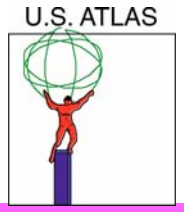
Abe (and the ATLAS Experiment) Looks Forward to Physics

Howard Gordon, BNL

Abe Fest – September 11, 2006



Outline

- The LHC Machine Schedule is for collisions in 2007 at 0.9 TeV
  - 14 TeV in 2008
- The ATLAS Experiment while still needing a year for the completion of installation and commissioning – will be ready for the first collisions in 2007
  - Abe has contributed significantly since about 1994!
- Abe is looking forward to the expected compelling physics results
  - An Upgrade to 10^{35} $cm^{-2}s^{-1}$ is being planned
    - Abe is also a leader on the Upgrade R&D for ATLAS

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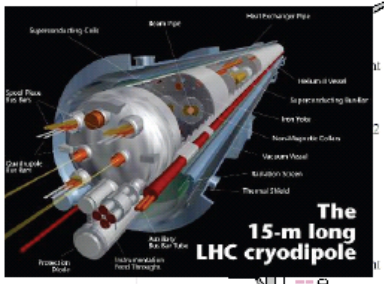
The Large Hadron Collider at CERN Geneva Switzerland

LHC

- pp $\sqrt{s}$ = 14 TeV $L_{design} = 10^{34}\ cm^{-2}\ s^{-1}$ (after 2009)
  $L_{initial} \leq$ few x $10^{33}\ cm^{-2}\ s^{-1}$ (until 2009)
- Heavy ions (e.g. Pb-Pb at $\sqrt{s} \sim 1000$ TeV)

TOTEM (integrated with CMS):
pp, cross-section, diffractive physics

ATLAS and CMS :
general purpose



27 km LEP ring
1232 superconducting
dipoles B=8.3 T

Here:
ATLAS and CMS

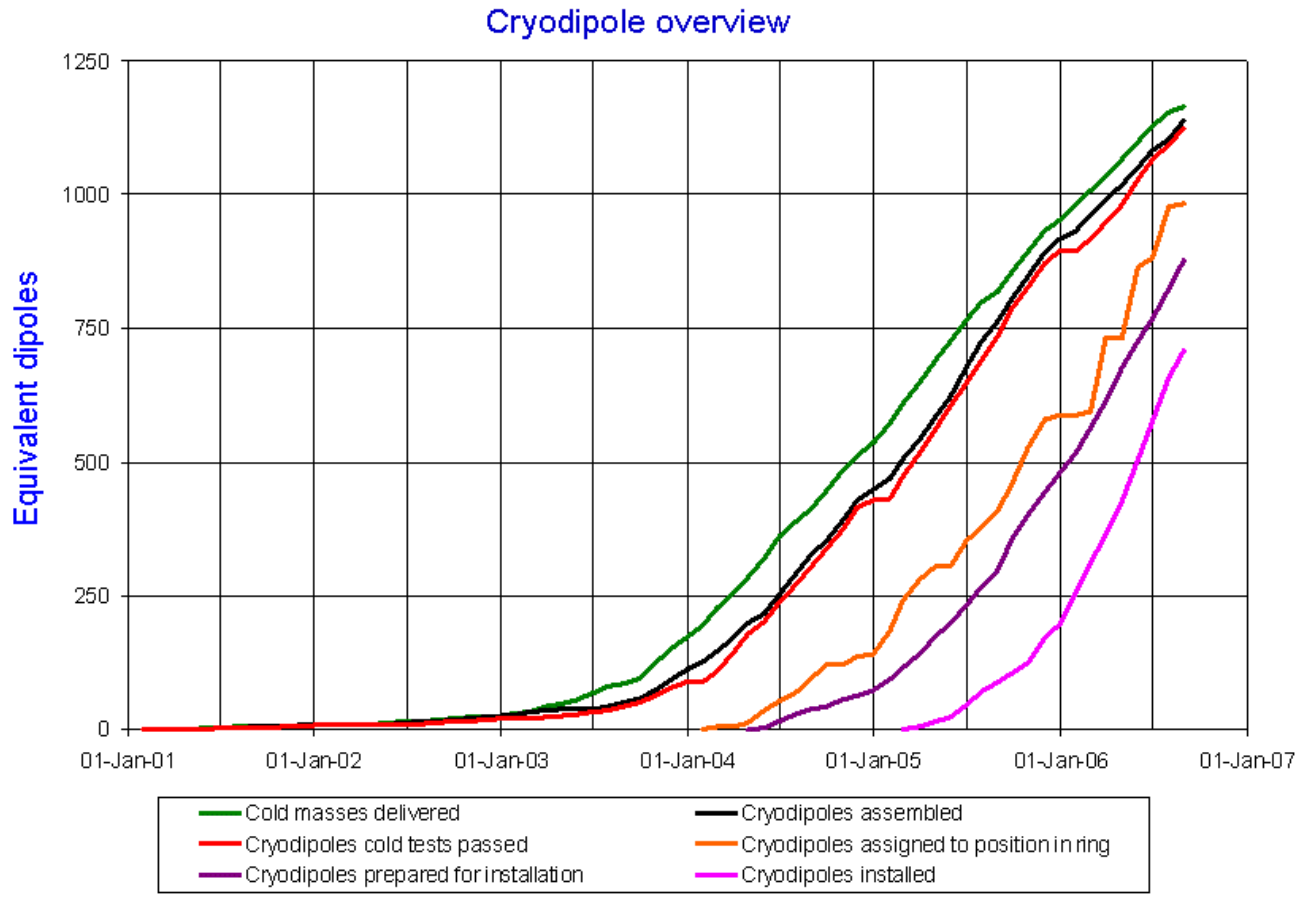
ALICE :
ion-ion,
p-ion

LHCb :
pp, B-physics, CP-violation

LHC Machine Status from Dashboard

LHC Progress Dashboard

Accelerator Technology Department

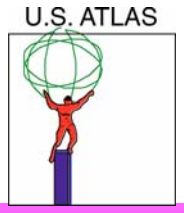


Updated 31 Aug 2006

Data provided by D. Tommasini AT-MAS, L. Bottura AT-MTM

20-25 dipoles/week being installed leads to a magnet installation completion in Feb. 2007

As of end of August > 700 of 1282 dipoles installed



Revised LHC Schedule as presented to CERN Council on June 23, 2006

- Last magnet installed : March 2007
  Machine and experiments closed : 31 August 2007
- First collisions ($\sqrt{s}$ = 900 GeV, L~10^{29} cm^{-2} s^{-1}) : November 2007
  Commissioning run at injection energy until end 2007, then shutdown (3 months ?)
- First collisions at $\sqrt{s}$=14 TeV (followed by first physics run): Spring 2008

Goal : deliver integrated luminosity of few fb^{-1} by end 2008

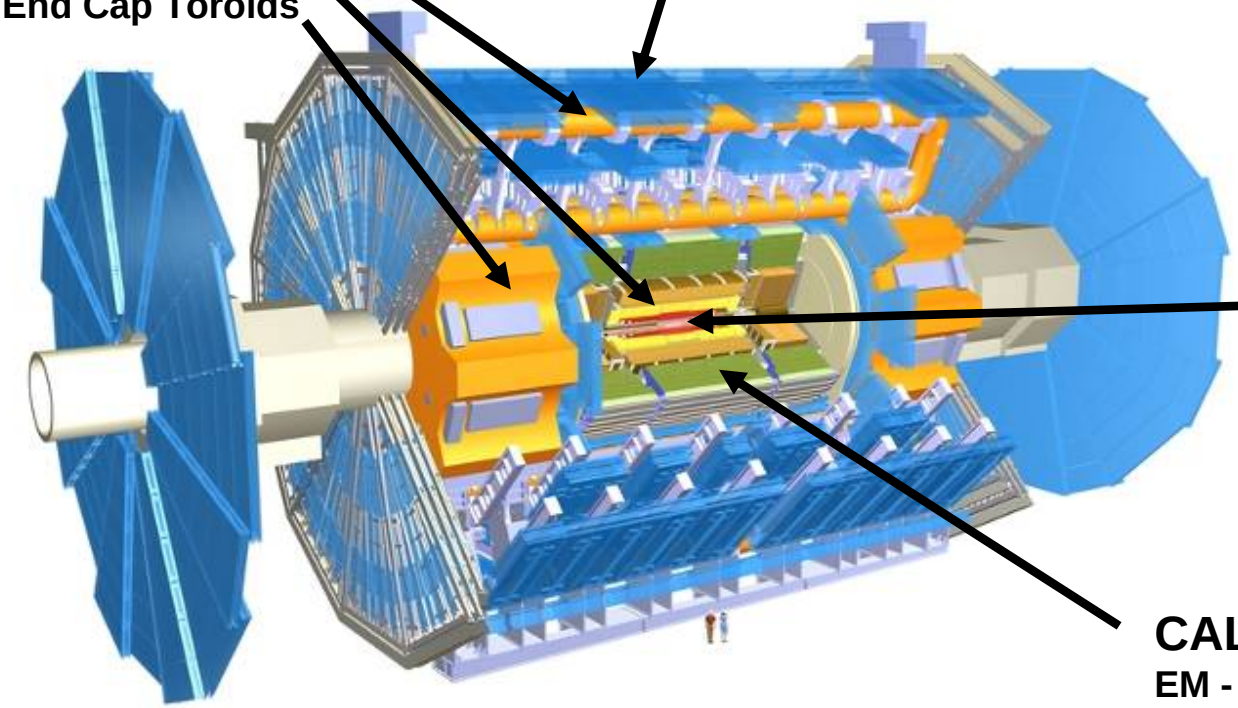
L. Evans, CERN Council, 23/6/2006

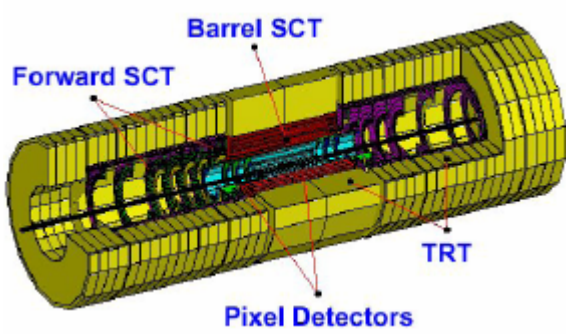
- Sectors 7-8 and 8-1 will be fully commissioned up to 7 TeV in 2006-2007.
  If we continue to commission the other sectors up to 7 TeV, we will not get circulating beam in 2007.
- The other sectors will be commissioned up to the field needed for de-Gaussing.
- Initial operation will be at 900 GeV (CM) with a static machine (no ramp, no squeeze) to debug machine and detectors.
- Full commissioning up to 7 TeV will be done in the winter 2008 shutdown

ATLAS Layout

MUON SYSTEM |η|<2.7
Monitored Drift Tubes (MDT)
Cathode Strip Chambers (CSC)
Resistive Plate Chambers (RPC)
Thin Gap Chambers (TGC)

MAGNETS
8 Barrel Toroids
Central Solenoid
End Cap Toroids





INNER DETECTOR (ID)
2 T solenoid, |η|<2.5
Pixels
Silicon Strip (SCT)
Transition Radiation Tracker (TRT)

CALORIMETERS |η|<5
EM - Liquid Argon – Lead
HAD - Scintillator Tile

Diameter 25m
Length 46m
Weight 7,000 tons
3000 km of cables, >10^8 channels

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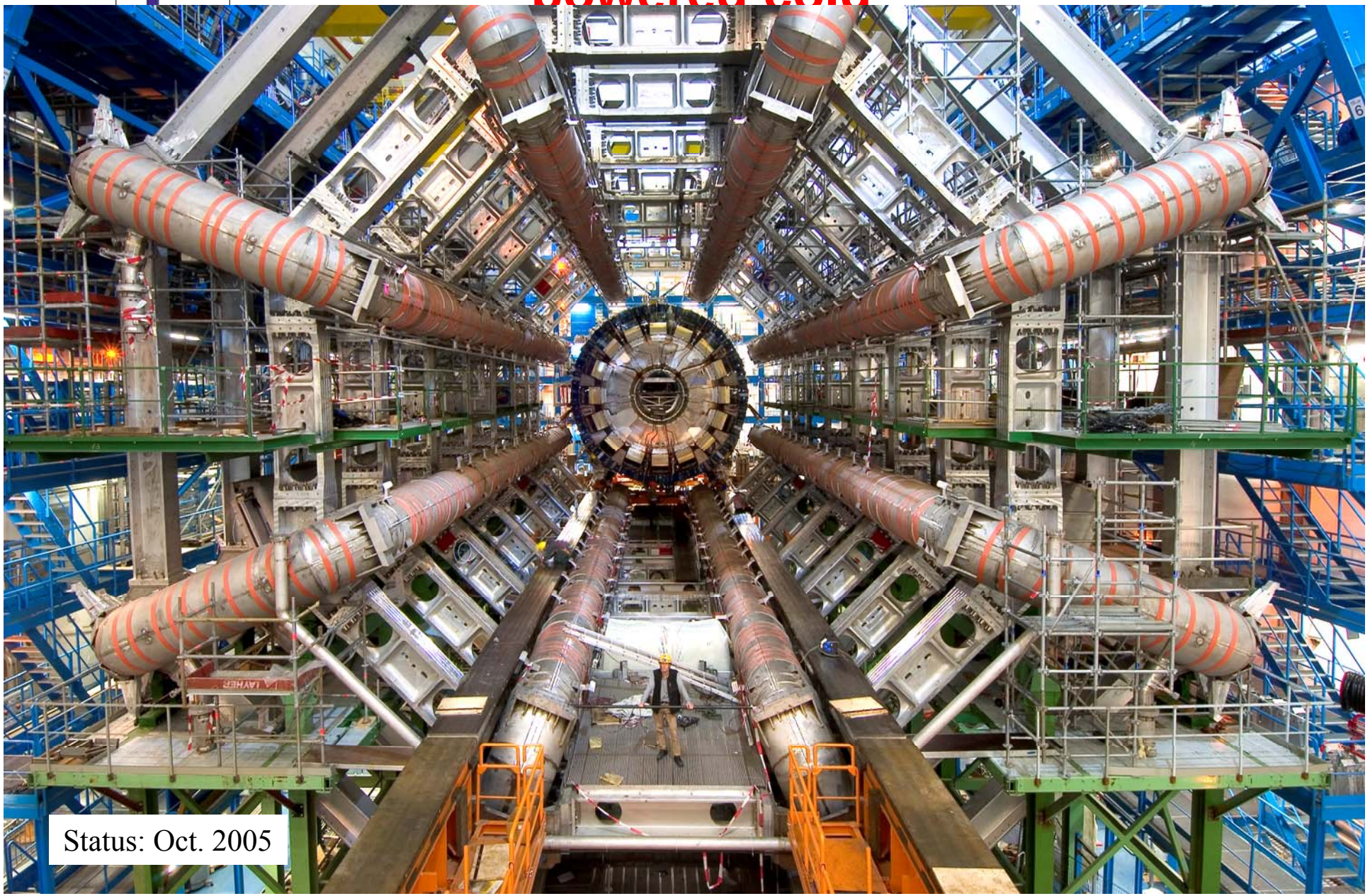
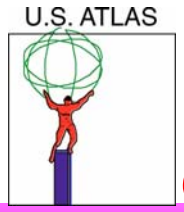
Barrel Toroids are now being powered cold



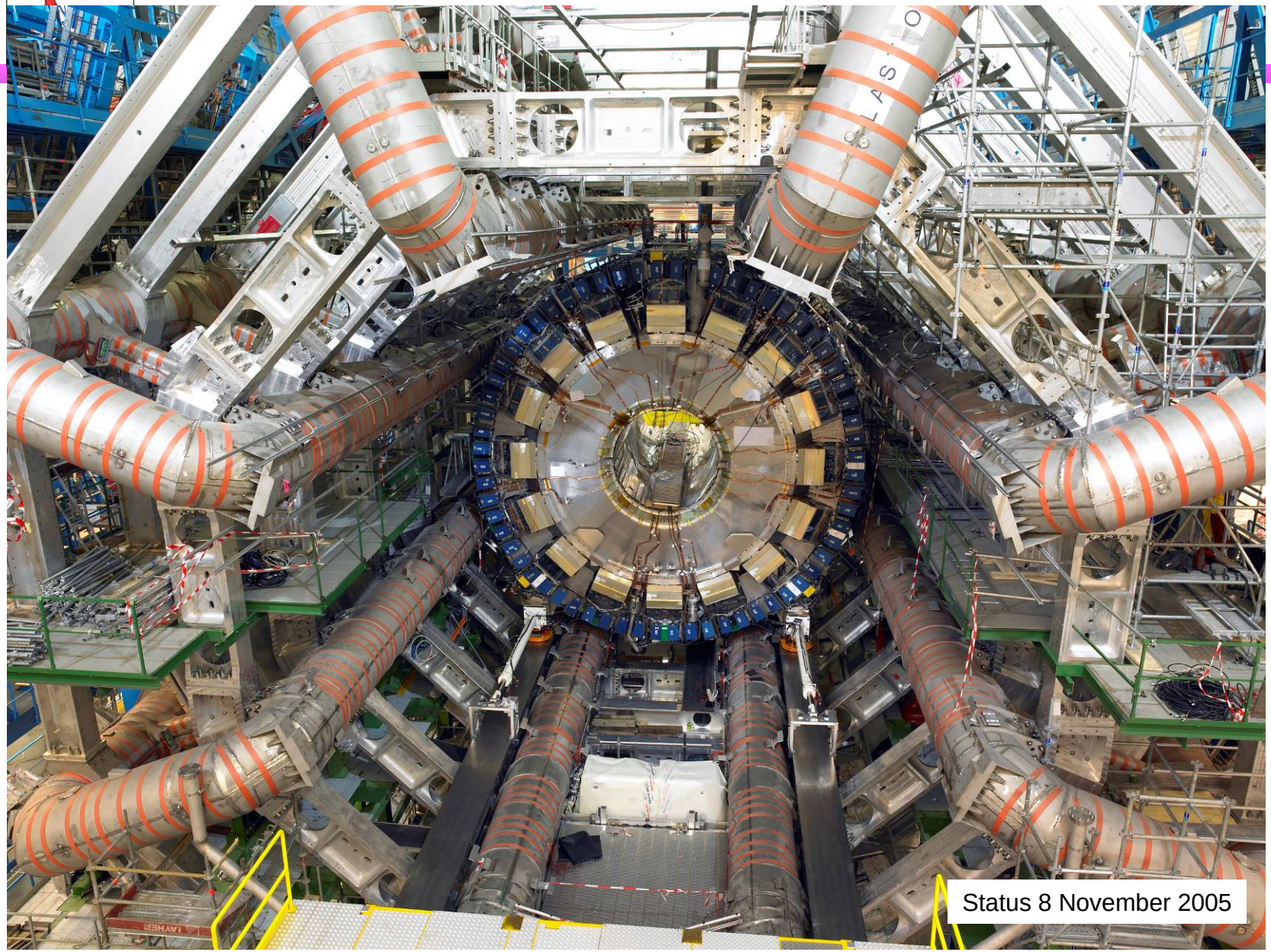


ATLAS Collaboration

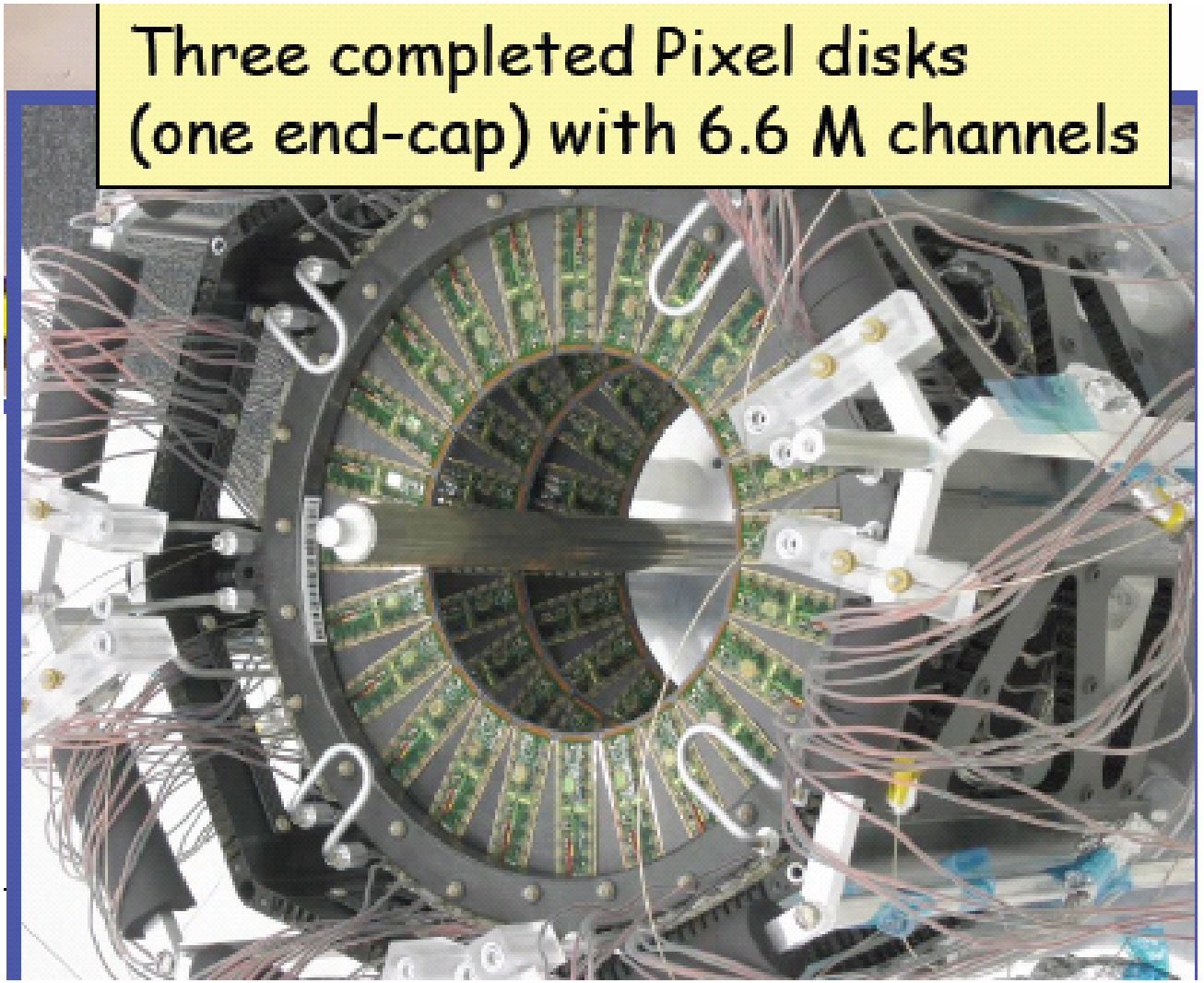
35 Countries
162 Institutions
1650 Scientific Authors total
(1300 with a PhD, for M&O share)

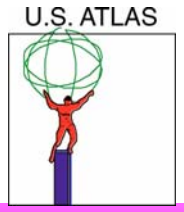
Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku,
IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, Bern, Birmingham, Bologna, Bonn, Boston, Brandeis,
Bratislava/SAS Kosice, Brookhaven NL, Buenos Aires, Bucharest, Cambridge, Carleton, Casablanca/Rabat, CERN, Chinese Cluster, Chicago, Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, AGH UST Cracow, IFJ PAN Cracow, DESY, Dortmund, TU Dresden,
JINR Dubna, Duke, Frascati, Freiburg, Geneva, Genoa, Giessen, Glasgow, LPSC Grenoble, Technion Haifa, Hampton, Harvard, Heidelberg, Hiroshima,
Hiroshima IT, Humbolt U Berlin(GE), Indiana, Innsbruck, Iowa SU, Irvine UC, Istanbul Bogazici, KEK, Kobe, Kyoto, Kyoto UE, Lancaster, UN La Plata, Lecce,
Lisbon LIP, Liverpool, Ljubljana, QMW London, RHBNC London, UC London, Lund, UA Madrid, Mainz, Manchester, Mannheim, CPPM Marseille,
Massachusetts, MIT, Melbourne, Michigan, Michigan SU, Milano, Minsk NAS, Minsk NCPHEP, Montreal, McGill Montreal, FIAN Moscow, ITEP Moscow, MEPhI Moscow, MSU Moscow, Munich LMU,
MPI Munich, Nagasaki IAS, Naples, Naruto UE, New Mexico, New York U., Nijmegen, BINP Novosibirsk, Ohio SU, Okayama, Oklahoma, Oklahoma SU,
Oregon, LAL Orsay, Osaka, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, Pisa, Pittsburgh, CAS Prague,
CU Prague, TU Prague, IHEP Protvino, Ritsumeikan, UFRJ Rio de Janeiro, Rochester, Rome I, Rome II, Rome III,
Rutherford Appleton Laboratory, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, SLAC,
Southern Methodist Dallas, NPI Petersburg, Stockholm U, KTH Stockholm, Stony Brook, Sydney, AS Taipei, Tbilisi, Tel Aviv, Thessaloniki, Tokyo ICEPP, Tokyo MU, Toronto, TRIUMF, Tsukuba, Tufts, Udine, Uppsala, Urbana UI, Valencia, UBC Vancouver, Victoria, Washington, Weizmann Rehovot, Wisconsin,
Wuppertal, Yale, Yerevan

Barrel TileCal and Liquid Argon at z=0



Three Layers of Pixels are Progressing but on the Critical Path





SCT

- SCT== Semiconductor Tracker == Silicon Strip
- Abe contributed much to this area
- Mike Tyndel will be talking about the details of the SCT

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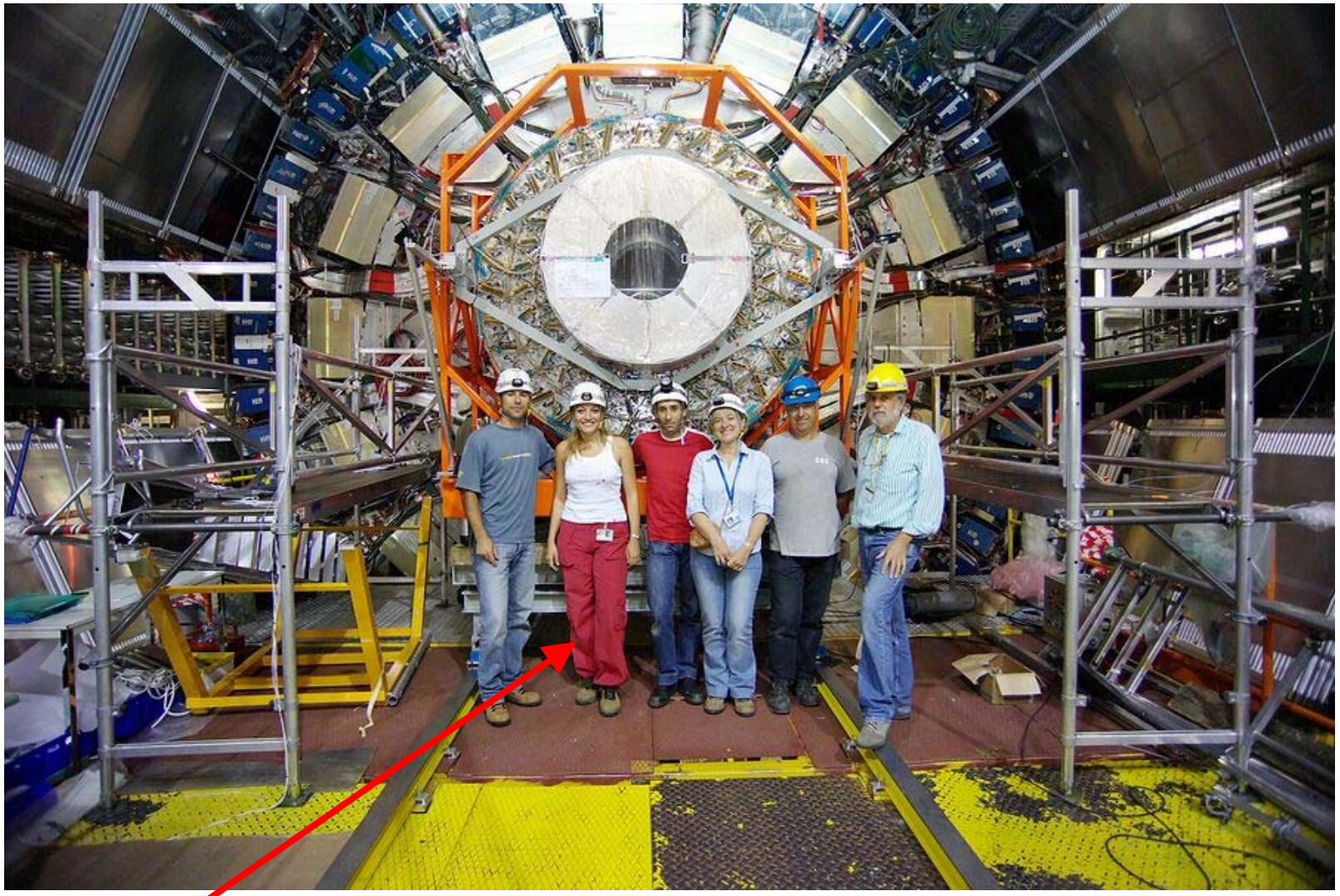
The Barrel SCT and TRT were Installed in the Cavern on Aug. 24, 2006



Sofia Chouridou from UCSC!

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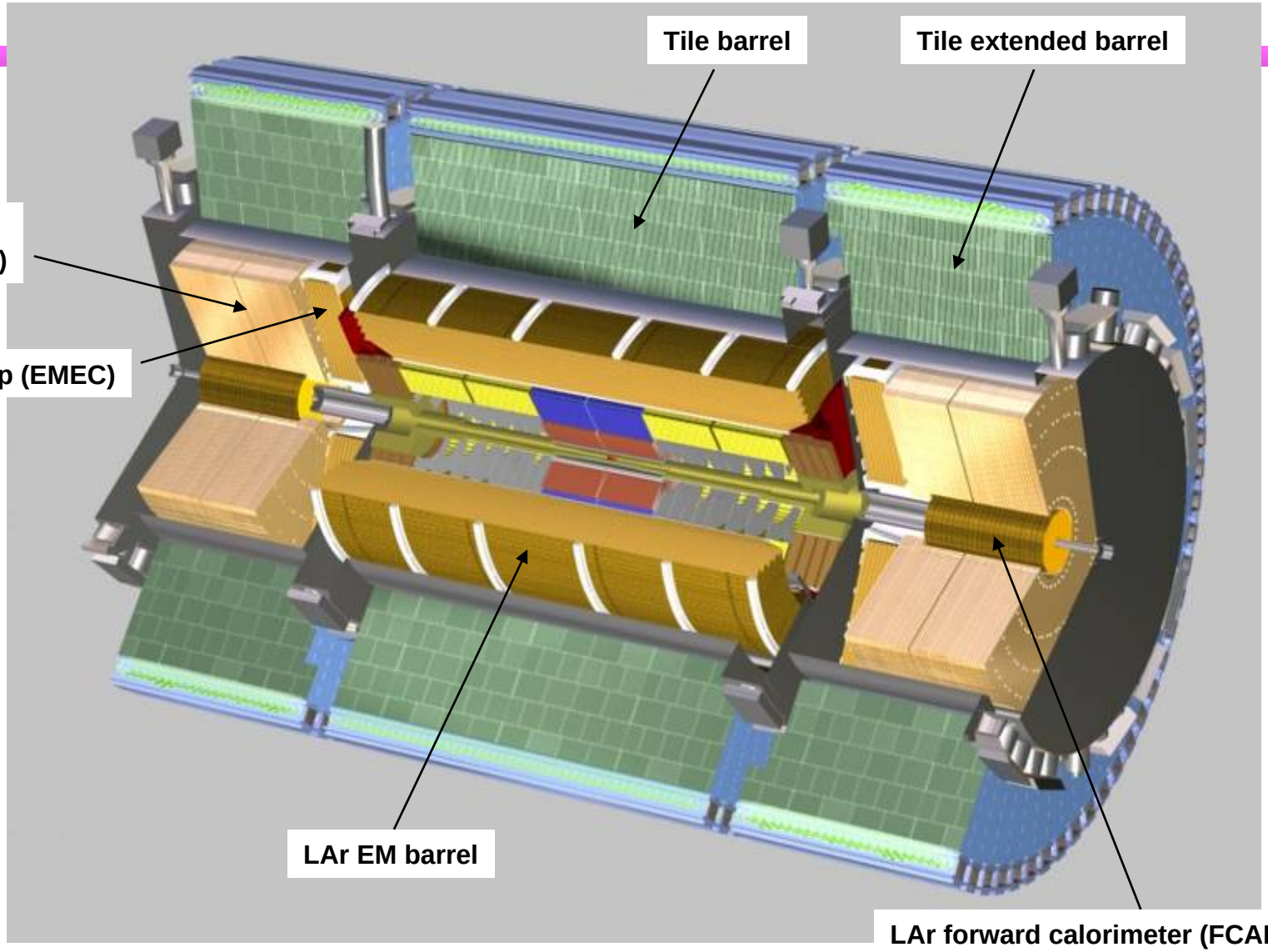
LAr and Tile Calorimeters



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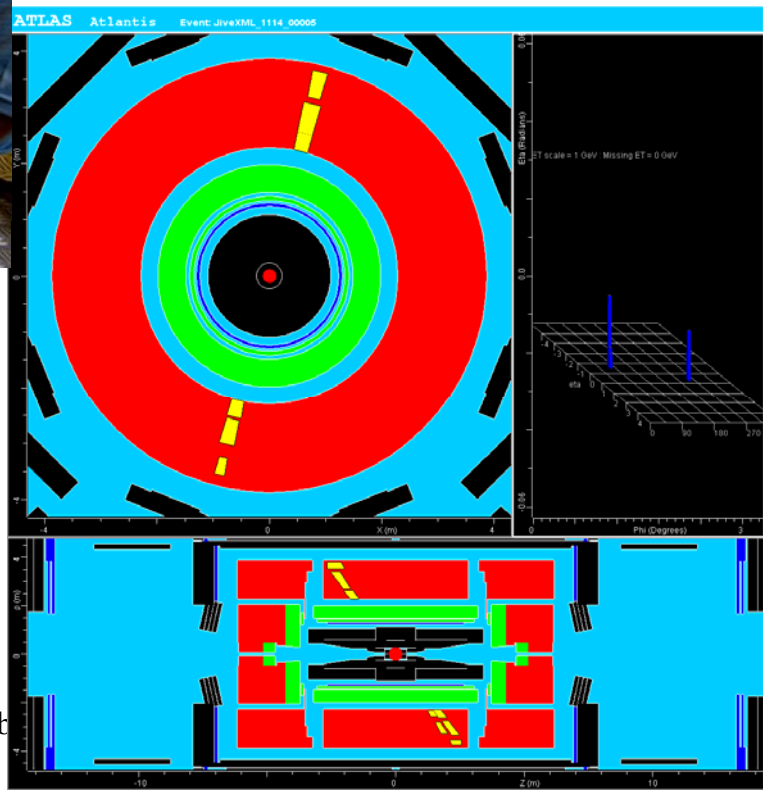
Barrel LAr and Tile Calorimeters

The barrel LAr and scintillator tile calorimeters were in the cavern in their 'garage position' (on one side, below the installation shaft) between January 2005 and November 2005

Low voltage DC-DC converters for LAr are still not completed.

A cosmic ray muon registered in the barrel Tile Calorimeter



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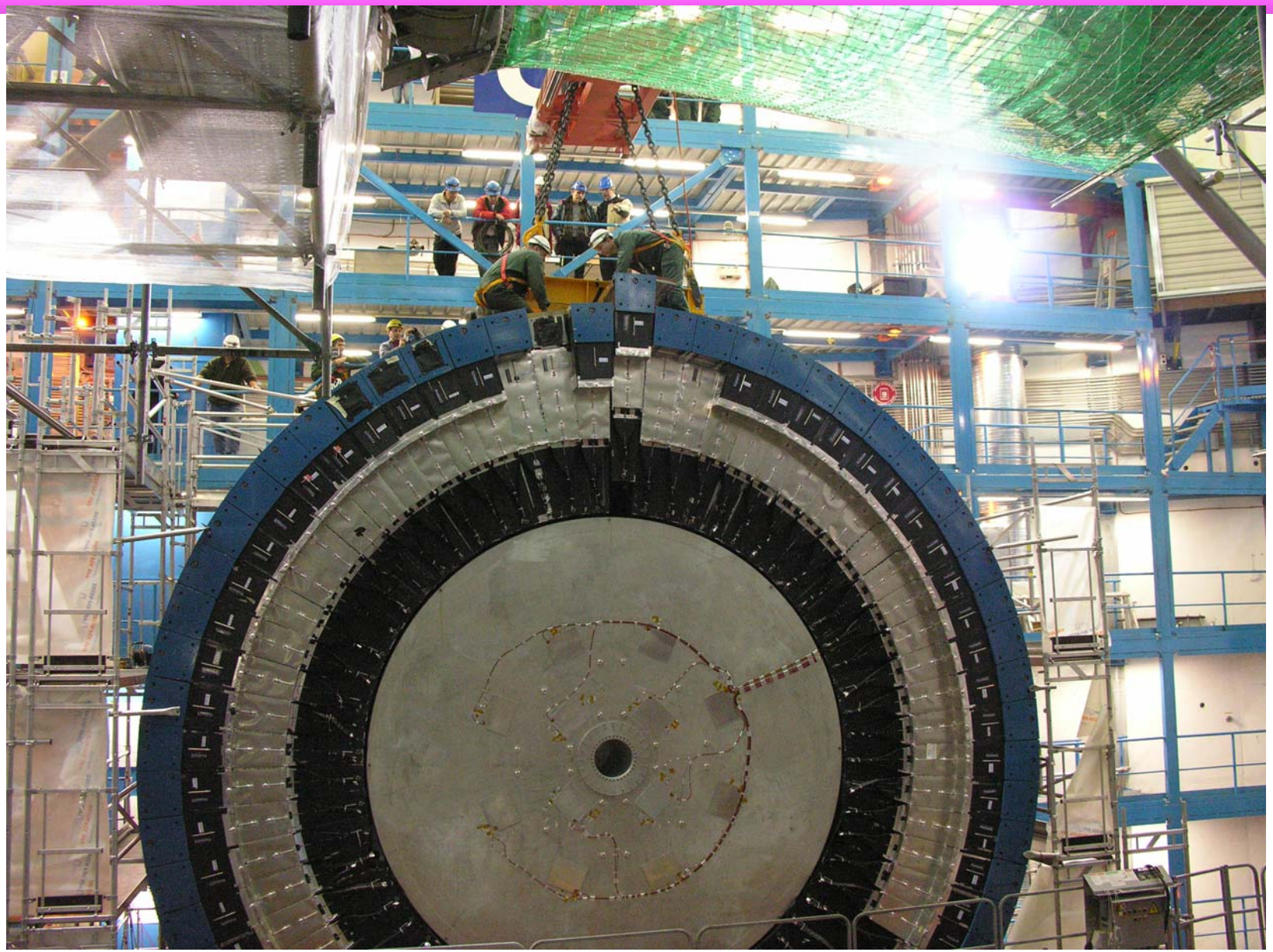
ATLAS Status-Extended Barrel C TileCal Completed Feb. 2, 2006



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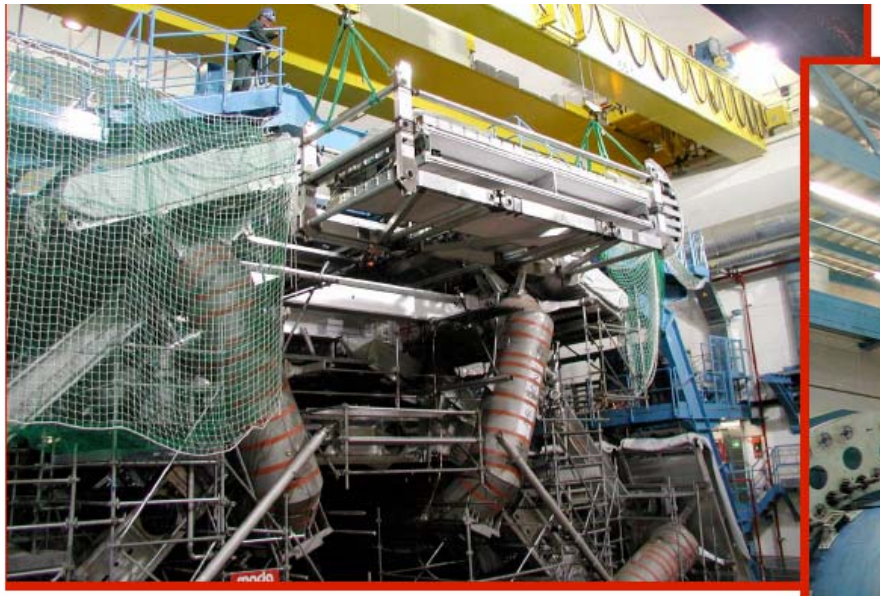
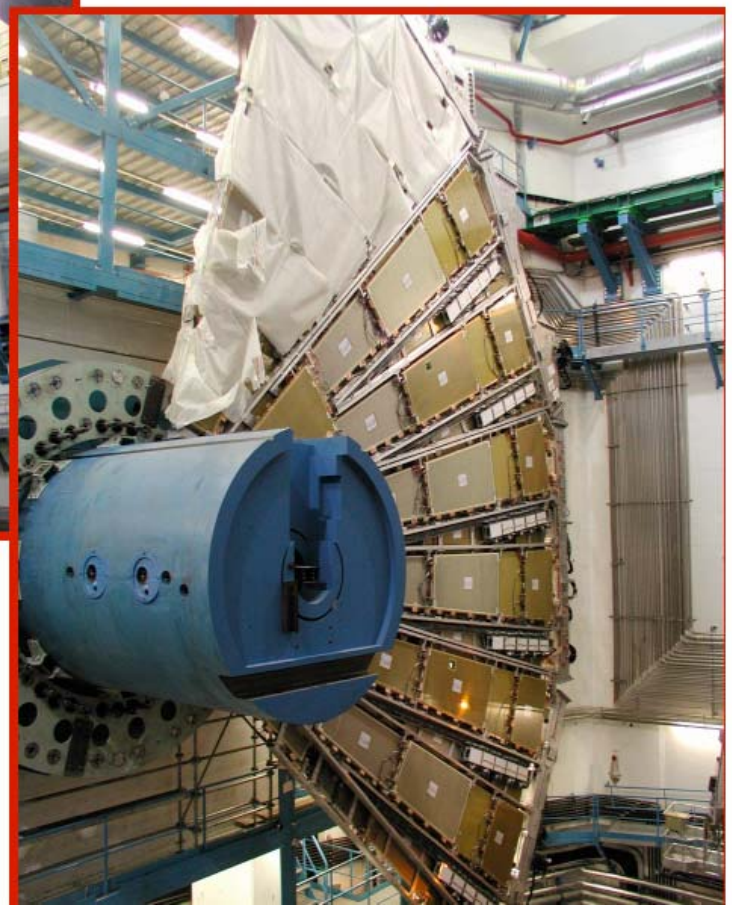
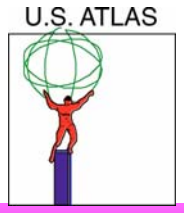
Muon Spectrometer is being Installed



~50% of barrel stations installed
(mostly complete end of Summer '06)



First sectors of TGC end-cap
"big-wheels" installed



Selected LHC Physics Topics

- **Standard Model Physics before any Discoveries**
  - **Alignment and calibration**
  - **Top, W, Z, jets, γ, b-tagging, etc.**
- **Source of Electro-Weak Symmetry Breaking**
  - **SuperSymmetry**
    - **Existence?**
    - **Spectrum**
  - **Higgs – Standard Model**
    - **Existence?**
    - **Properties: Mass, spin, couplings**
- **New Heavy Bosons?**
- **New Phenomena: Extra Dimensions, Black Holes, monopoles, etc.?**

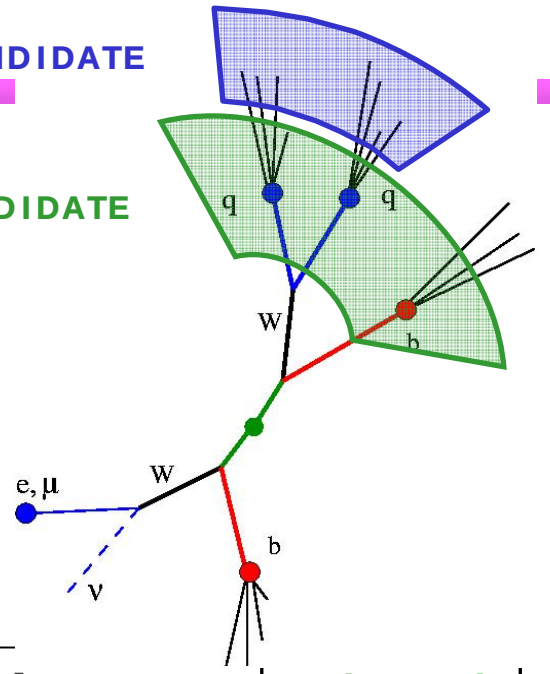
top mass reconstruction

1 Hadronic top:

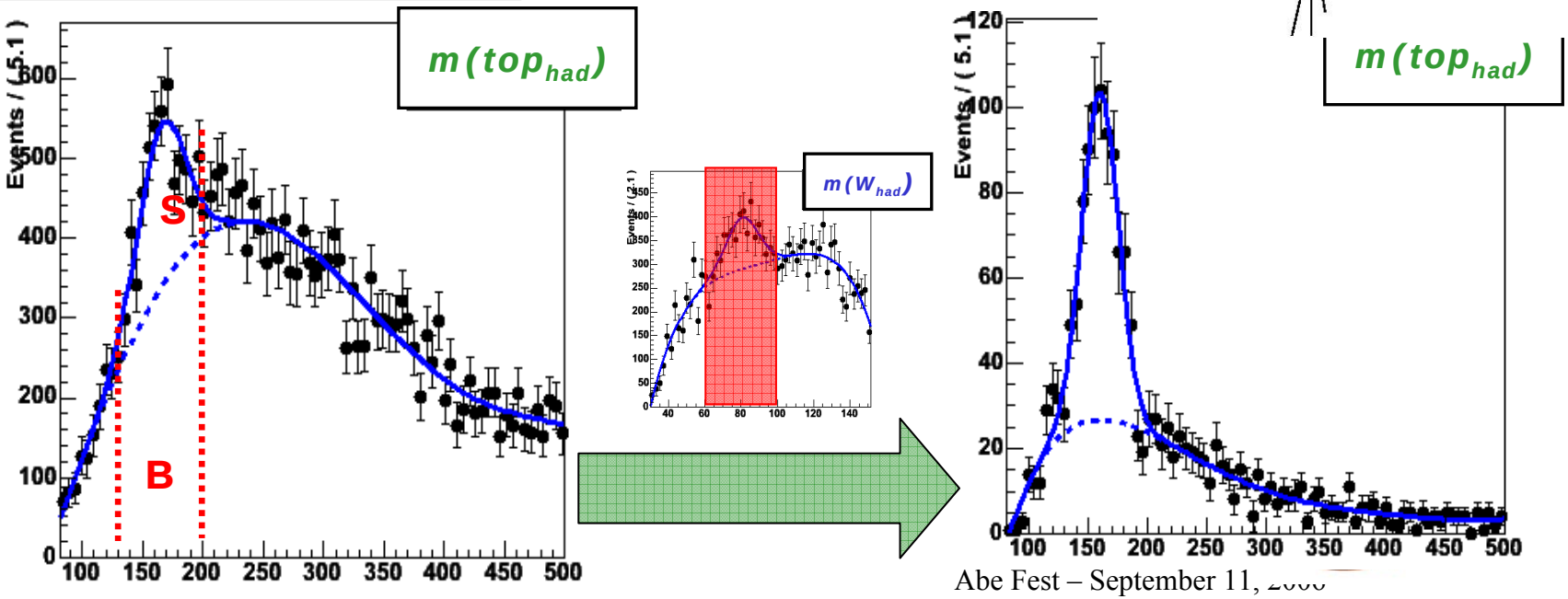
Three jets with highest vector-sum p_T as the decay products of the top

2 W boson:

Two jets in hadronic top with highest momentum in reconstructed jjj C.M. frame.



Hadron side No b-tag
L=300 pb^{-1} (1st Year?)



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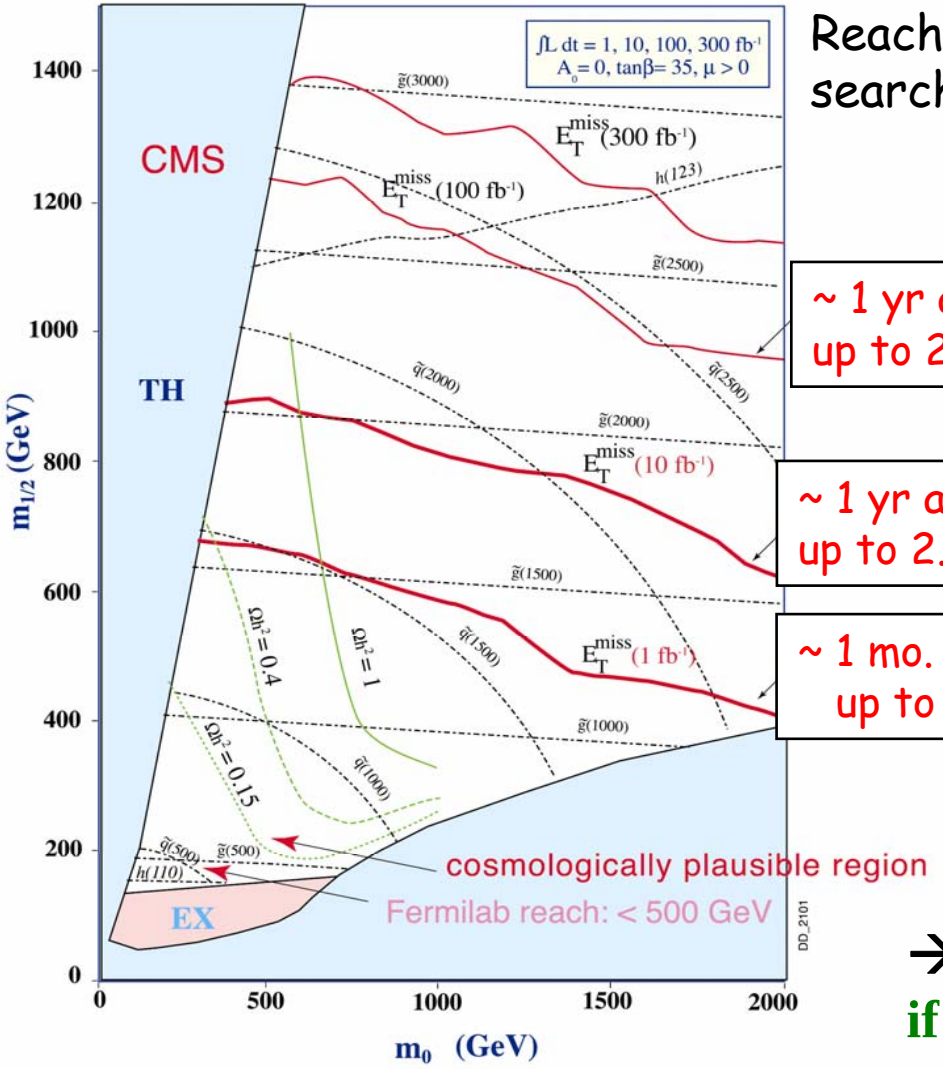
A Supersymmetry Discovery Could Come Soon
We need to work hard to understand the backgrounds



Reach of Multijet + E_T^{miss} search

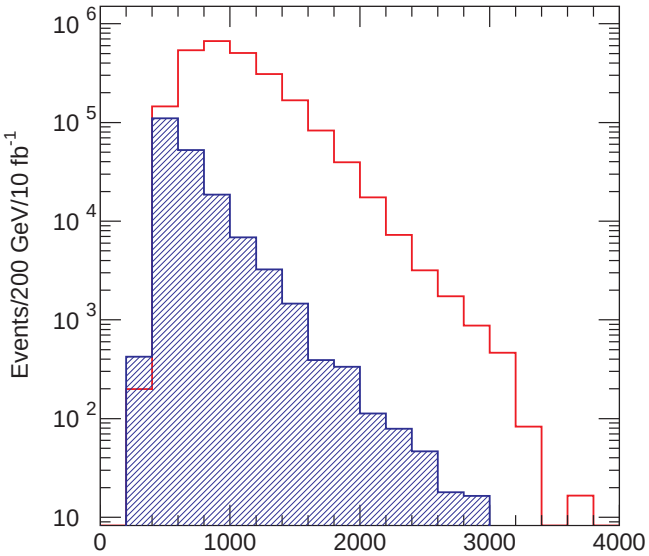
~ 1 yr at 10^{34}: up to 2.8 TeV

~ 1 yr at 10^{33}: up to 2.3 TeV

~ 1 mo. at 10^{33}: up to 2 TeV

This was the older S/B

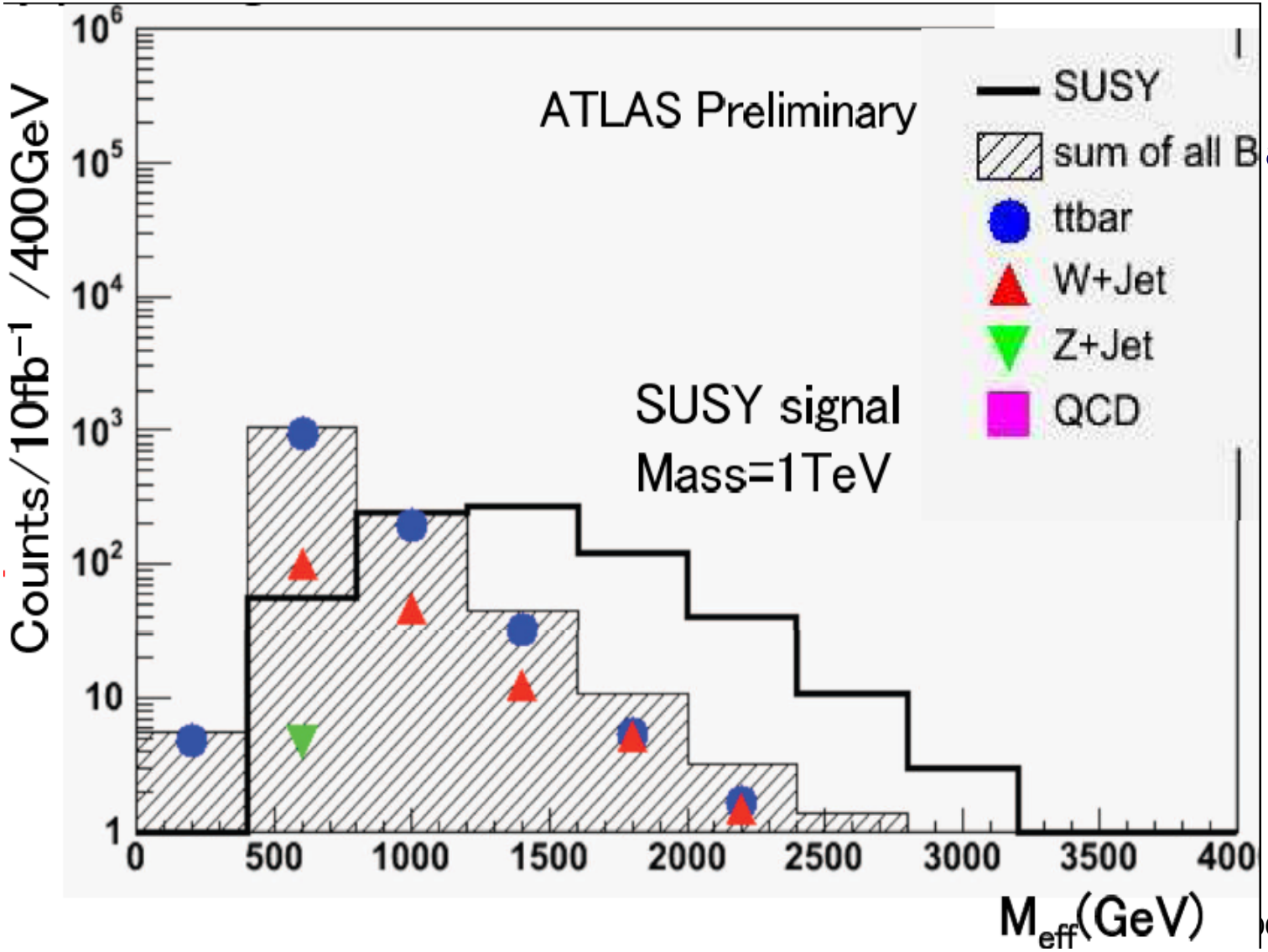
ATLAS SUGRA Pt. 6



Meff = $\Sigma p_T(j_i) + E_T^{miss}$

→ **SUSY could be found quickly if isolated from SM backgrounds**

We now believe SUSY may need a Lepton Trigger

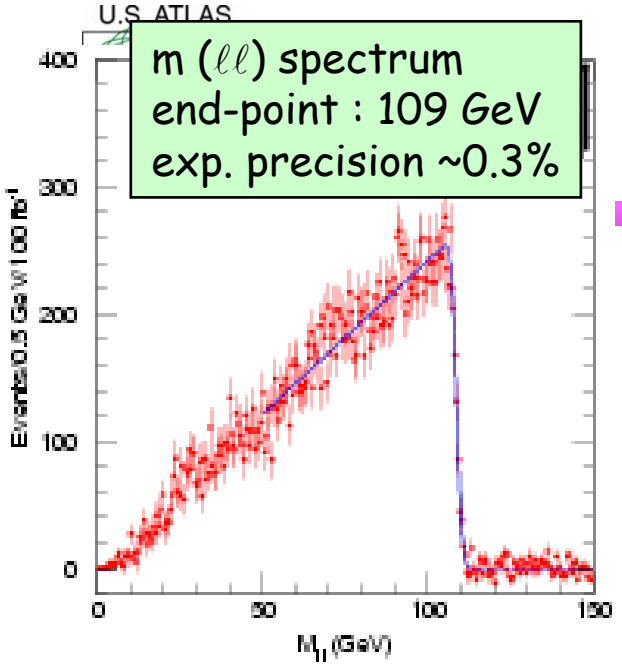


Background

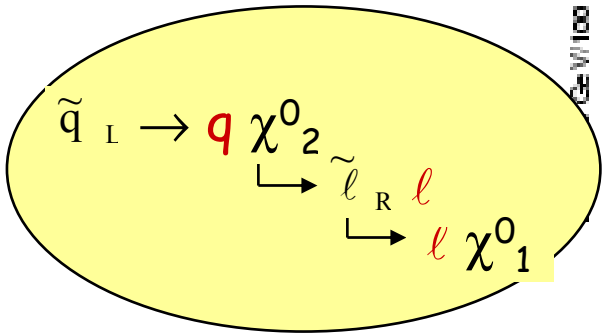
Signature for SUSY from Multi-jets and Missing E_T is more robust if a lepton is required.

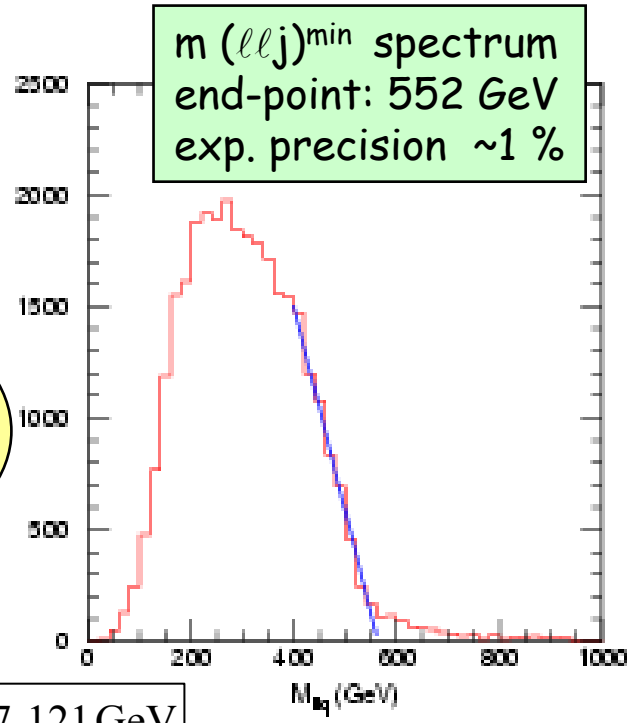
Using more modern generators indicates that the background in the no-lepton channel is higher than we thought.

Example Reconstruction Of a SUSY Decay Chain

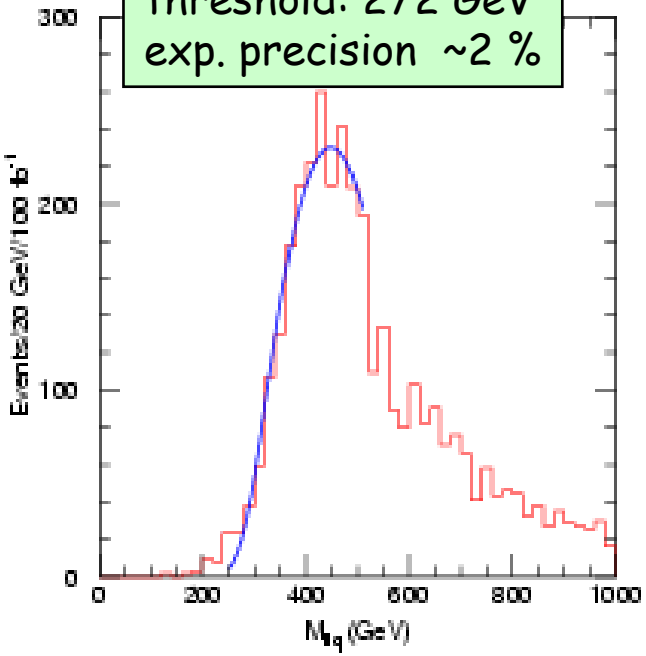


m ($\ell\ell$) spectrum
end-point : 109 GeV
exp. precision ~0.3%





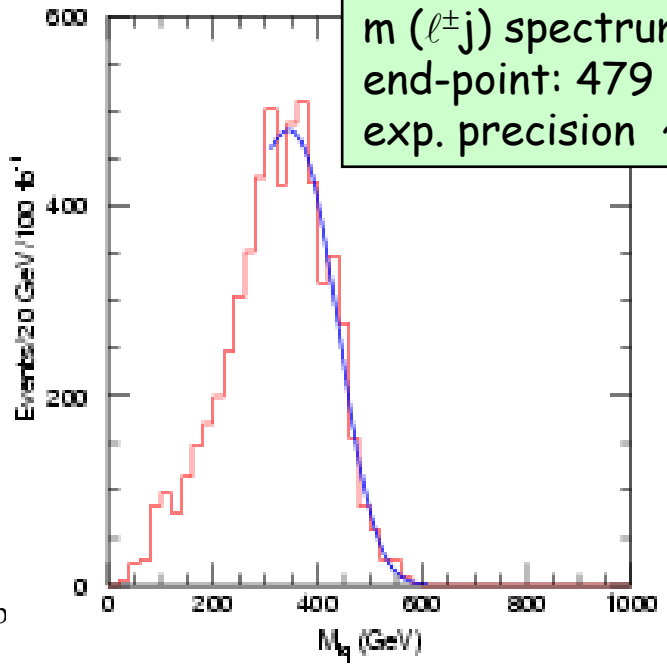
m ($\ell\ell$j)^{min} spectrum
end-point: 552 GeV
exp. precision ~1 %



m ($\ell\ell$j)^{max} spectrum
threshold: 272 GeV
exp. precision ~2 %

$$m(\tilde{q}_L, \chi^0_2, \tilde{\ell}_R, \chi^0_1) = 690, 232, 157, 121\,\text{GeV}$$

ATLAS
100 fb^{-1}
LHC Point 5

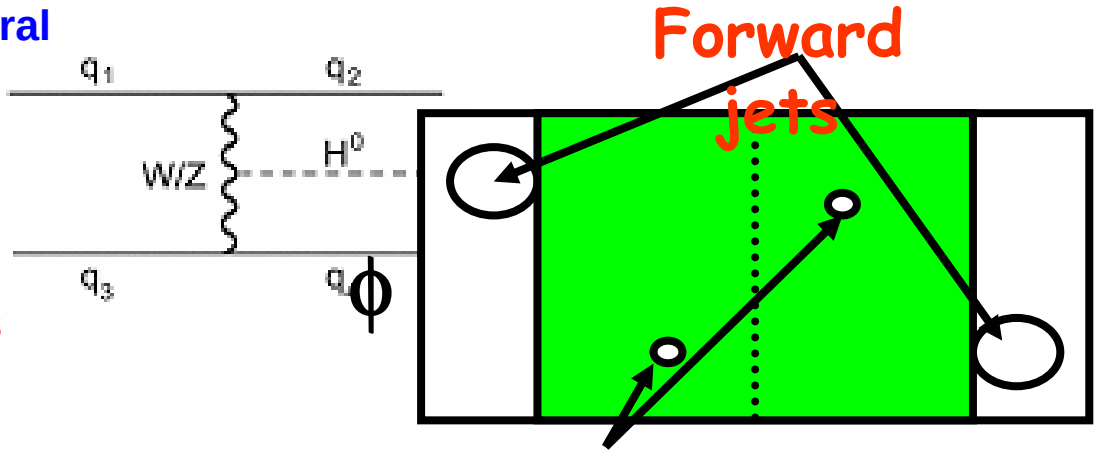


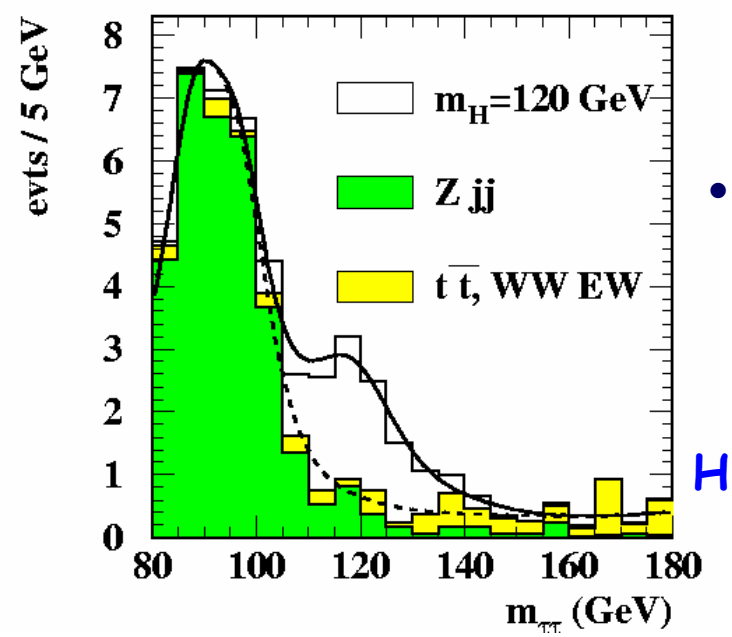
m ($\ell^{\pm}$j) spectrum
end-point: 479 GeV
exp. precision ~1 %

Ab

Vector Boson Fusion Modes

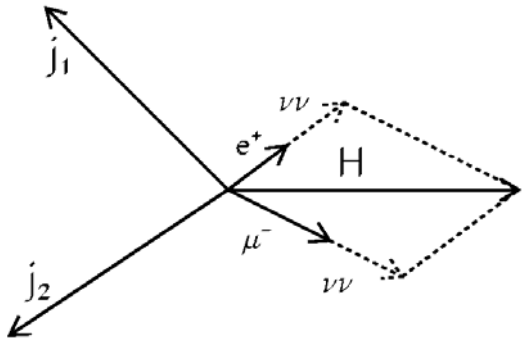
- **Exploit topology: two fwd jets, only Higgs decay products in central region**
- **Useful for:**
  - Higgs discovery potential
  - Measuring Higgs couplings
  - Exotica (eg. “invisible” Higgs decays)



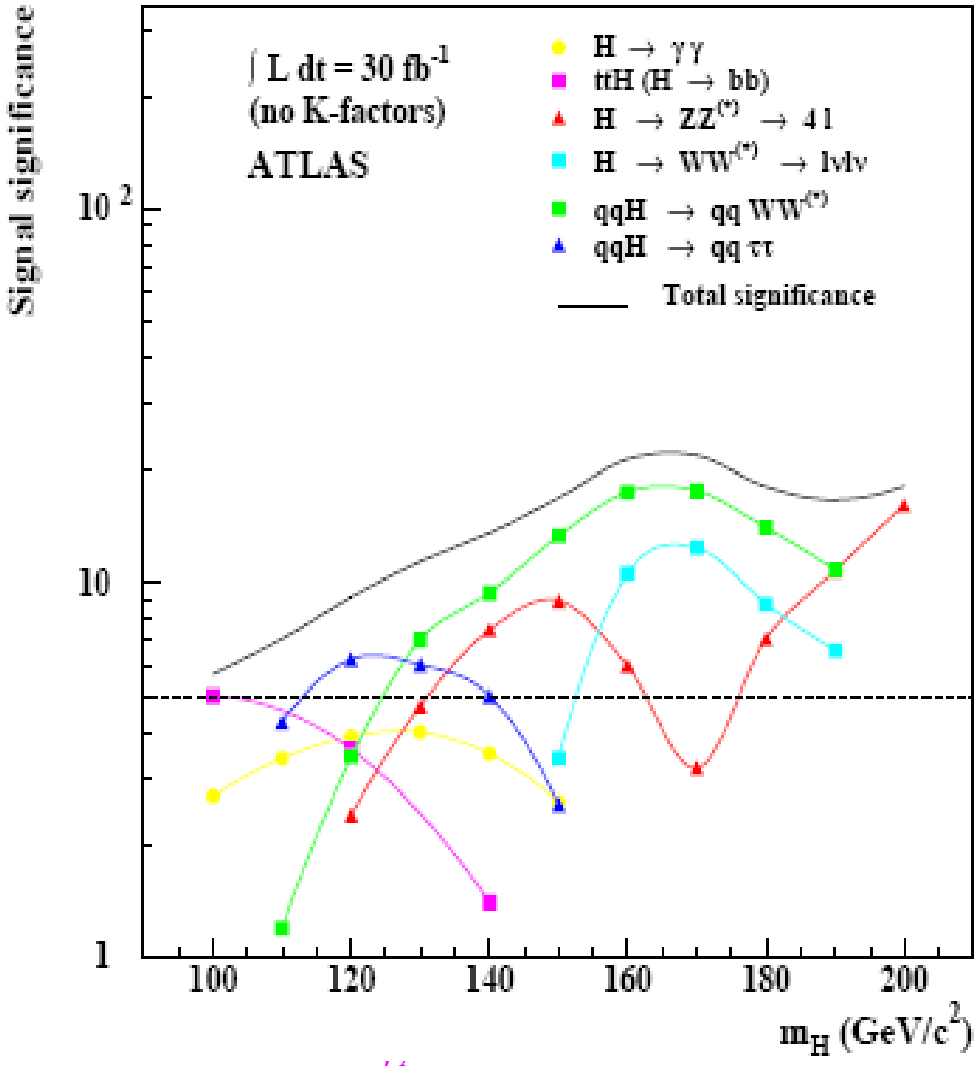


- **Example: H→ττ (ττ->ll,lh):**
  - $M_{\tau\tau}$ reconstruction using collinear approximation
  - Mass resolution ~10%

$H \rightarrow \tau\tau \rightarrow ll$ (30 fb^{-1})



Higgs Discovery will take some time but again if it exists we will find it.



ATLAS (and CMS) will discover the Higgs with >5σ after 3 years of running at 1/10 of the nominal luminosity.

Signal significance is $S/B^{1/2}$ or using Poisson statistics

Changes from ATLAS TDR

-the addition of the blue curve the so-called Vector Boson Fusion (VBF) Higgs to ττ, denoted in the plot as qqH→qqττ
- the addition of the green curve VBF H->WW→*ll* νν
- the magenta curve for ttH with H→bb has gone down with recent simulations.

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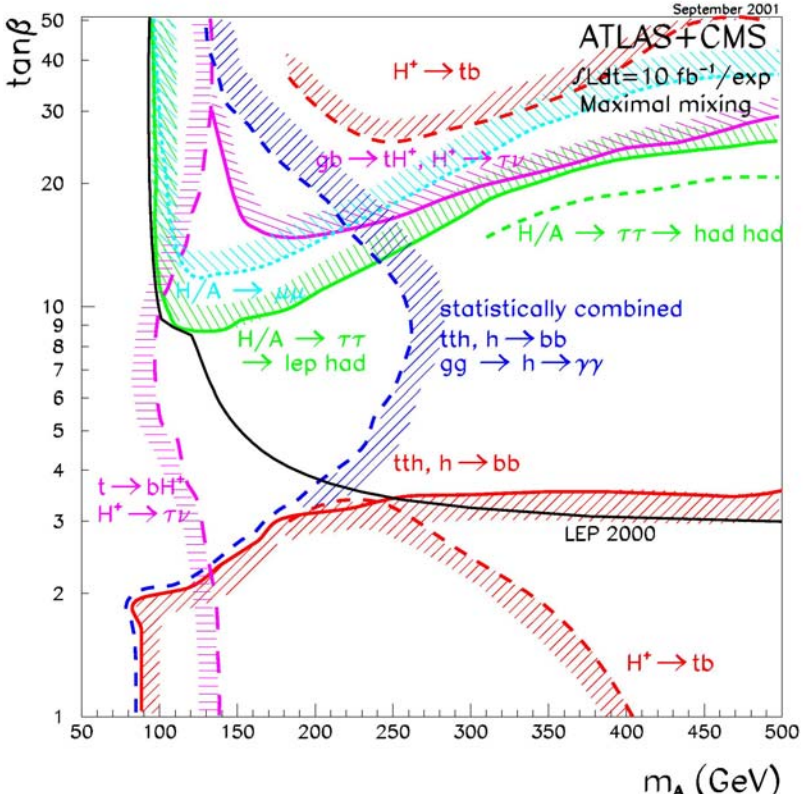
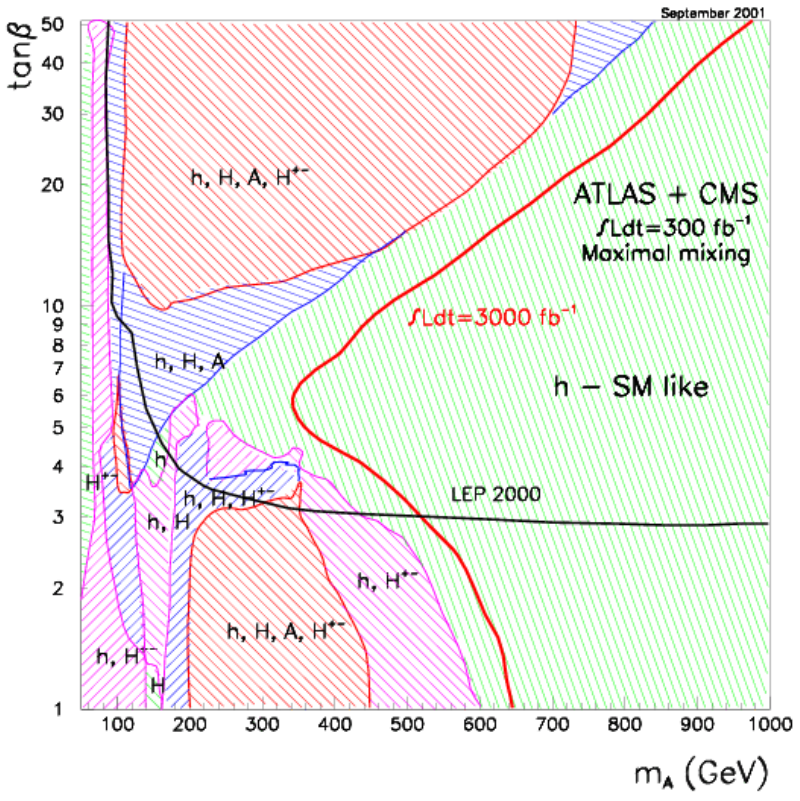
MSSM Higgs Discovery Potential

- 2 Higgs doublets ⇒ physical Higgs states are h, H, A, $H^{\pm}$
- At least one Higgs observable over entire m_A-tanβ plane (covered almost completely already with 10 fb^{-1})
- Sizeable region with SM-like h gets better covered if include decays to sparticles, but then very model dep.

4 Higgs observable
3 Higgs observable
2 Higgs observable
1 Higgs observable

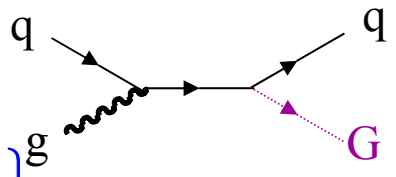




Extra Dimensions

- **Many different theoretical variants exist:**
  - Large extra dimensions (ADD)
  - Randall-Sundrum models with “warped” extra dimensions
  - Strong gravity at the TeV scale (with Black Hole production!)
  - …

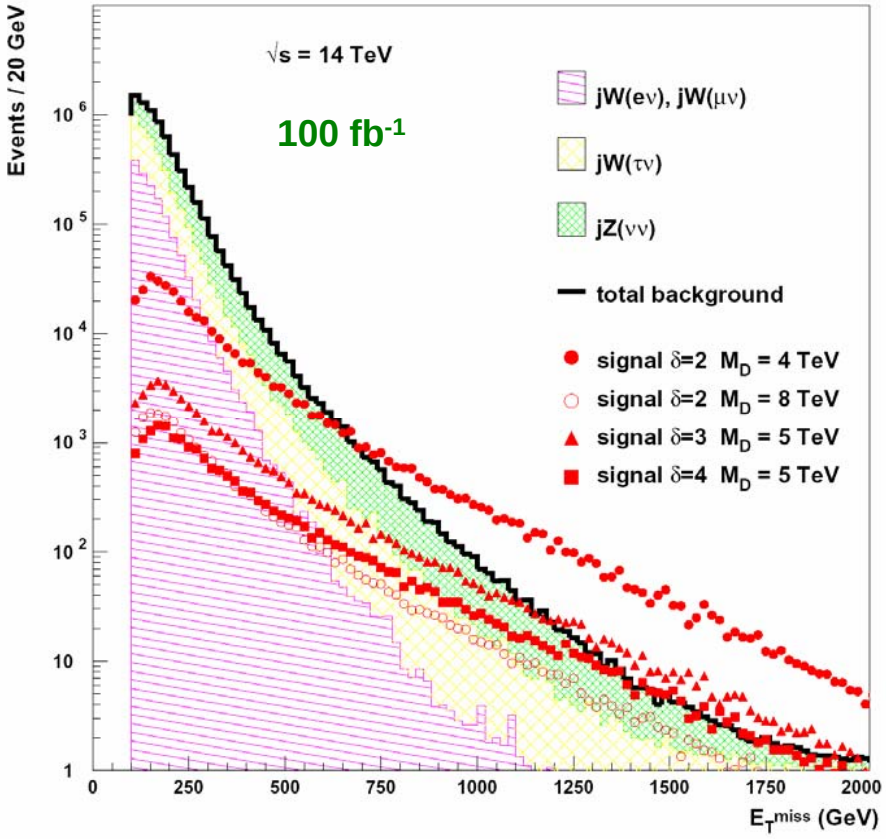
- **ADD example:**



$$\bar{q}q \to gG^{(k)},\ \gamma G^{(k)}$$
$$qg \to qG^{(k)}$$
$$gg \to gG^{(k)}$$

} jets + $\not{E}_T$, $\gamma + \not{E}_T$

δ	M_D^{max} (TeV) LL, 30 fb^{-1}	M_D^{max} (TeV) HL, 100 fb^{-1}	M_D^{min} (TeV)
2	7.7	9.1	~ 4
3	6.2	7.0	~ 4.5
4	5.2	6.0	~ 5



Future Upgrade: "Super LHC"

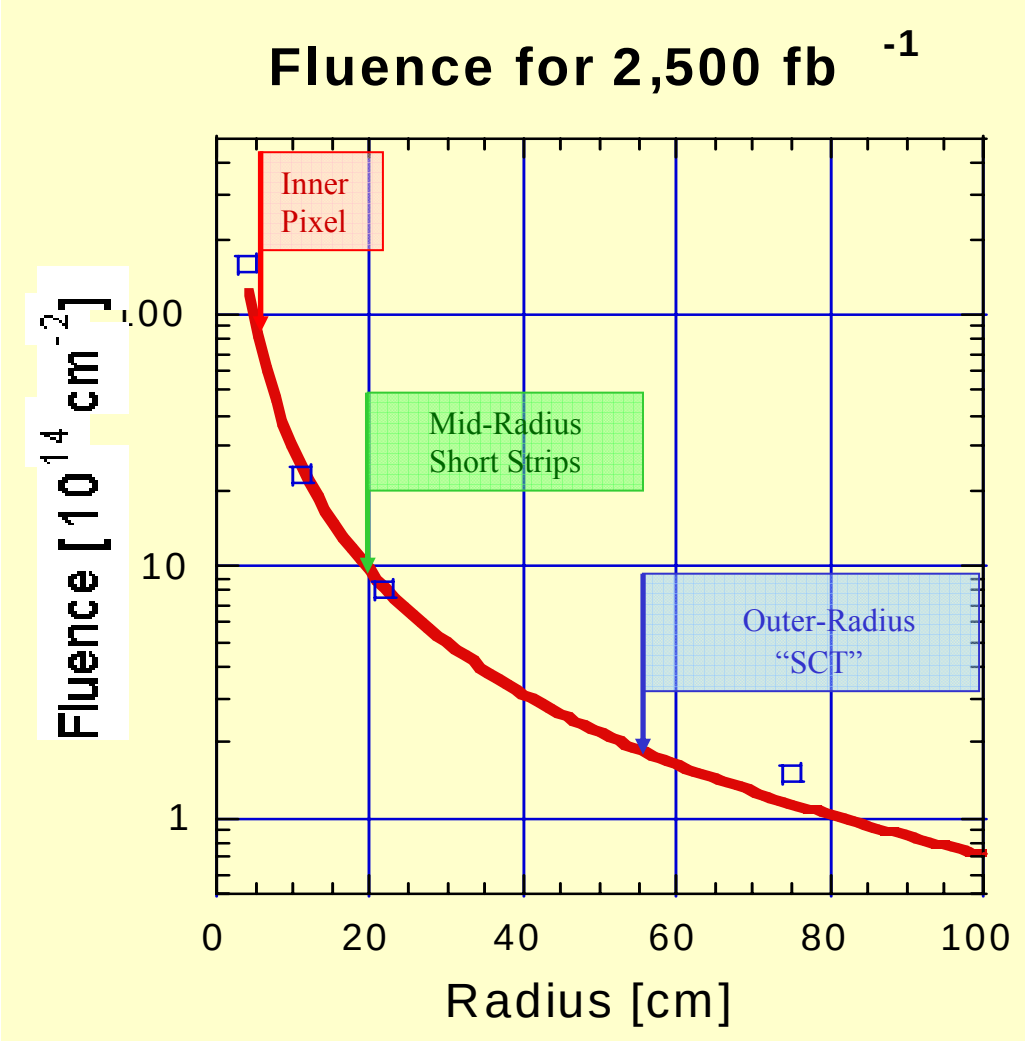
- **Although we expect to make discoveries and a lot of measurements at the LHC, plans have started for upgrading LHC**
  - Higher energy difficult without major R&D development
  - Higher luminosity (10^{35} cm^{-2} s^{-1}) seems feasible

- **Some studies have been done to evaluate increased physics potential:**

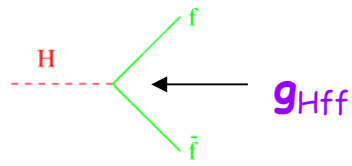
PROCESS	LHC 14 TeV 100 fb^{-1}	SLHC 14 TeV 1000 fb^{-1}	28 TeV 100 fb^{-1}
Squarks	2.5	3	4
Z'	5	6	8
Extra-dim (δ=2)	9	12	15
q*	6.5	7.5	9.5
Λcompositeness	30	40	40
TGC (λ_γ)	0.0014	0.0006	0.0008

- **Very prelim. studies also suggest it is possible with 3000 fb^{-1} per experiment to make the first measurement of the Higgs self-coupling via HH production**
- **Detector R&D is getting underway, to be ready for ~ 2010-2014 Construction Period**

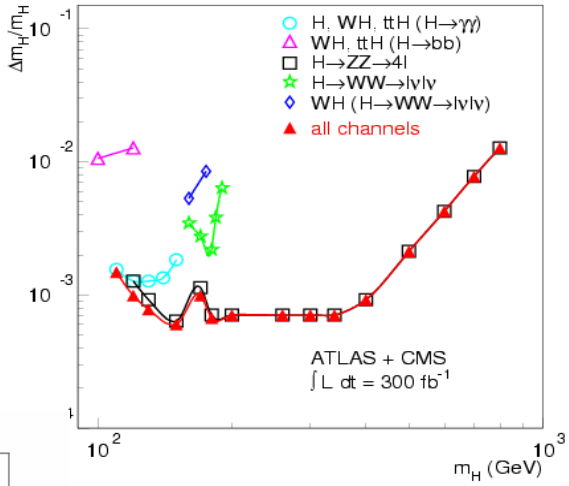
SLHC Tracking Constraints



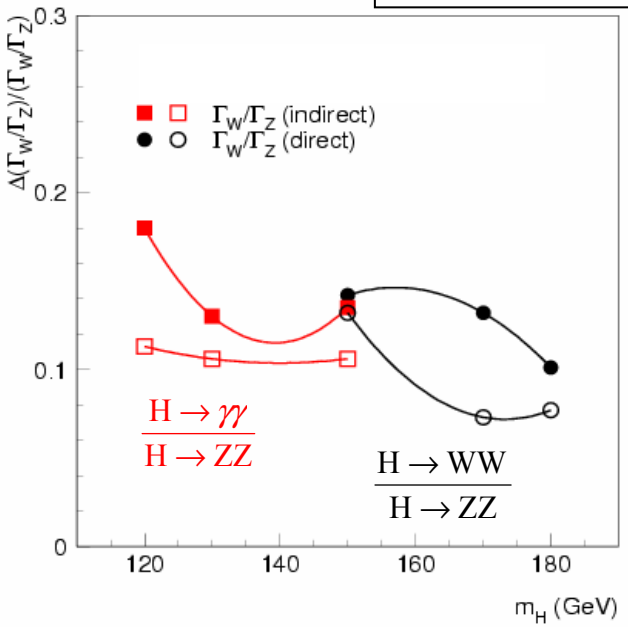
Measurement of SM Higgs Parameters

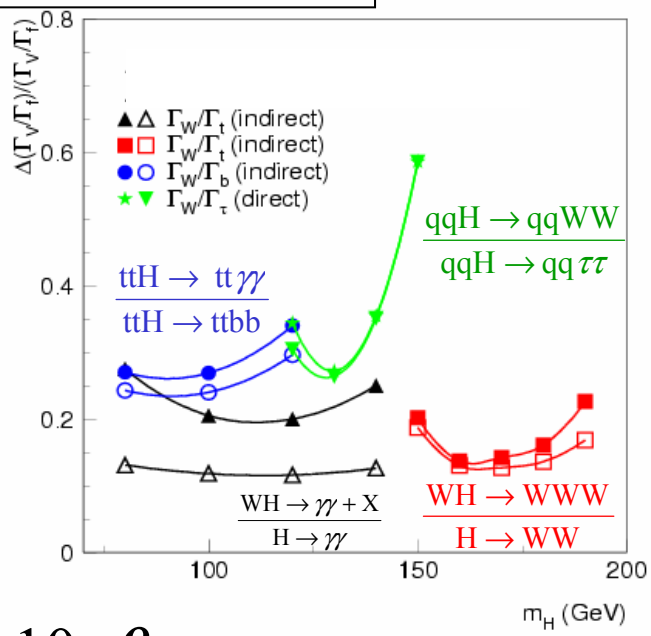


- m(H) can be measured to < 0.1% precision over entire mass range
- Ratios of rates in different production/decay modes provide info. about couplings (theory input needed to determine couplings separately)



Closed symbols: LHC 600 fb^{-1}
Open symbols: SLHC 6000 fb^{-1}

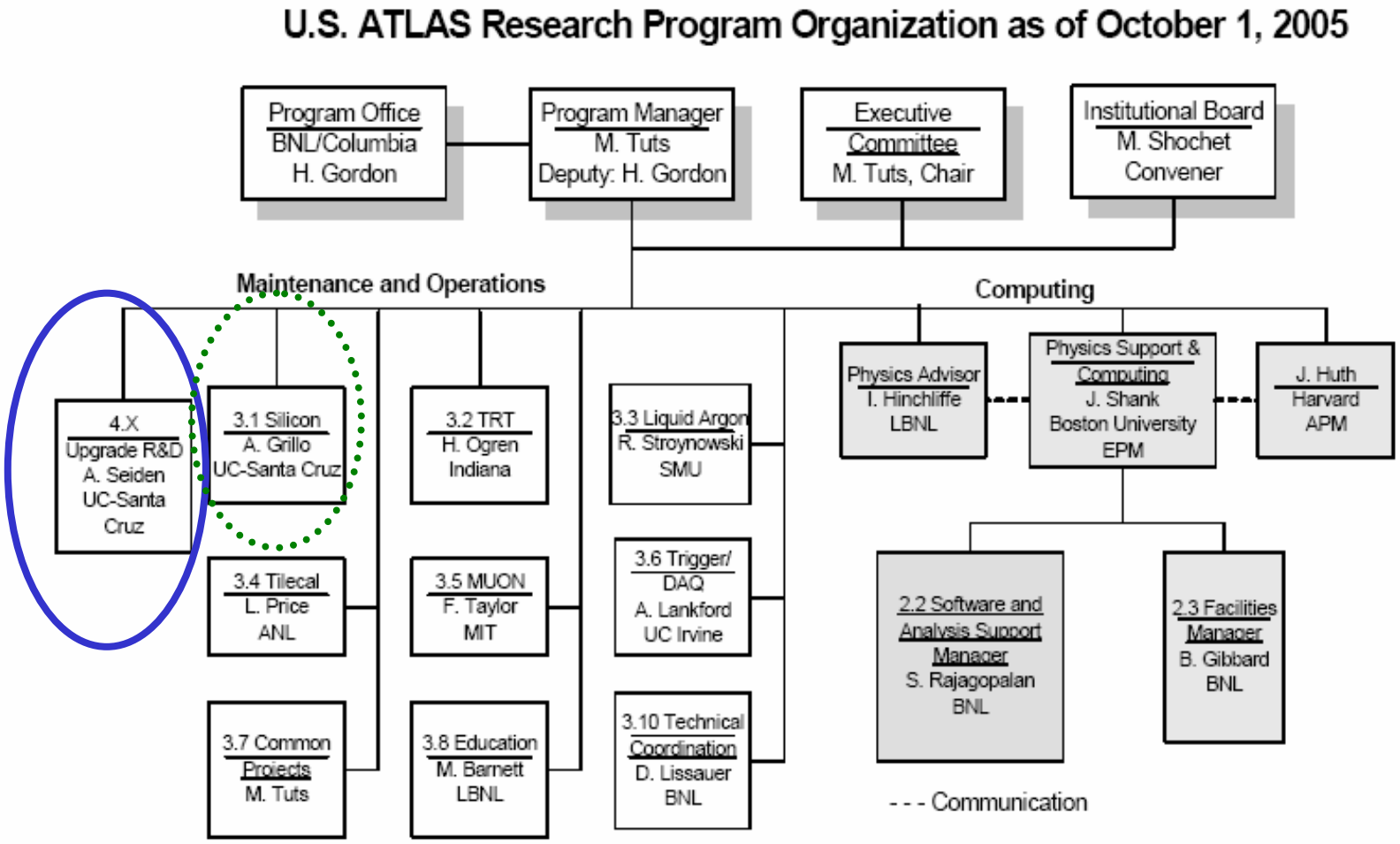


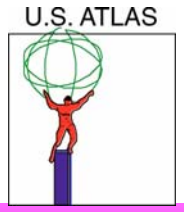


- SLHC could improve LHC precision by up to ~ 2 before ILC becomes operational
- Measurement of the couplings not competitive with the ILC precision of ≈ 1%

SLHC=Super LHC! 10x$\mathcal{L}$

US ATLAS Organization Chart





Abe Seiden is a Successful Manager in U.S. ATLAS

- Abe started as a Level 3 Manager for the Silicon Strip System (aka SCT) (WBS 1.1.2)
  - Work carried on from the SSC
- Abe then became a Level 2 Manager for the entire Silicon System: Pixels, SCT, and RODs (Read-Out Drivers) (WBS 1.1)
- Abe is now the Manager for the Upgrade R&D (WBS 4.0)
  - He is a member of the ATLAS High Luminosity Steering Group
- Abe is creative, productive and a pleasure to work with
  - He anticipates problems and brings possible solutions
  - He is prompt in supplying information