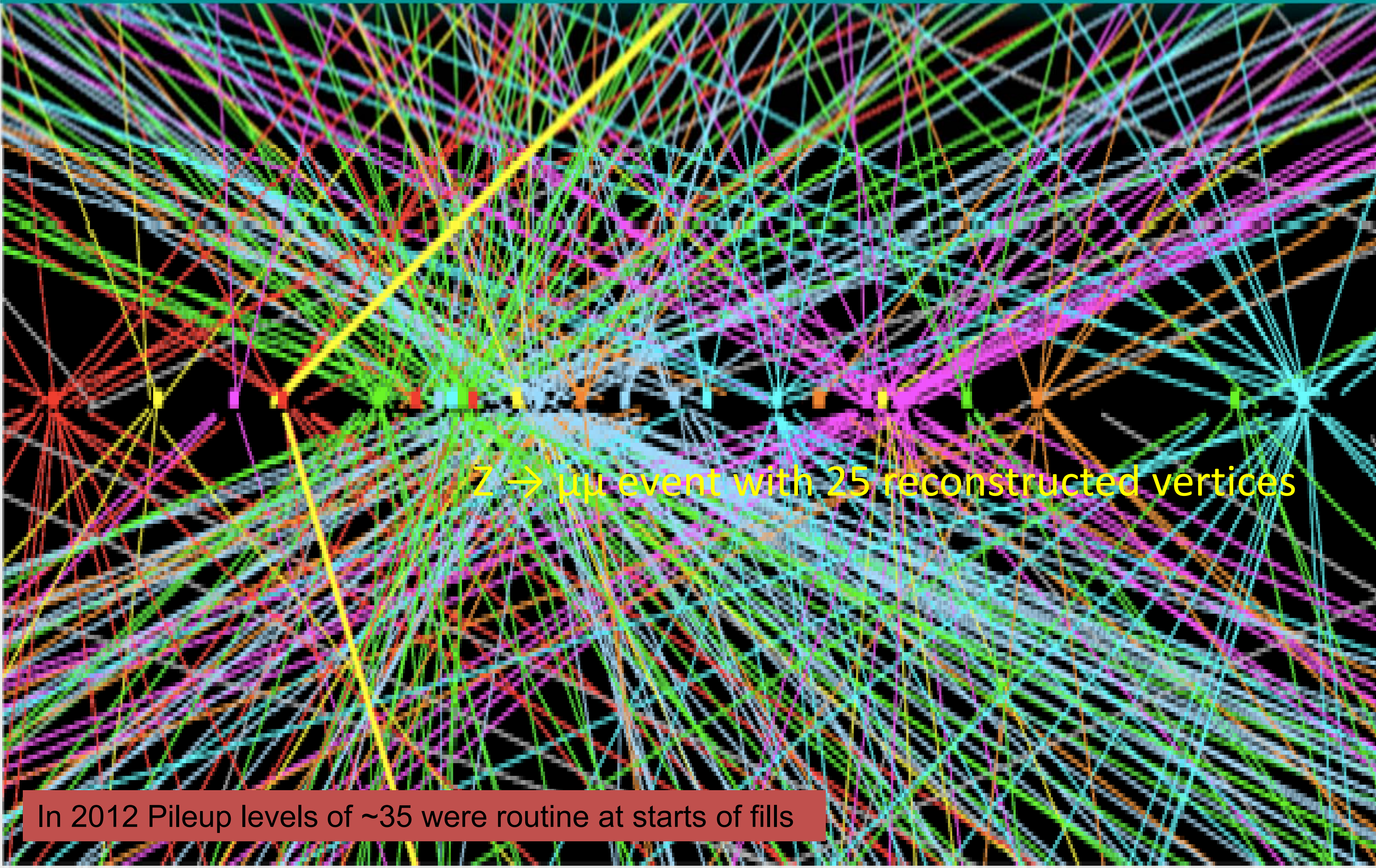
- Proton rate ≈ 30MHz → split the intensity between foils, readout by Flash ADC 8 bits at 960 MHz

⇒ time resolution : 140 ps

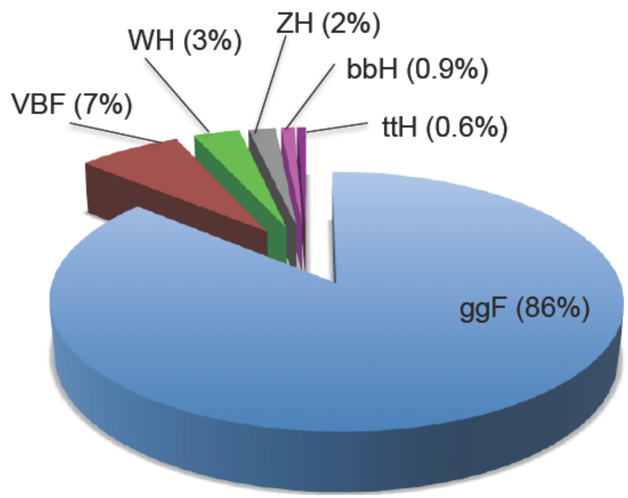
⇒ double pulse separation : 4 ns



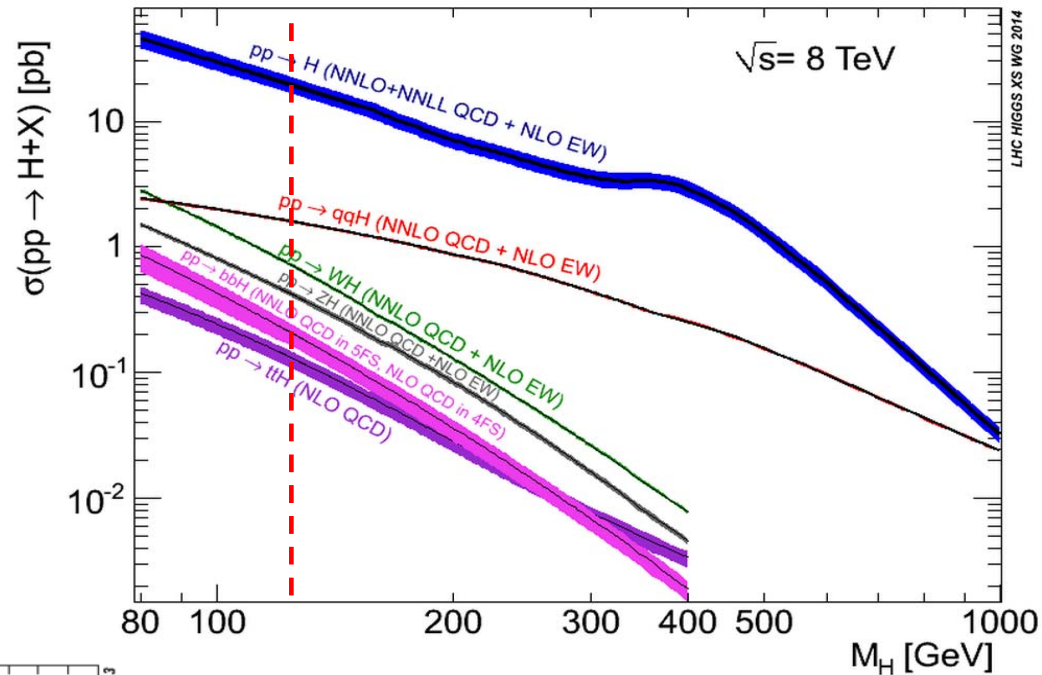
Pileup challenge

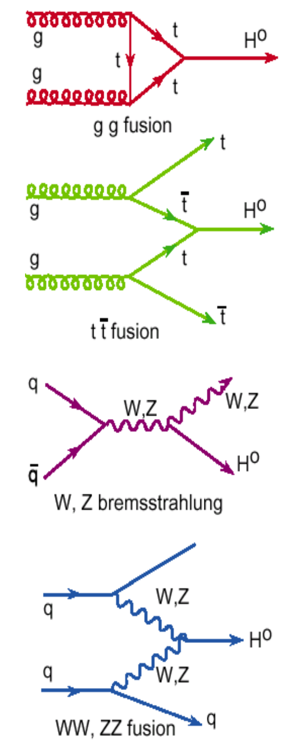


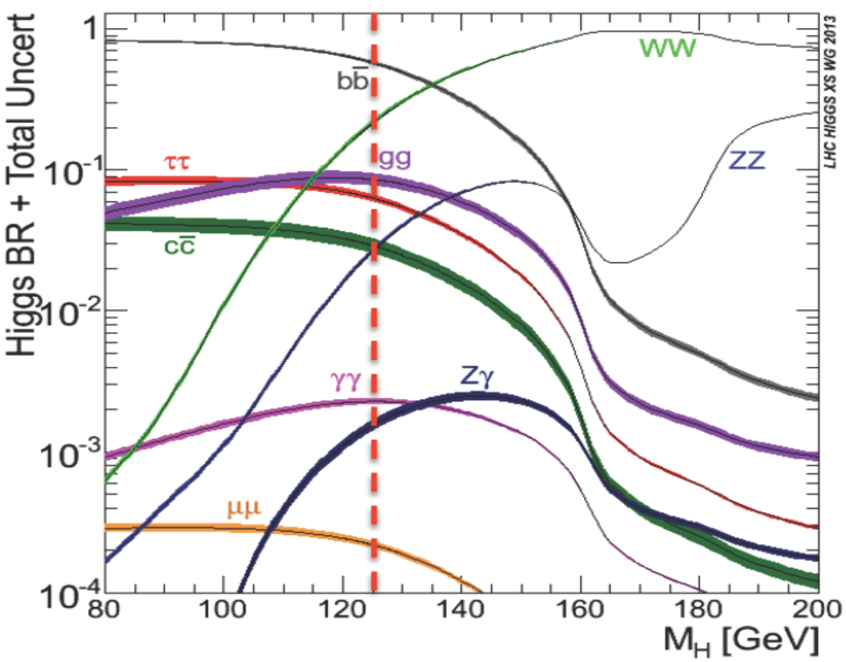
Higgs production and decay



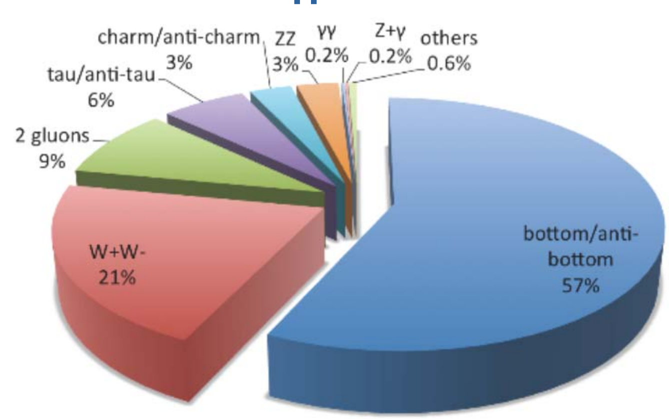
for m_H=125 GeV







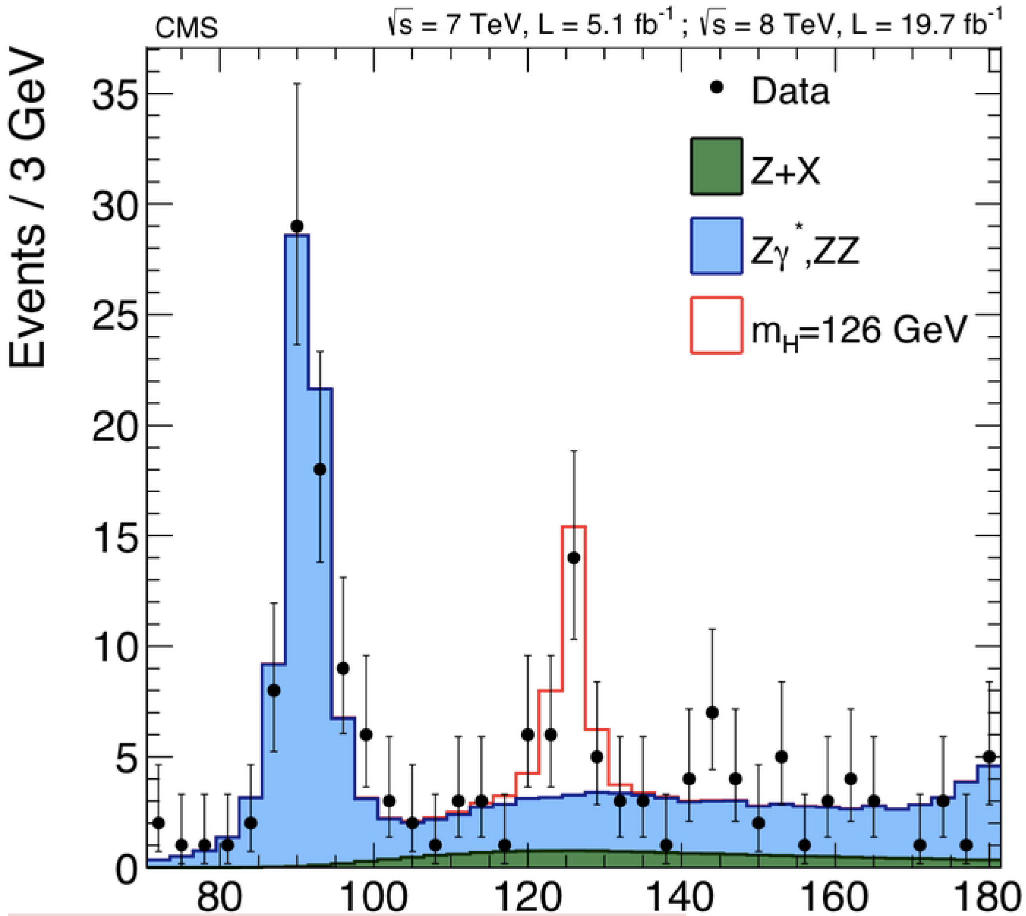
for m_H=125 GeV



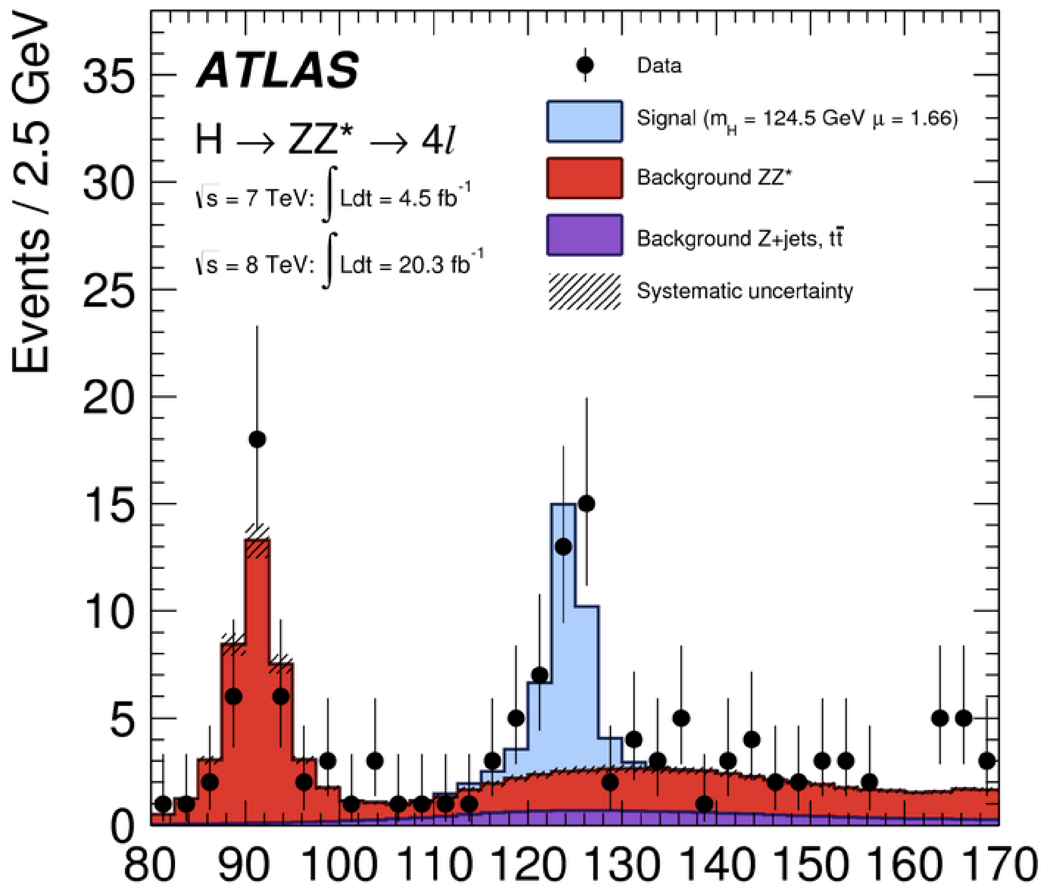
Most sensitive channels:

- H → ZZ* → 4l
- H → γγ
- H → WW → 2l2ν
- H → ττ
- H → bb

Higgs → ZZ* → 4l results



PhysRevD 89 (2014) 092007

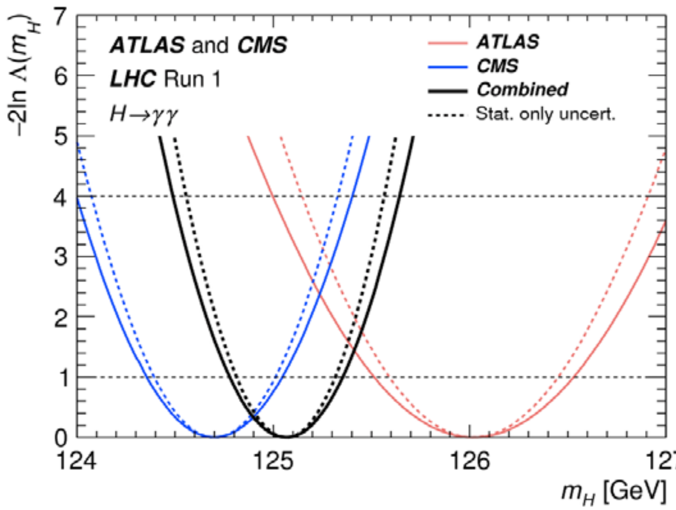


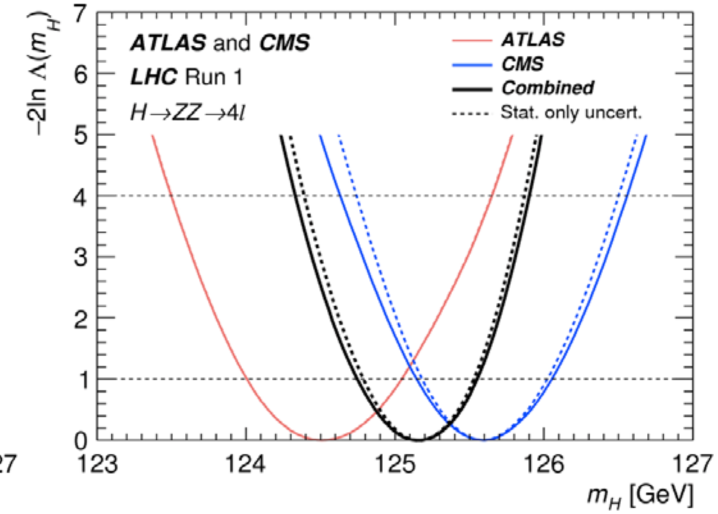
PhysRevD 90 (2014) 052004

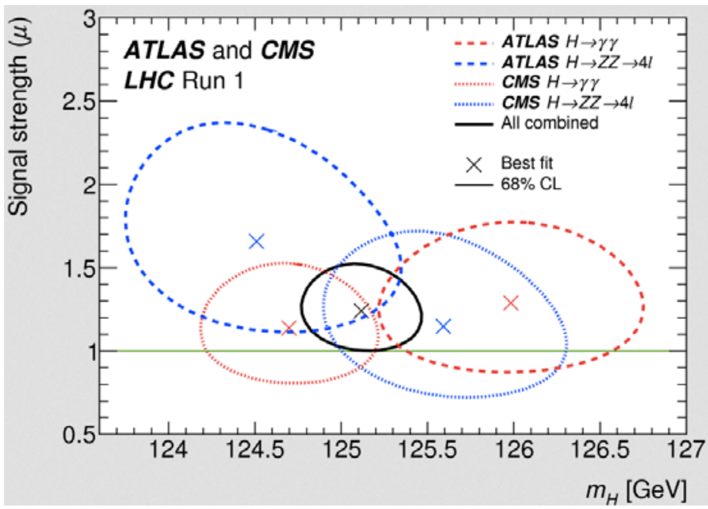
m_H = 125.6 ± 0.4 GeV
Significance = 6.7 (expected 7.2) s
$\mu = \sigma\, BR/\sigma_{SM}\, BR_{SM}$= 0.9 ± 0.3
Γ_H < 3.4 GeV @ 95% CL

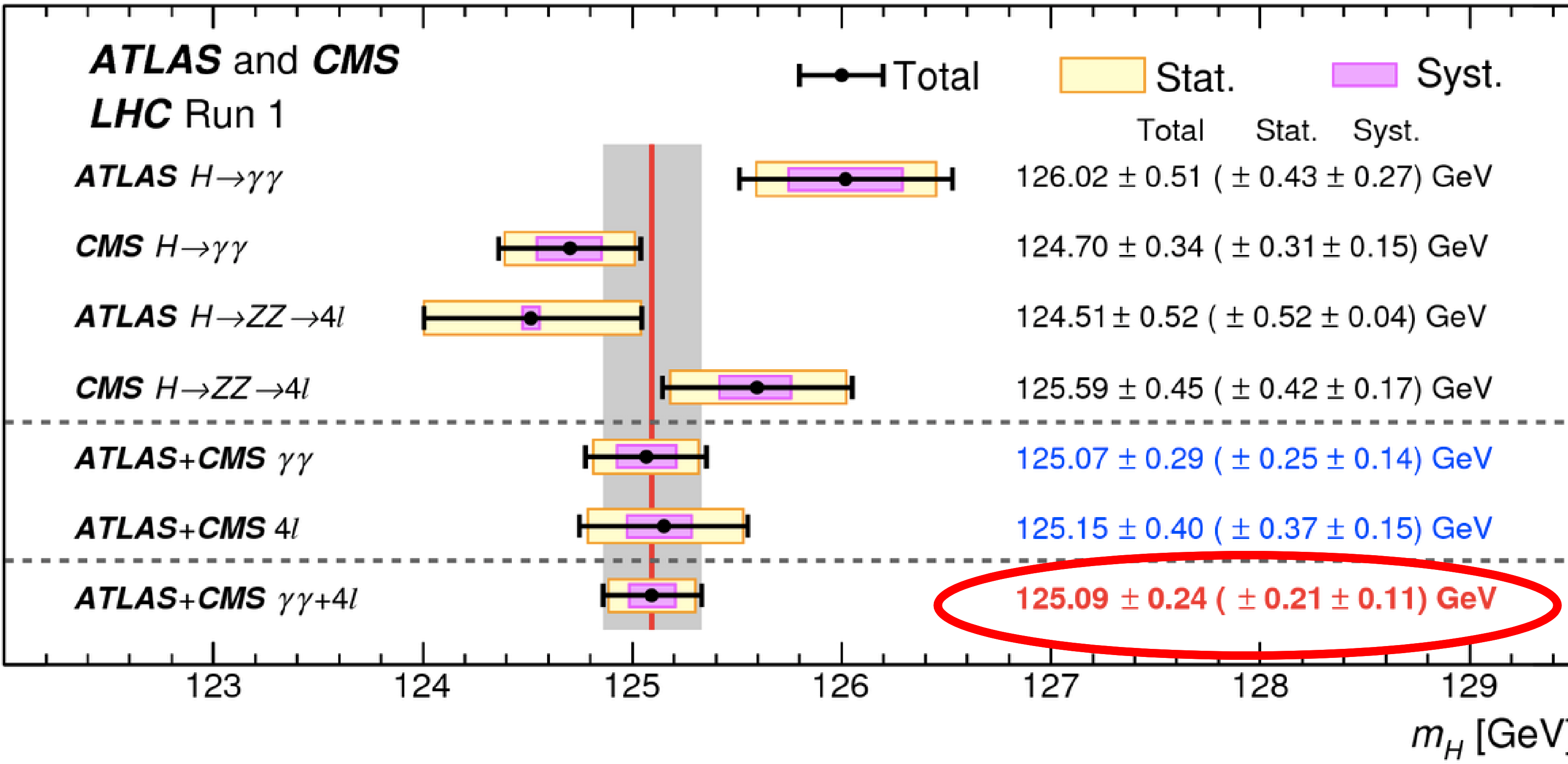
m_H = 124.5 ± 0.5 GeV
Significance = 8.2 (expected 5.8) σ
$\mu = \sigma\, BR/\sigma_{SM}\, BR_{SM}$= 1.7 ± 0.4
Γ_H < 2.6 GeV @ 95% CL

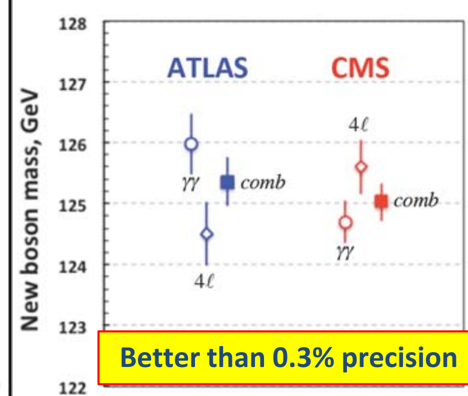
Higgs results combination: m_H











ATLAS&CMS:
arXiv:1503.07589
LHC combination

Limits on total Higgs width

- From direct measurements are dominated by instrumental resolution:

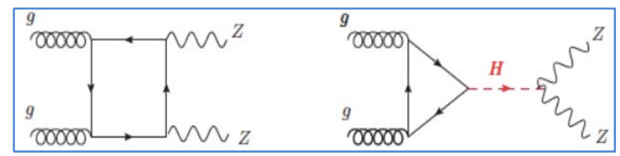
	CMS		ATLAS
$H \rightarrow \gamma\gamma$	Γ_H < 2.4 GeV @95% CL	$H \rightarrow \gamma\gamma$	Γ_H < 5.0 GeV @ 95% CL
$H \rightarrow ZZ \rightarrow 4l$	Γ_H < 3.4 GeV " "	$H \rightarrow ZZ \rightarrow 4l$	Γ_H < 2.6 GeV " "

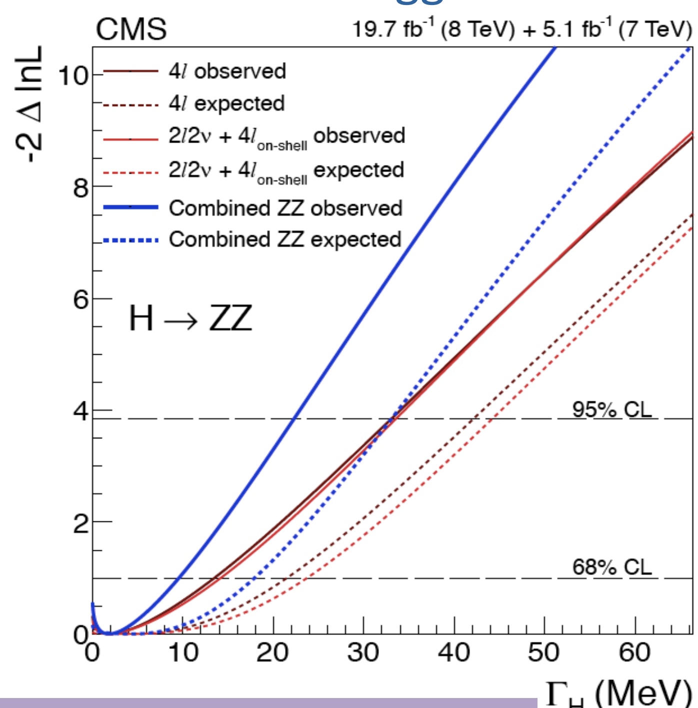
but SM expectations is: **Γ_{SM} = 4.15 MeV**!

- Indirect measurements based on comparison of *on-shell* and *off-shell* $H^* \rightarrow ZZ$. *Off-shell* to *on-shell* ratio is ~proportional to Γ_H

*Should consider negative interference with box diagram

*Assume that gg is the dominant production mechanism



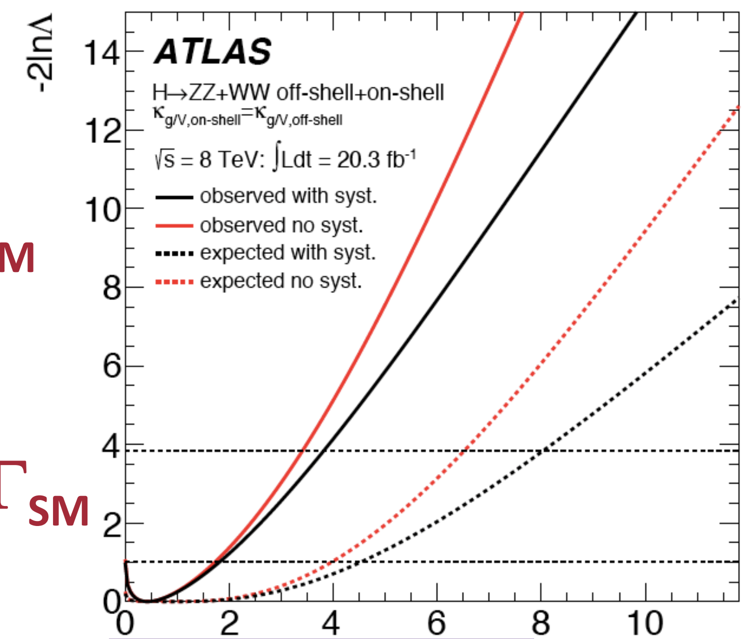


CMS:

Γ_H < 22 MeV < 5.4 Γ_{SM}

ATLAS:

Γ_H < 22.7 MeV < 5.5 Γ_{SM}



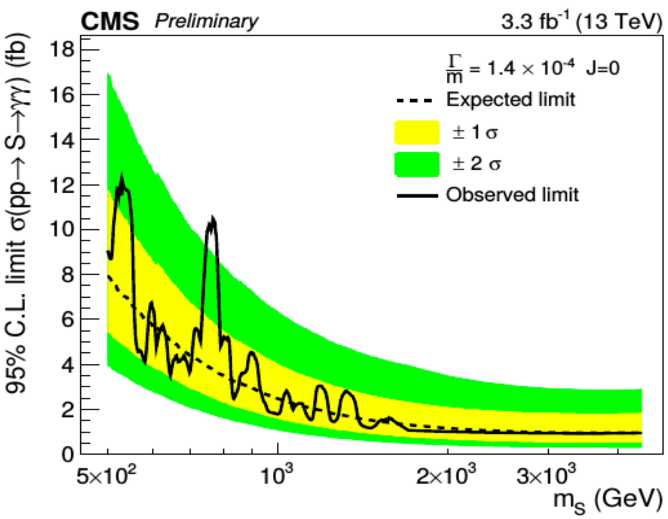
Phys.Lett. B 736(2014) 64

arXiv:1503.01060

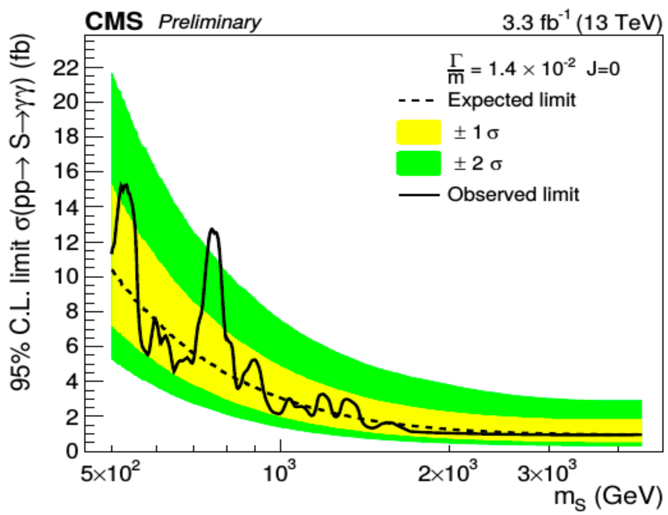
Upper limits for spin=0 hypotheses

- Hypothesis test based on simultaneous unbinned likelihood fit to $m_{\gamma\gamma}$ in all four analysis categories.
- Signal model.
  Shape from convolution of detector response and intrinsic line-shape.
  Mass window: 500GeV-4.5TeV.

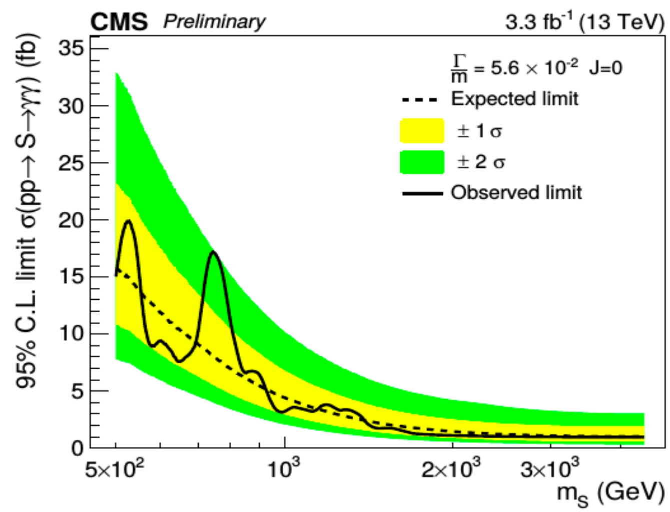
$\Gamma/m = 1.4\text{x}10^{-4}$



$\Gamma/m = 1.4\text{x}10^{-2}$



$\Gamma/m = 5.6\text{x}10^{-2}$

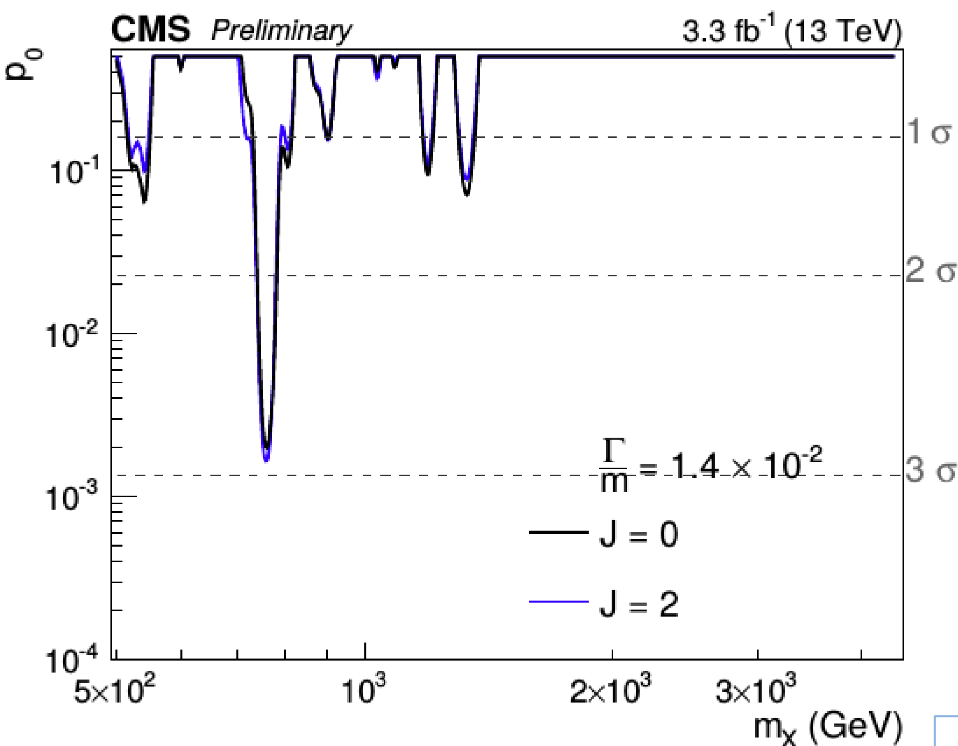


Spin-2 version gives equivalent message

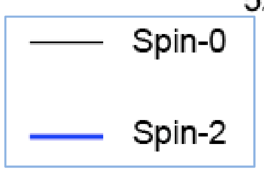
p-values

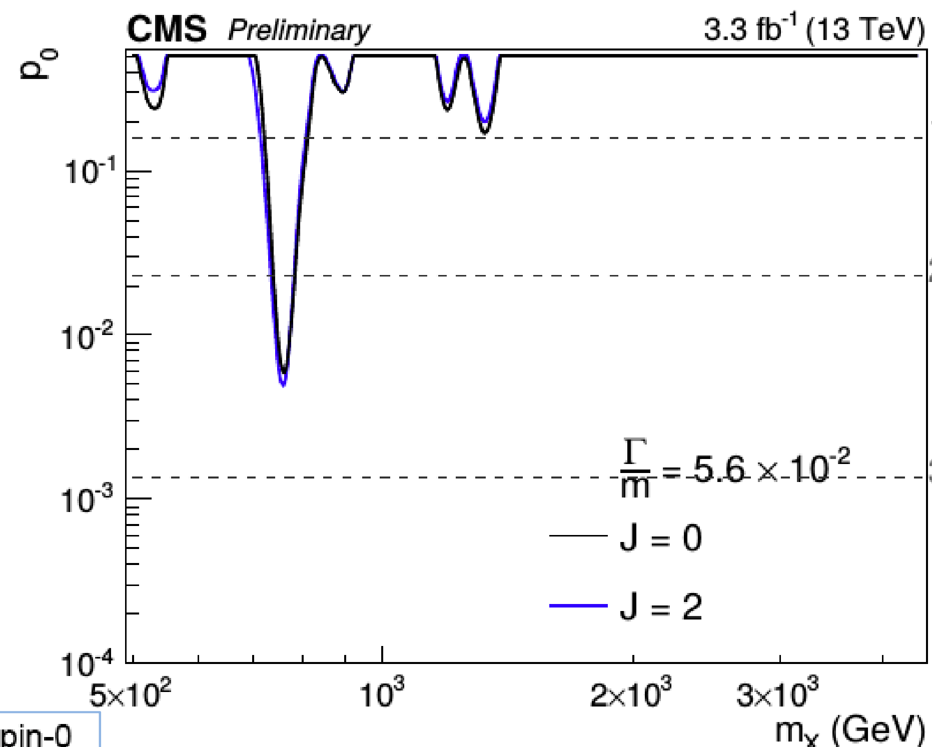
Largest excess observed for $\mathbf{m_X}$ **= 760GeV** and **□/m = 1.4x10**$^{\mathbf{-2}}$.

- **Local** significance: **2.8-2.9** □ depending on the spin hypothesis.
- Similar significance for narrow-width hypothesis.
- **Trial factors** estimated from **sampling distribution** of max(p0),
- taking into account all the 6 signal hypotheses (spin and width).
- **"Global"** significance **< 1**□.



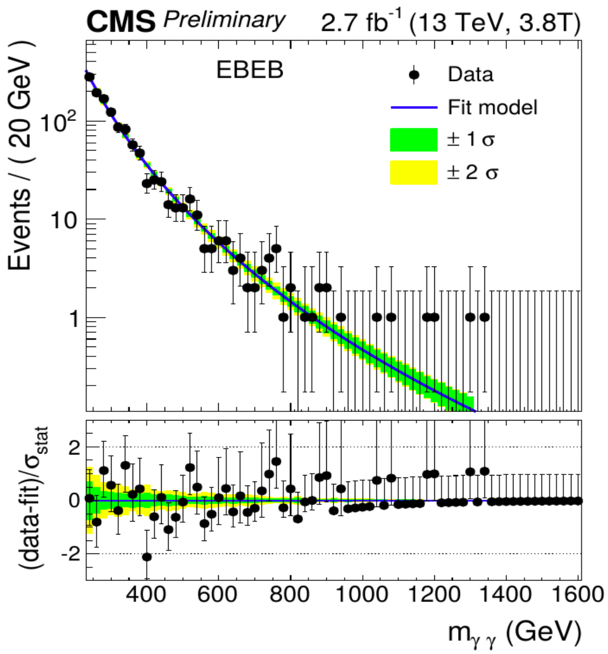
□/m = 1.4x10^{-2}

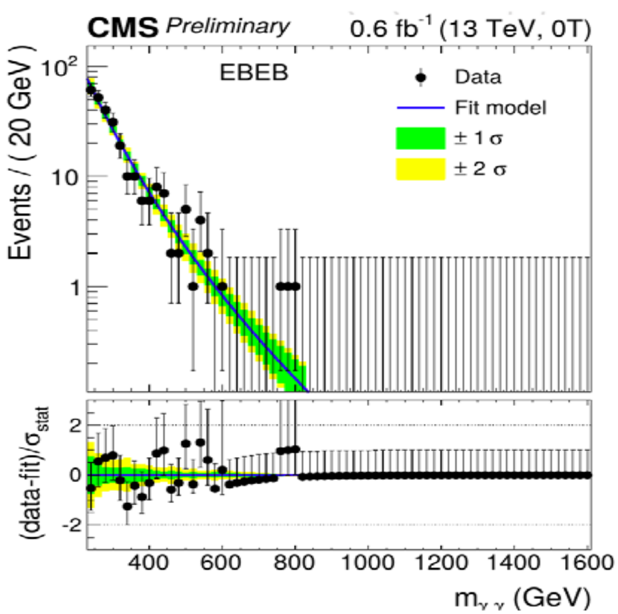


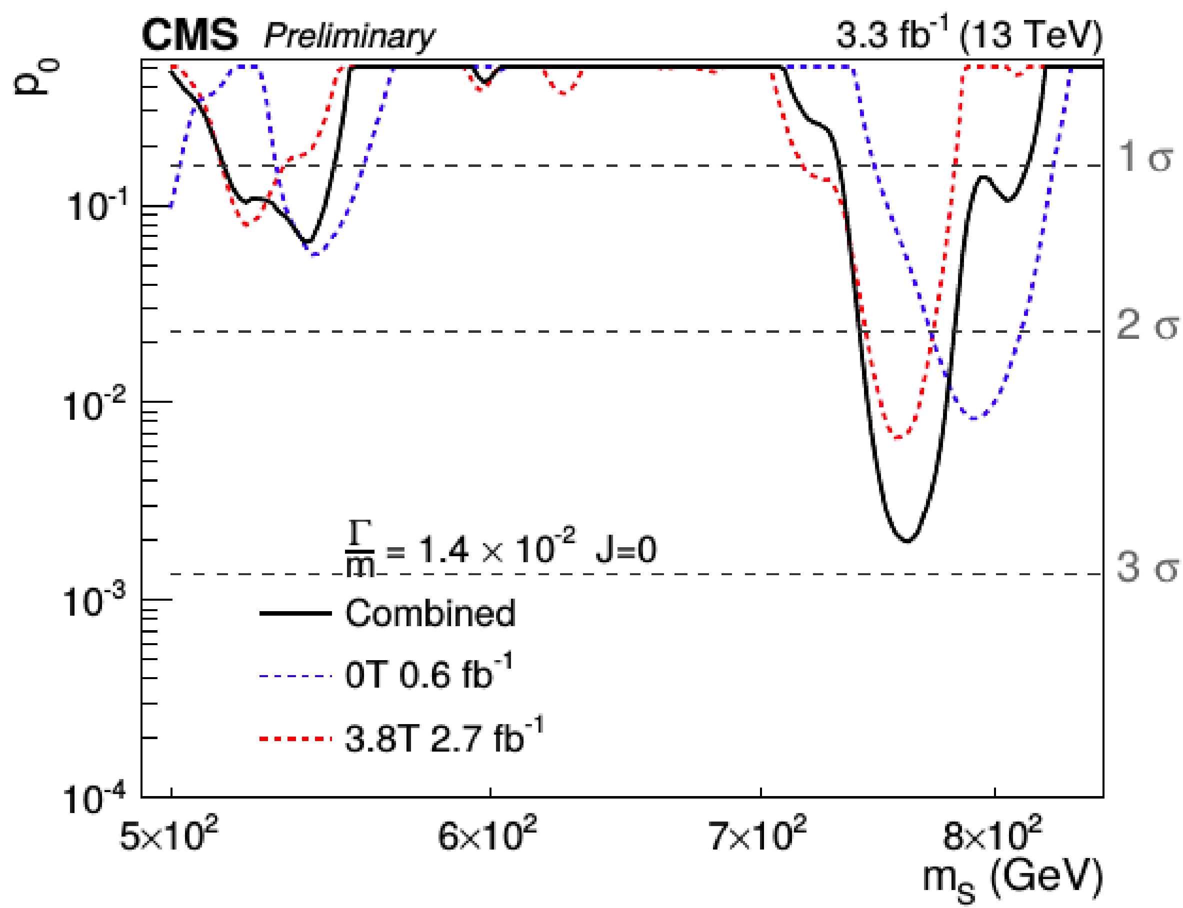


□/m = 5.6x10^{-2}

Excess at 760GeV comes mostly from EB-EB categories.
Driven by 3.8T category.
(where the observed excess is ~unchanged w.r.t. the previous results).
Observed one event in the 0T dataset compatible with 3.8T excess.





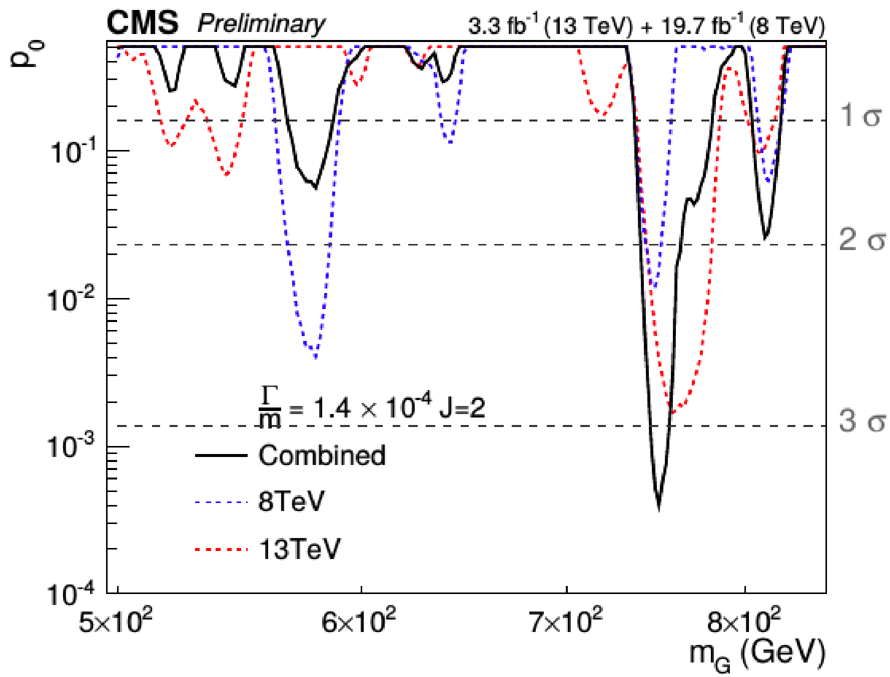


p-values

Results interpreted in terms of scalar resonances and RS gravitons production
of different widths.

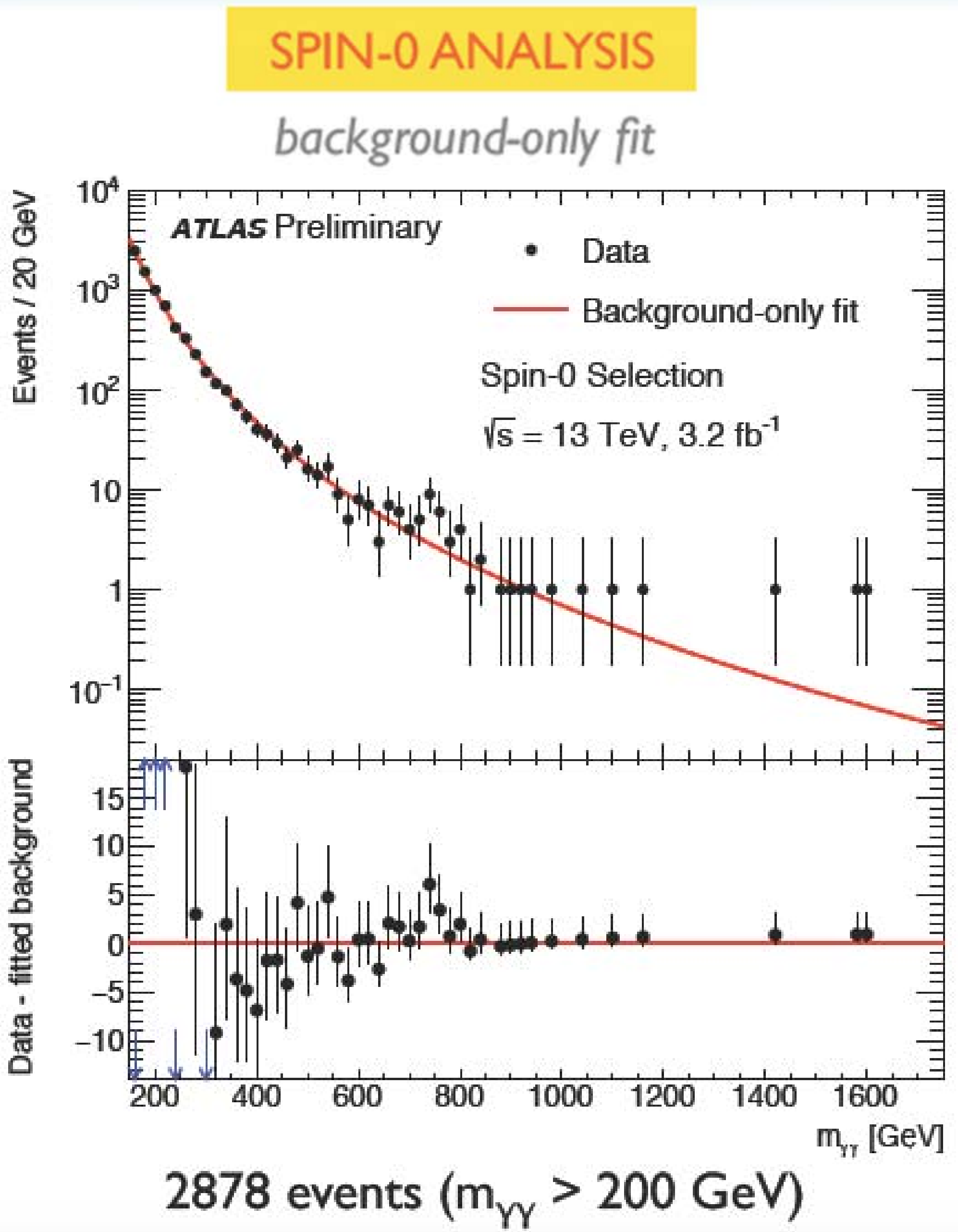
- Observation generally consistent with SM expectations.
- **Modest excess** of events observed at **m_X = 750(760) GeV** for the 8+13TeV(13TeV) dataset.

Local significance is **3.4(2.9)**, **reduced to 1.6(<1)** after accounting for look-elsewhere-effect.



More data needed to verify excess origin: looking forward to 2016 LHC run

Mass spectra at ATLAS



Search for new resonances decaying to diphotons performed with 3.2 fb^{-1} 13 TeV data, with two analyses targeting "spin-0" and "spin-2" scenarios

- Most of the γγ spectrum consistent with B-only hypothesis
- Largest deviation from background-only hypothesis observed in broad region around 750 GeV, with global significance 2.0 (1.8) σ for the spin-0 (spin-2) analysis
- 8 TeV data re-analyzed using latest Run1 calibration, compatibility with 13 TeV results assessed
  - Scalar 1.2 σ (gg) – 2.1 σ (qq)
  - Graviton 2.7 σ (gg) – 3.3 σ (qq)
- **More data needed to verify excess origin: looking forward to 2016 LHC run**