Welcome to CERN

8th Concertation meeting
CERN, Globe of Science and Innovation

Sergio Bertolucci
Director for Research and Computing
4 November 2010

The Mission of CERN

- **Push back** the frontiers of knowledge

  E.g. the secrets of the Big Bang …what was matter like within the first moments of the Universe's existence?

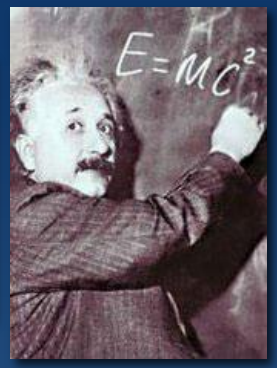
- **Develop** new technologies for accelerators and detectors

  Information technology - the Web

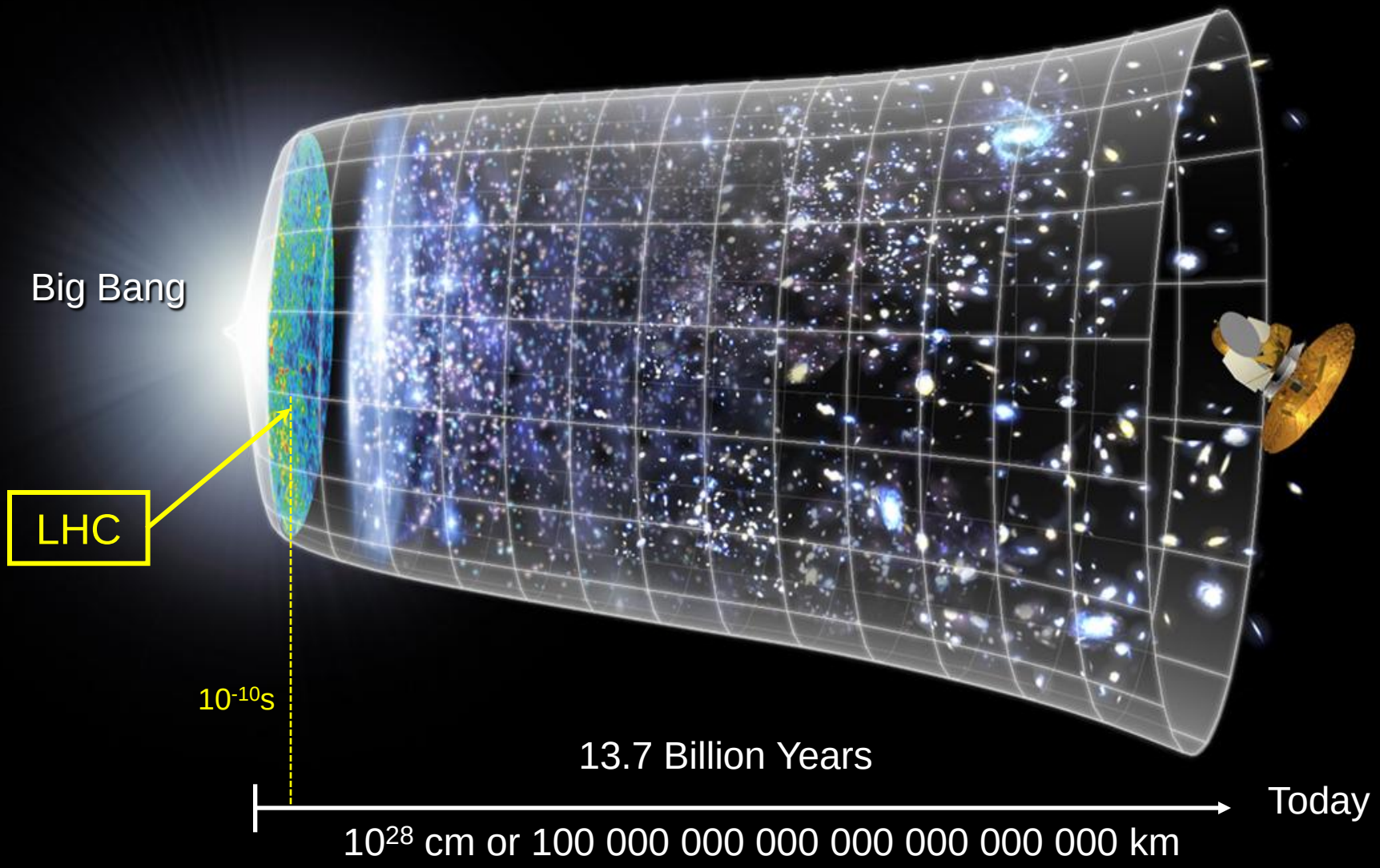
  Medicine - diagnosis and therapy

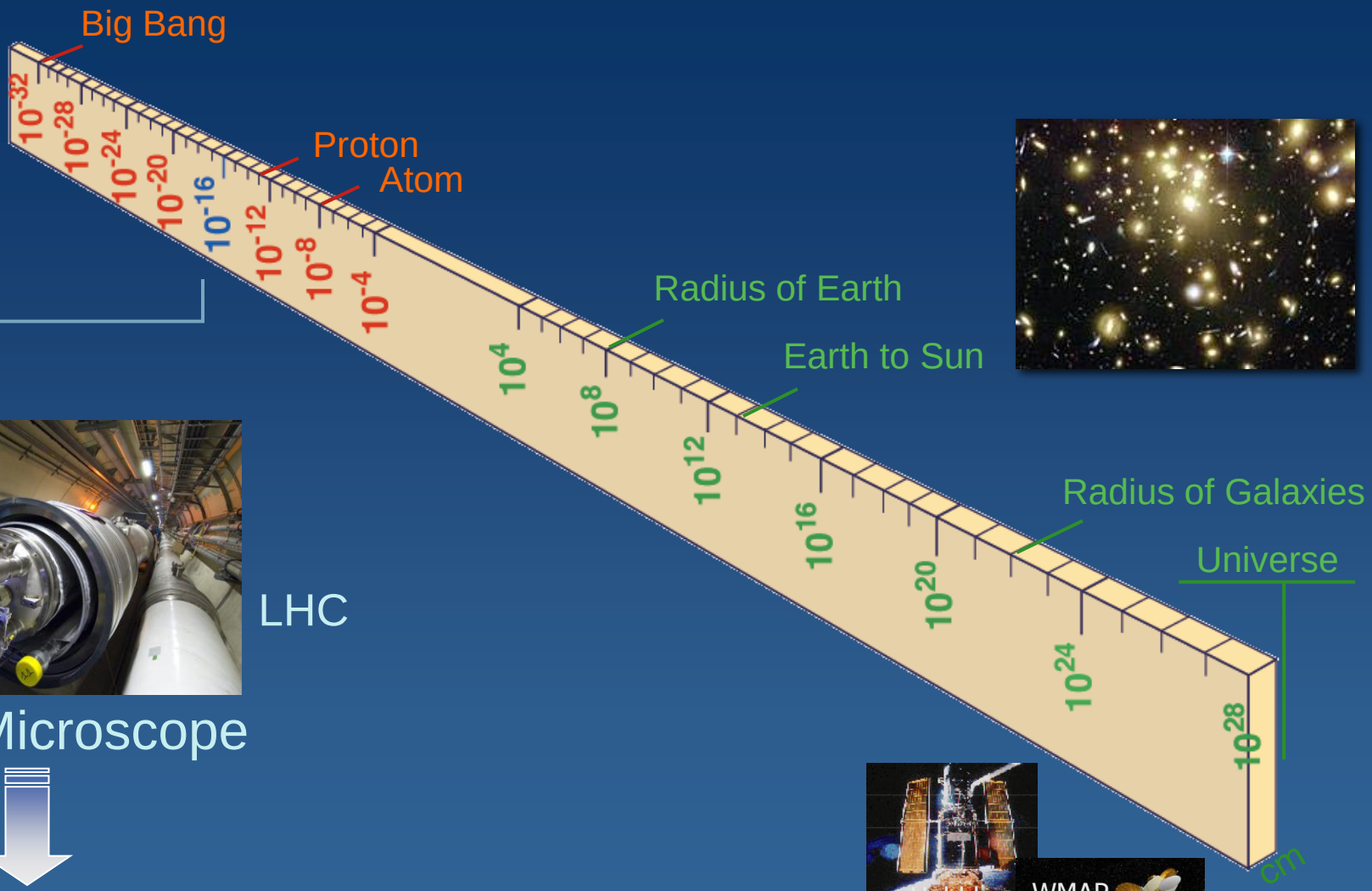
- **Train** scientists and engineers for tomorrow

- **Unite** people from different countries and cultures



Evolution of the Universe





CERN

LHC

Super-Microscope

Study physics laws of first moments after Big Bang
increasing Symbiosis between Particle Physics,
Astrophysics and Cosmology

CERN Governance

Twenty Member States:

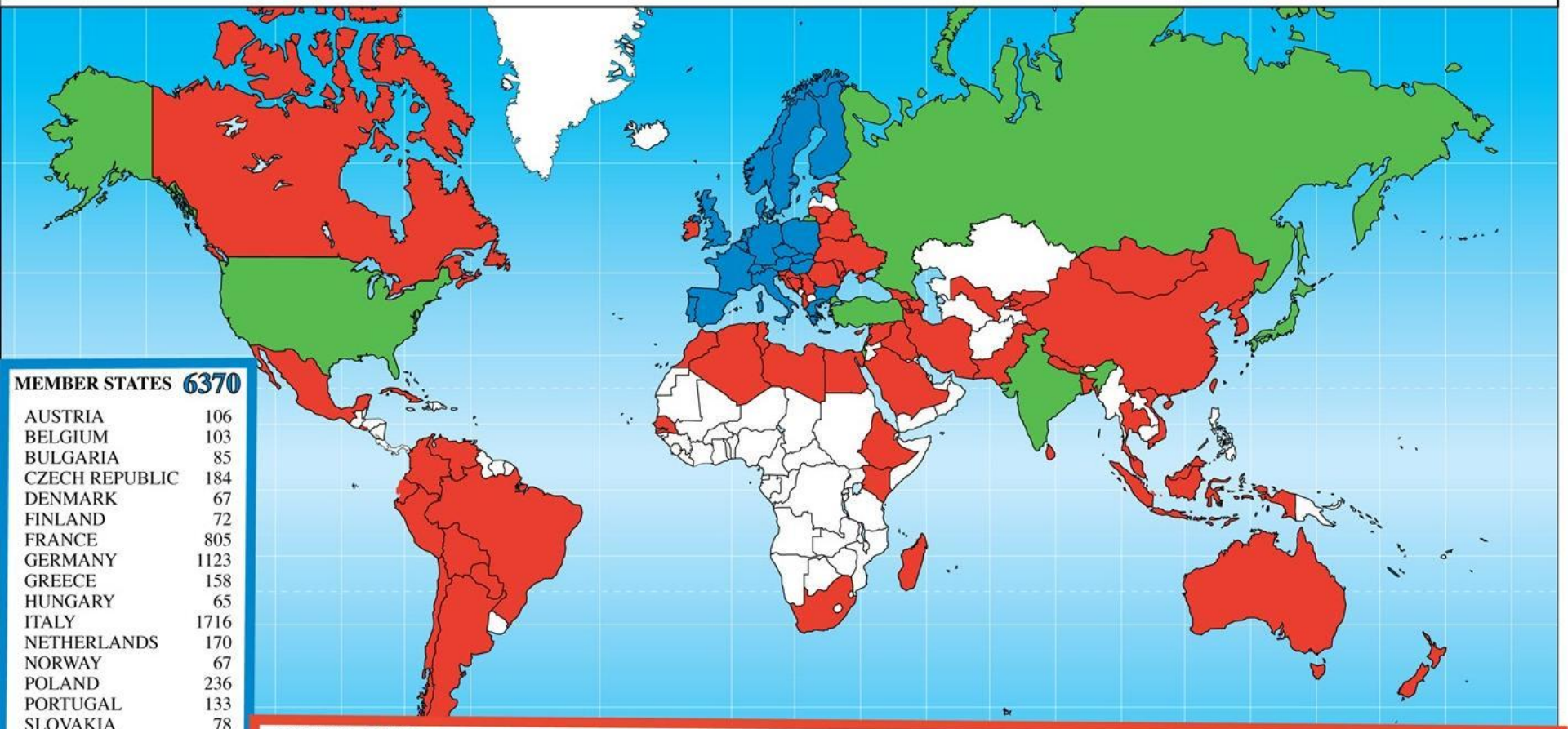
Austria	Belgium	Bulgaria	Czech Republic
Denmark	Finland	France	Germany
Greece	Hungary	Italy	Netherlands
Norway	Poland	Portugal	Slovak Republic
Spain	Sweden	Switzerland	United Kingdom

Plus eight Observers: European Commission, India, Israel, Japan, Russian Federation, Turkey, UNESCO and USA

Annual Budget: ~1000 MCHF

Personnel: 2250 Staff, 700 Fellows and Associates, >10'000 Users

Distribution of All CERN Users by Nationality on 20 January 2010



MEMBER STATES 6370

AUSTRIA	106
BELGIUM	103
BULGARIA	85
CZECH REPUBLIC	184
DENMARK	67
FINLAND	72
FRANCE	805
GERMANY	1123
GREECE	158
HUNGARY	65
ITALY	1716
NETHERLANDS	170
NORWAY	67
POLAND	236
PORTUGAL	133
SLOVAKIA	78
SPAIN	330
SWEDEN	67
SWITZERLAND	200
UNITED KINGDOM	605

OBSERVER STATES 2444

INDIA	158
ISRAEL	51
JAPAN	229
RUSSIA	1027
TURKEY	87
USA	892

OTHERS 1205

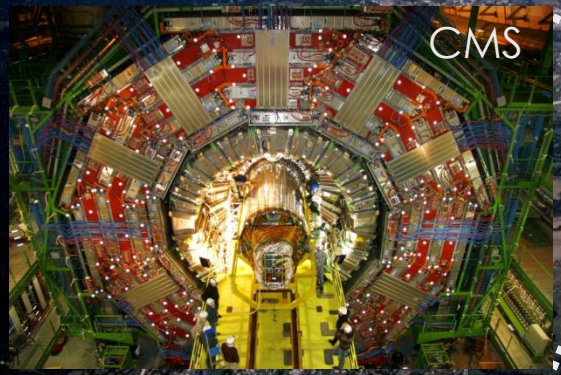
ALBANIA	2	BRAZIL	79	ESTONIA	9	KYRGYZSTAN	1	MOROCCO	16	SINGAPORE	1
ALGERIA	8	CANADA	136	ETHIOPIA	1	LEBANON	8	NEPAL	3	SLOVENIA	20
ARGENTINA	11	CHILE	3	GEORGIA	31	LITHUANIA	9	NEW ZEALAND	10	SOUTH AFRICA	9
ARMENIA	24	CHINA	202	GIBRALTAR	1	LUXEMBOURG	5	PAKISTAN	33	SRI LANKA	6
AUSTRALIA	20	CHINA (TAIPEI)	41	HONG KONG	2	LIBYA	1	PALESTINE (O.T.).	1	SYRIA	2
AZERBAIJAN	5	COLOMBIA	19	INDONESIA	1	MADAGASCAR	3	PARAGUAY	1	THAILAND	1
BANGLADESH	3	CROATIA	24	IRAN	20	MALAYSIA	7	PERU	2	TUNISIA	5
BELARUS	36	CUBA	4	IRAQ	1	MALTA	3	ROMANIA	101	UKRAINE	40
BOLIVIA	2	CYPRUS	12	IRELAND	20	MAURITIUS	1	SAN MARINO	1	UZBEKISTAN	2
BOSNIA AND HERZEGOVINA	1	ECUADOR	2	KENYA	2	MEXICO	46	SAUDI ARABIA	2	VENEZUELA	5
		EGYPT	6	KOREA, D.P.R.	3	MOLDOVA	1	SENEGAL	1	VIET NAM	6
		EL SALVADOR	1	KOREA REP.	85	MONGOLIA	1	SERBIA	34		

CERN's tools

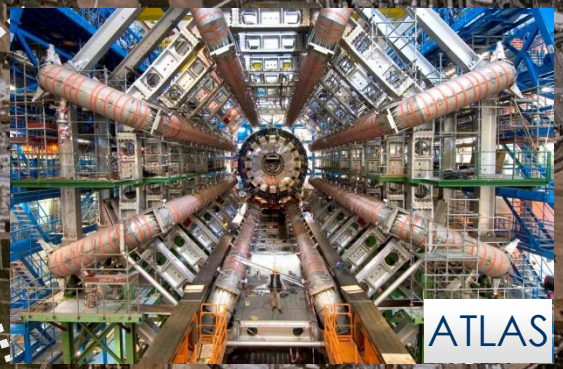
- The world's most powerful accelerator: LHC
  - A 27 km long tunnel filled with high-tech instruments
  - Equipped with thousands of superconducting magnets
  - Accelerates particles to energies never obtained before
  - Produces particle collisions creating microscopic "big bangs"
- Very large sophisticated detectors
  - Four experiments each the size of a cathedral
  - Hundred million measurement channels each
  - Data acquisition systems treating Petabytes per second
- Top level computing to distribute and analyse the data
  - A Computing Grid linking ~140 computer centres around the globe
  - Sufficient computing power, storage and networking to handle 15 Petabytes per year, making them available to thousands of physicists for analysis

Enter a New Era in Fundamental Science

Start-up of the Large Hadron Collider (LHC), one of the largest and truly global scientific projects ever, is the most exciting turning point in particle physics.



Exploration of a new energy frontier
Proton-proton collisions at E_{CM} = 7 TeV



Inside the Large Hadron Collider

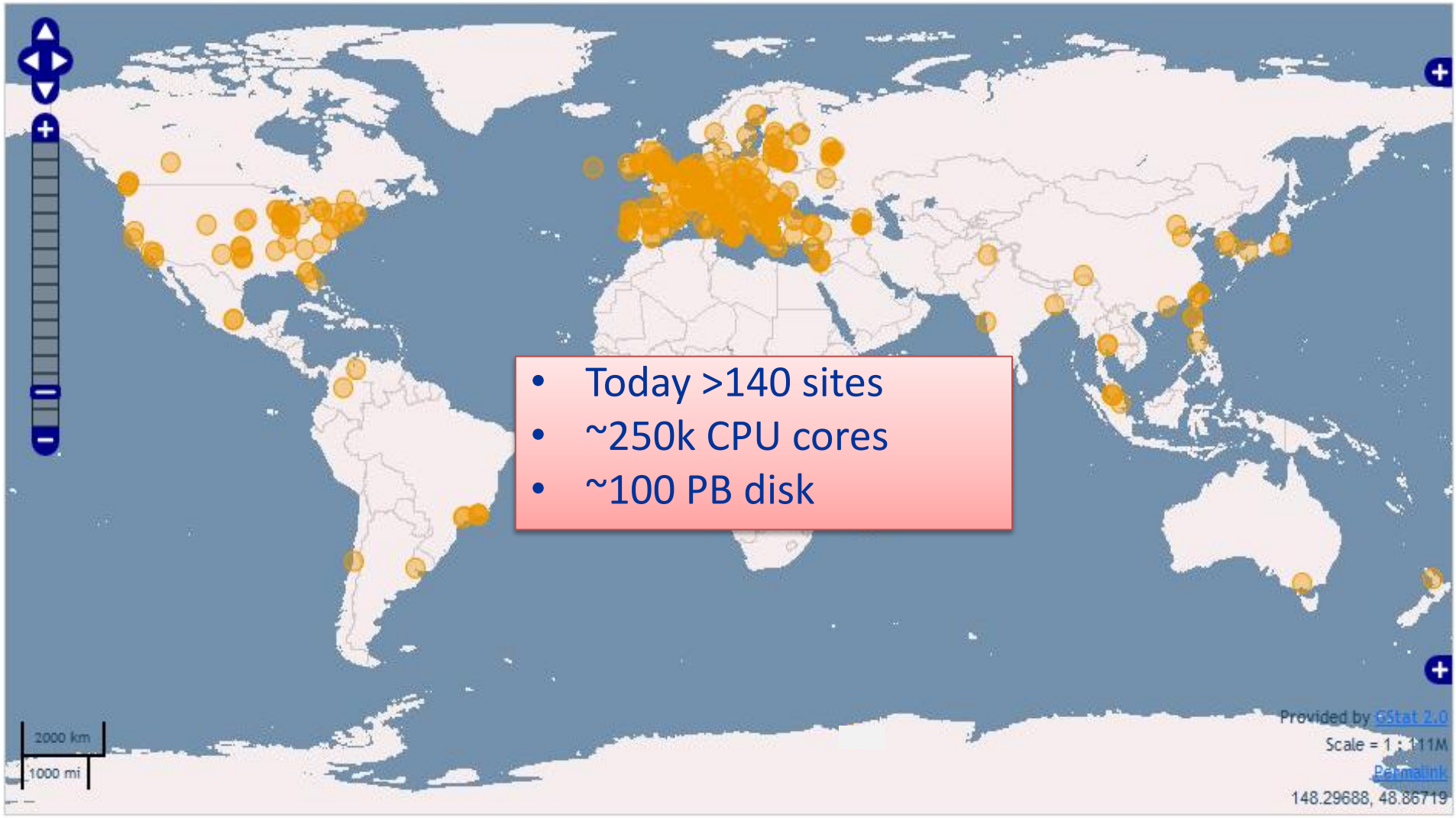
An impressive start

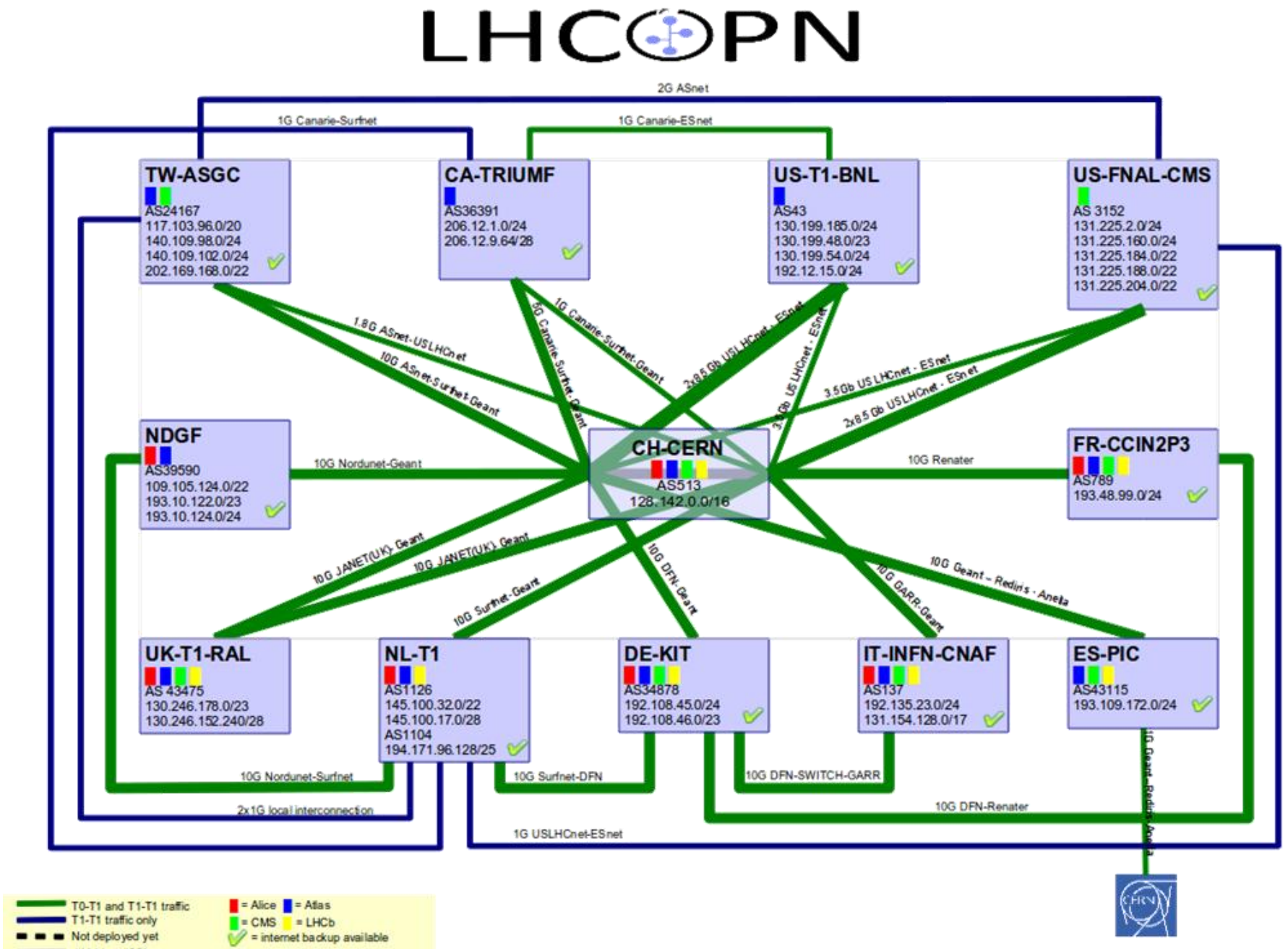
- LHC commissioning proceeding at an unprecedented pace
- Experiments showed their readiness in the exploitation of the 7 TeV data…
- …ready to follow with more complex triggers the increase of luminosity.
- Analyses proceeding very rapidly in all experiments and results being submitted for publication within days
- **Brilliant performances of the WLCG a key factor in the spectacular startup.**

The Computing Challenge

- Search for extremely rare events – a needle in huge hay stack
- Very high initial data rates – up to 1 Petabyte per second
- Massive data reduction directly at the detectors
- After filtering, still 1-2 GB/second leading to over 15 PB/year, to be stored, distributed and analyzed
- Users are distributed all over the Globe
- Many institutes/universities/teams contribute with compute power and disk storage, but all do their own way

Worldwide resources

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1G Canarie-ESnet
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AS 3152
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131.225.184.0/22
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131.225.204.0/22
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10G ASnet-Surfnet-Geant
5G Canarie-Surfnet-Geant
1G Canarie-Surfnet-Geant
2x8.5Gb USLHCnet - ESnet
3.5Gb USLHCnet - ESnet
3.5Gb USLHCnet - ESnet
2x8.5Gb USLHCnet - ESnet
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FR-CCIN2P3
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10G Surfnet-Geant
10G DFN-Geant
10G GARR-Geant
10G Geant-Rediris-Anella
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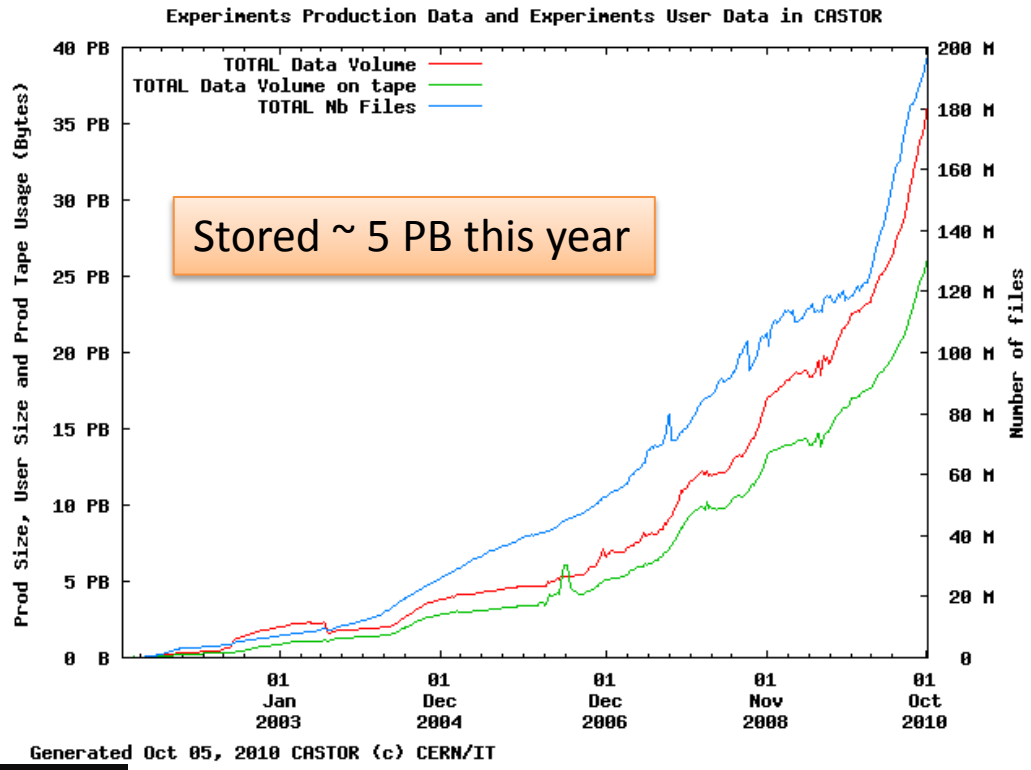
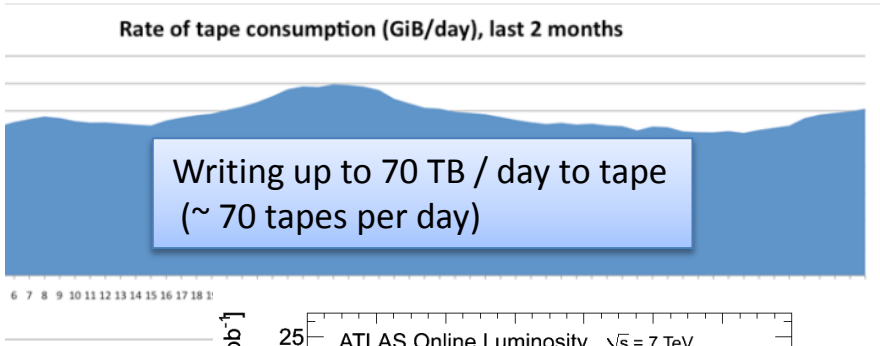
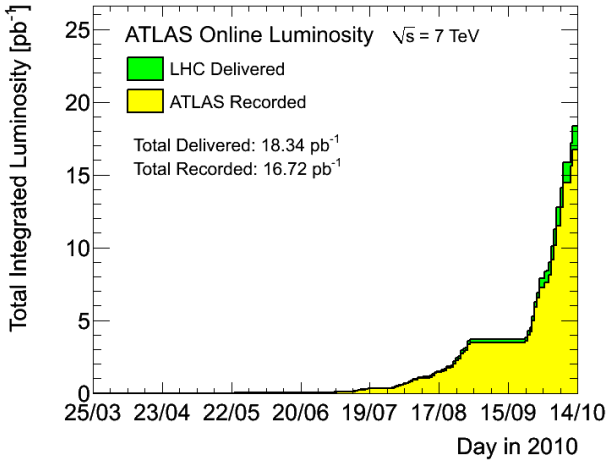
10G Nordunet-Surfnet
10G Surfnet-DFN
10G DFN-SWITCH-GARR
10G DFN-Renater
2x1G local interconnection
1G USLHCnet-ESnet
T0-T1 and T1-T1 traffic
T1-T1 traffic only
Not deployed yet
(thick) >=10Gbps
(thin) <10Gbps
= Alice
= Atlas
= CMS
= LHCb
= internet backup available
p2p prefix: 192.16.166.0/24
edoardo.martelli@cern.ch 20100916

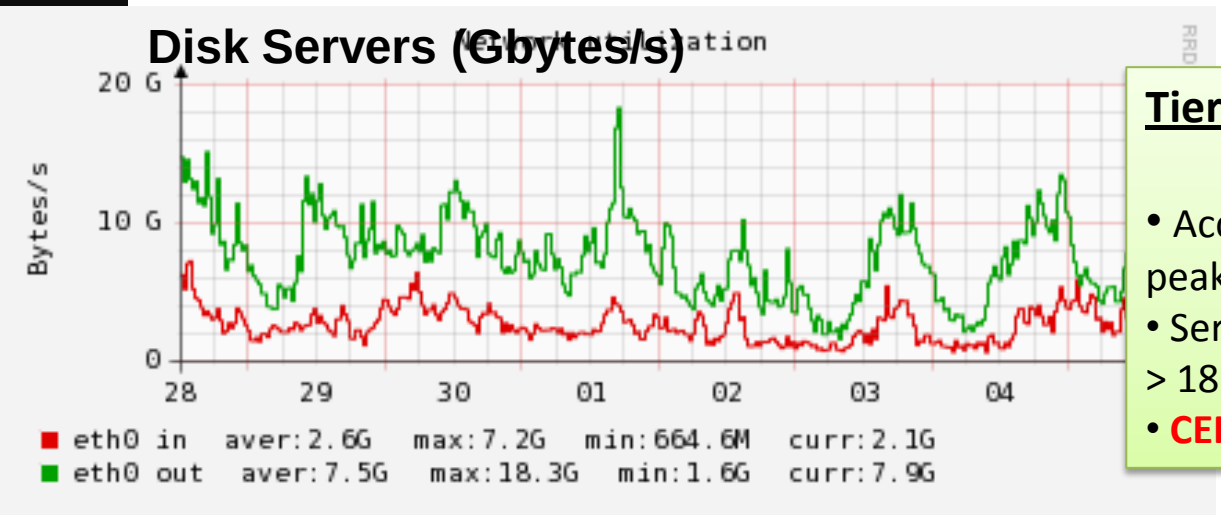
6 months of LHC data



Data written to tape (Gbytes/day)



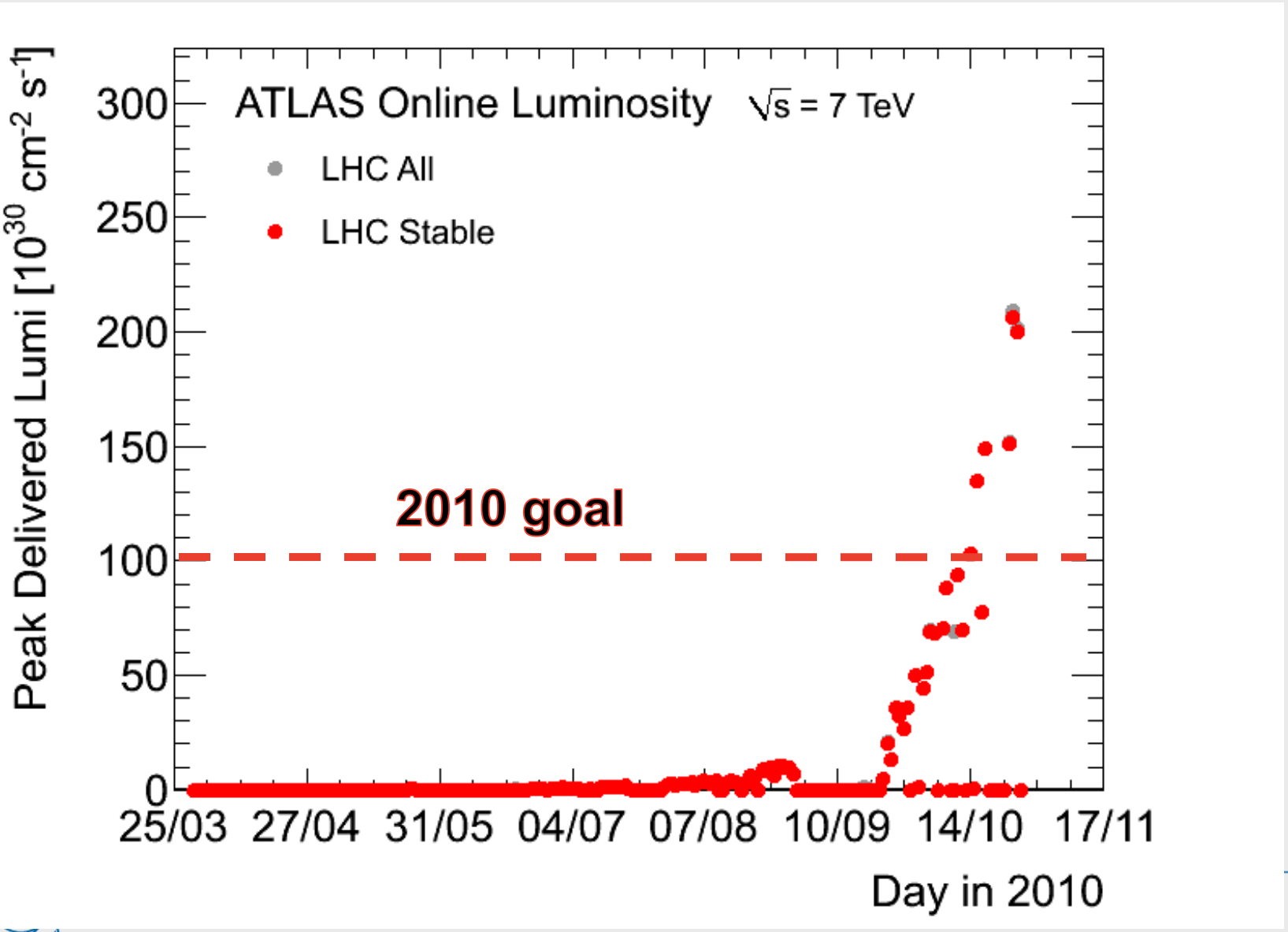




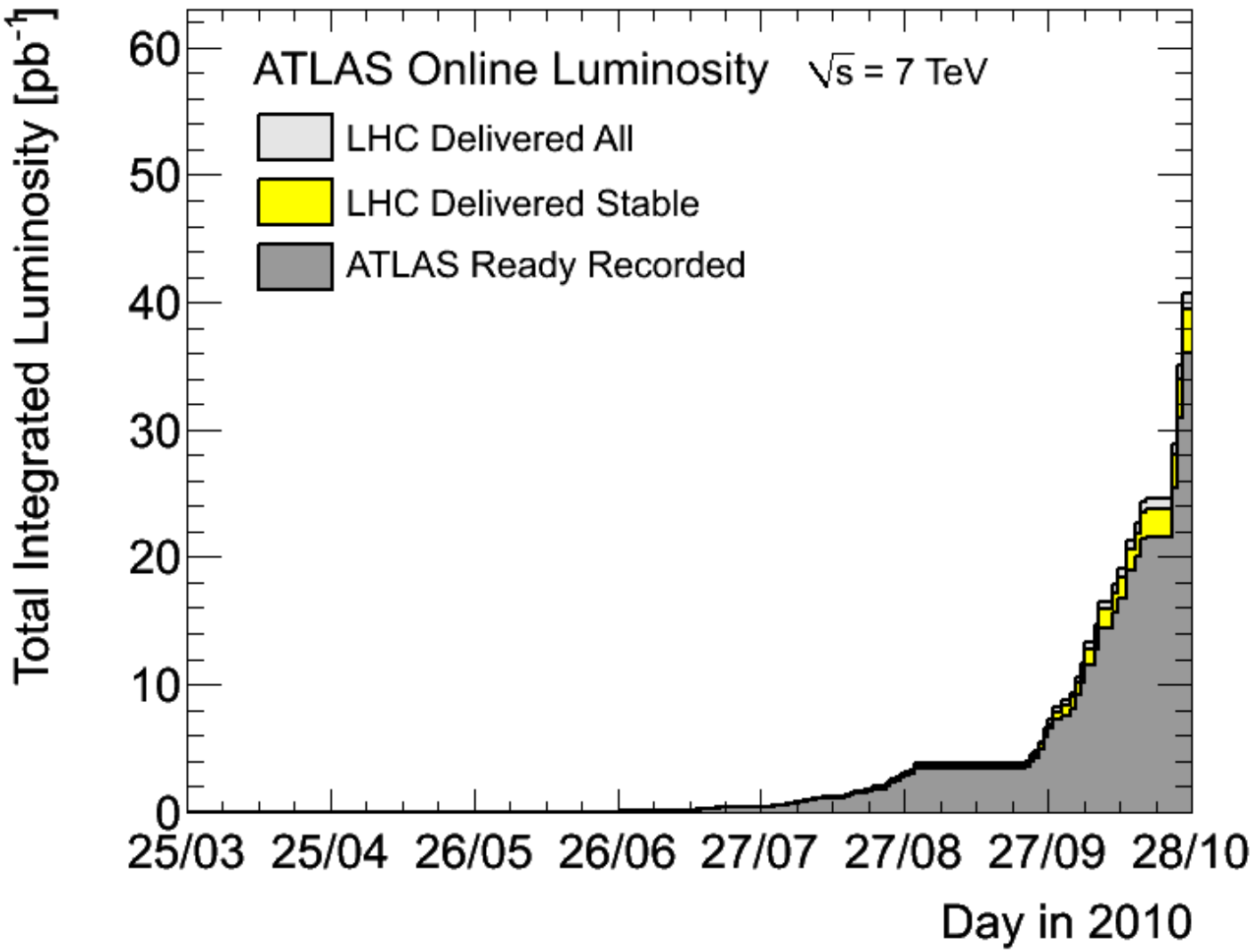
Tier 0 storage:

- Accepts data at average of 2.6 GB/s; peaks > 7 GB/s
- Serves data at average of 7 GB/s; peaks > 18 GB/s
- **CERN Tier 0 moves ~ 1 PB data per day**

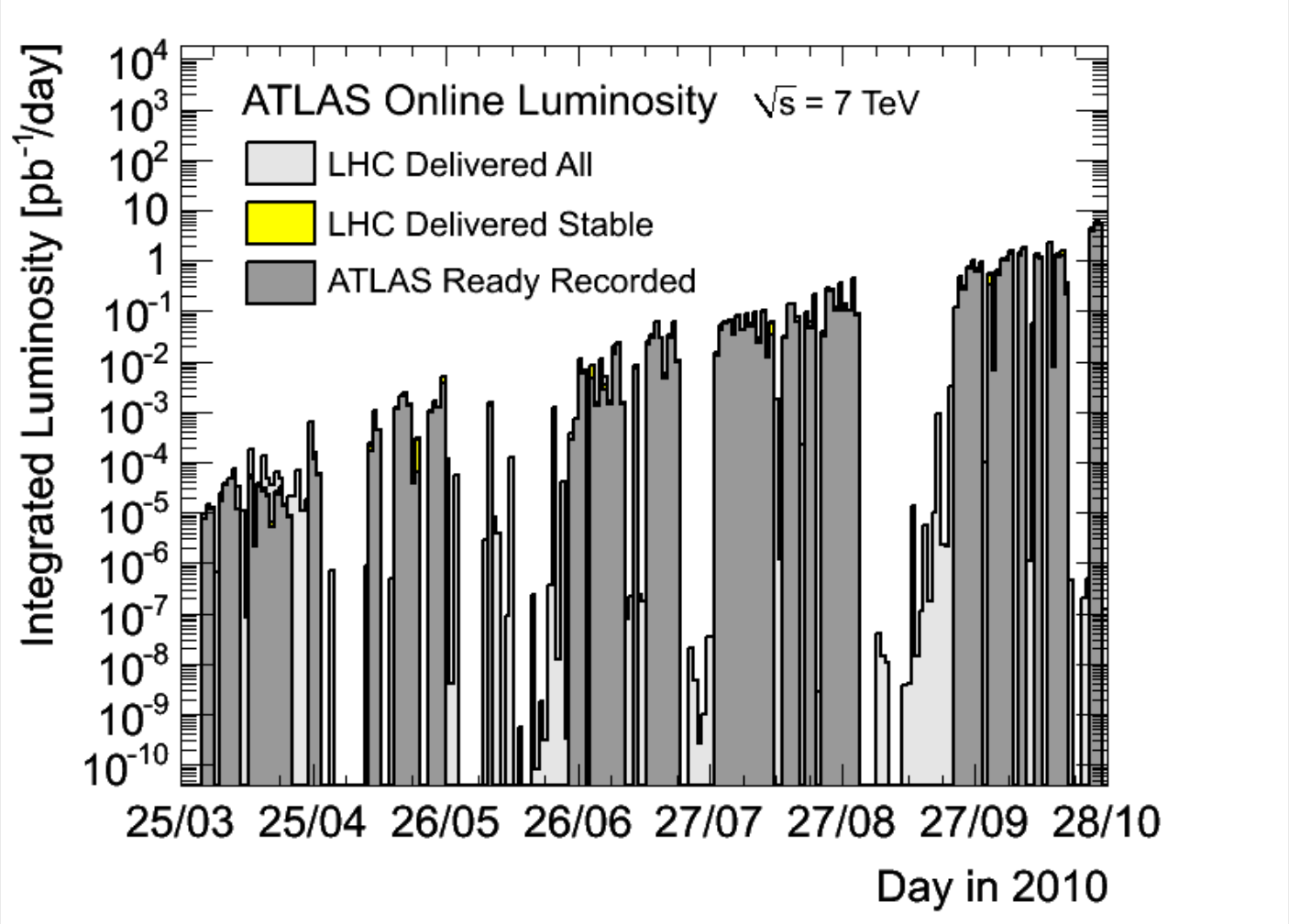
LHC progress



LHC progress



LHC progress

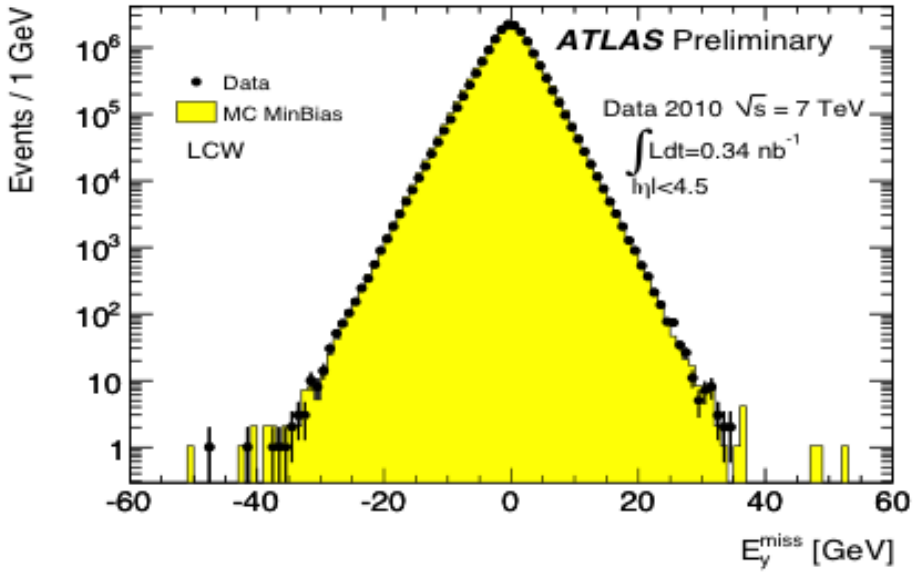


LHC Experiments

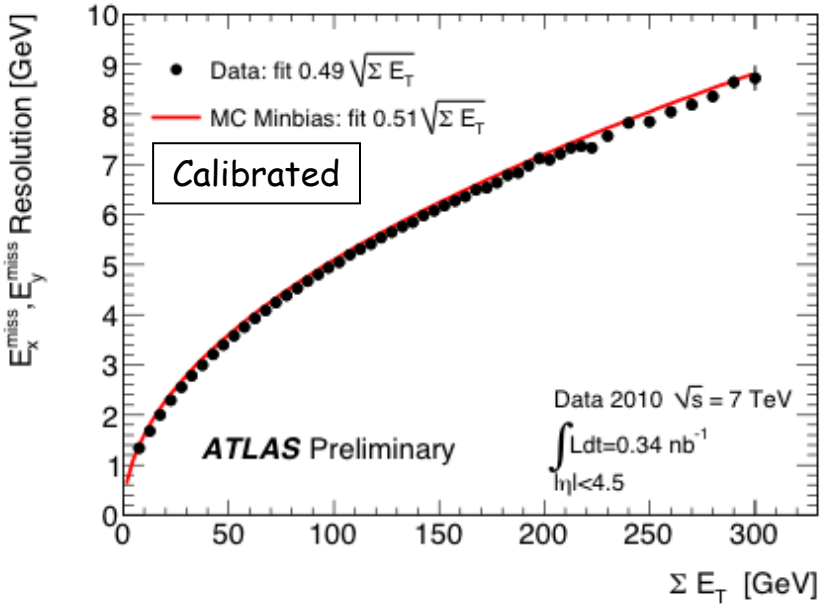
Missing transverse energy

- Sensitive to calorimeter performance (noise, coherent noise, dead cells, mis-calibrations, cracks, etc.), and non-collision backgrounds
- Fundamental for searches (Higgs, SUSY, ..)

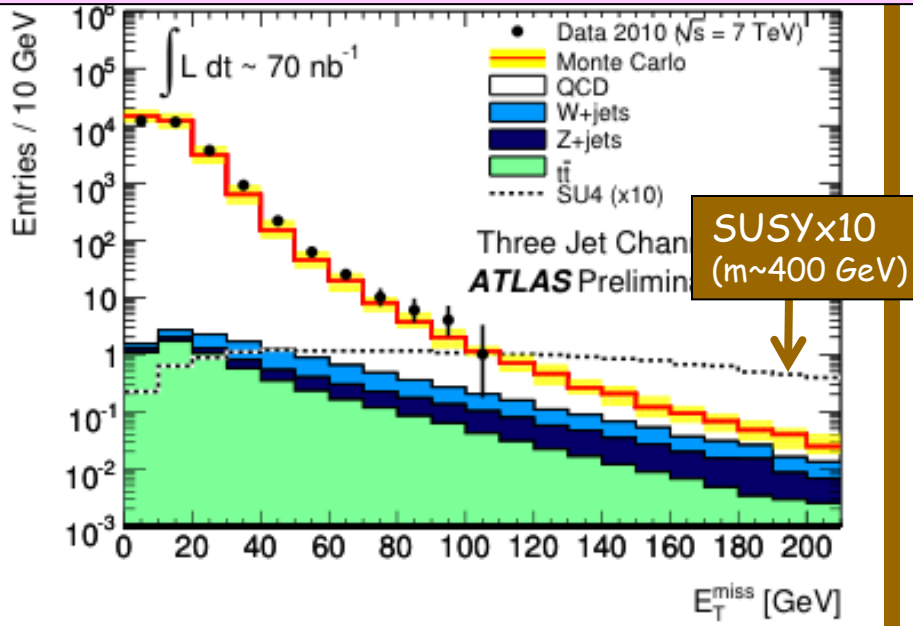
Calibrated E_T^{miss} from minimum-bias events



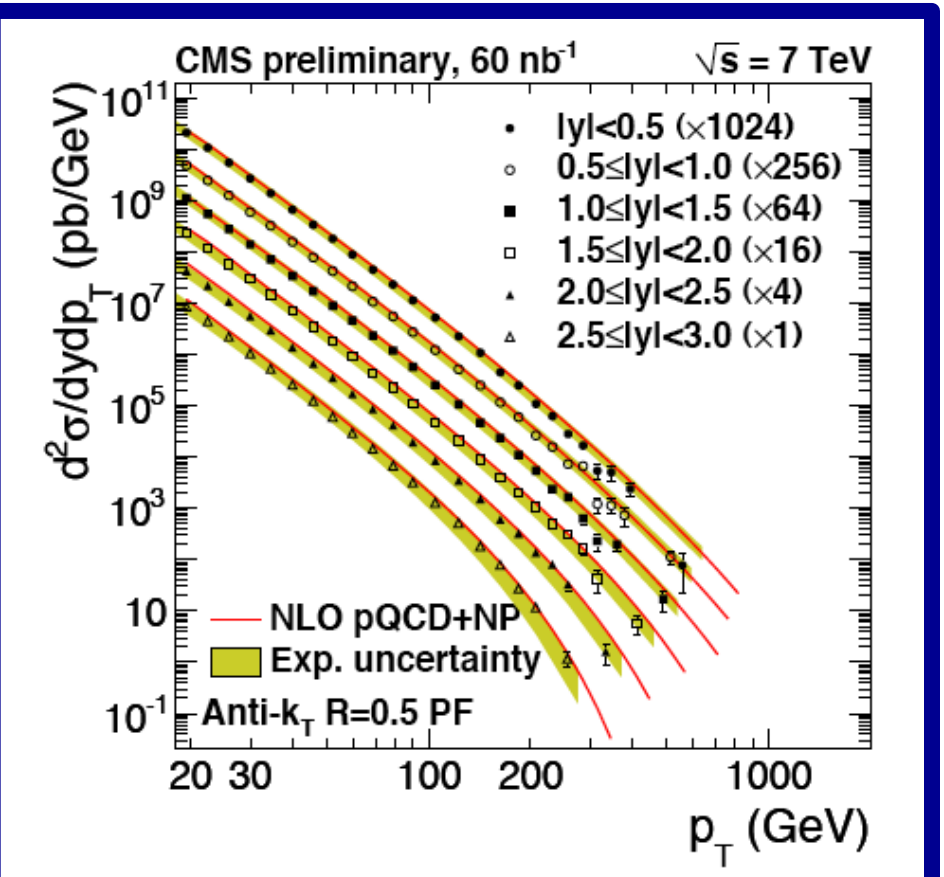
Measured over ~ full calorimeter coverage (360^0 in φ, $|\eta| < 4.5$, ~ 200k cells)

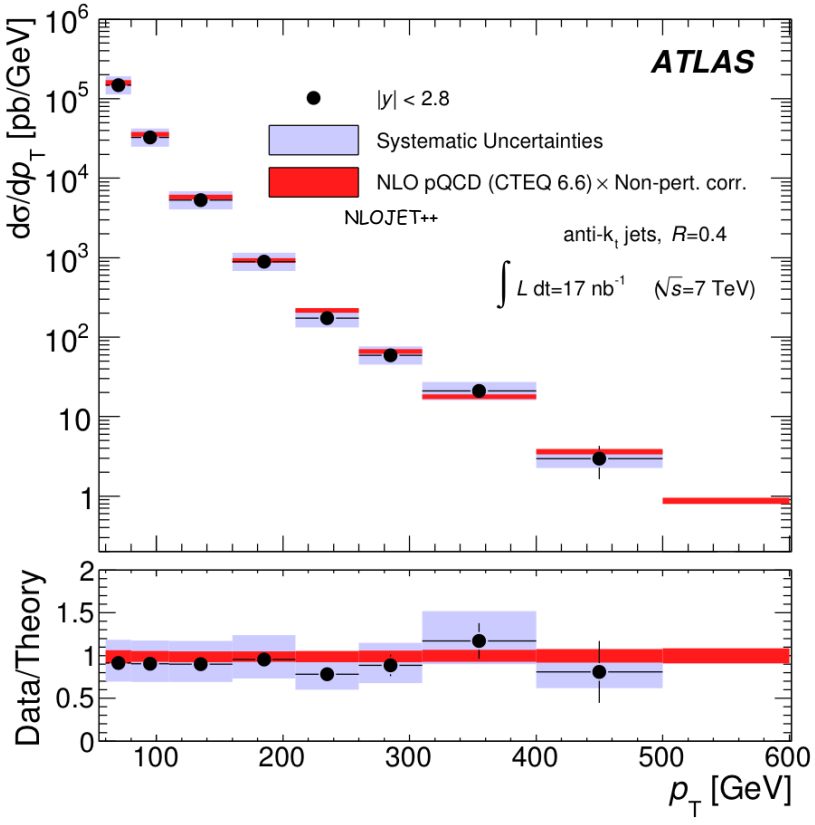


E_T^{miss} spectrum from SUSY searches: events with ≥ 3 high-p_T jets, p_T (j1) > 70 GeV



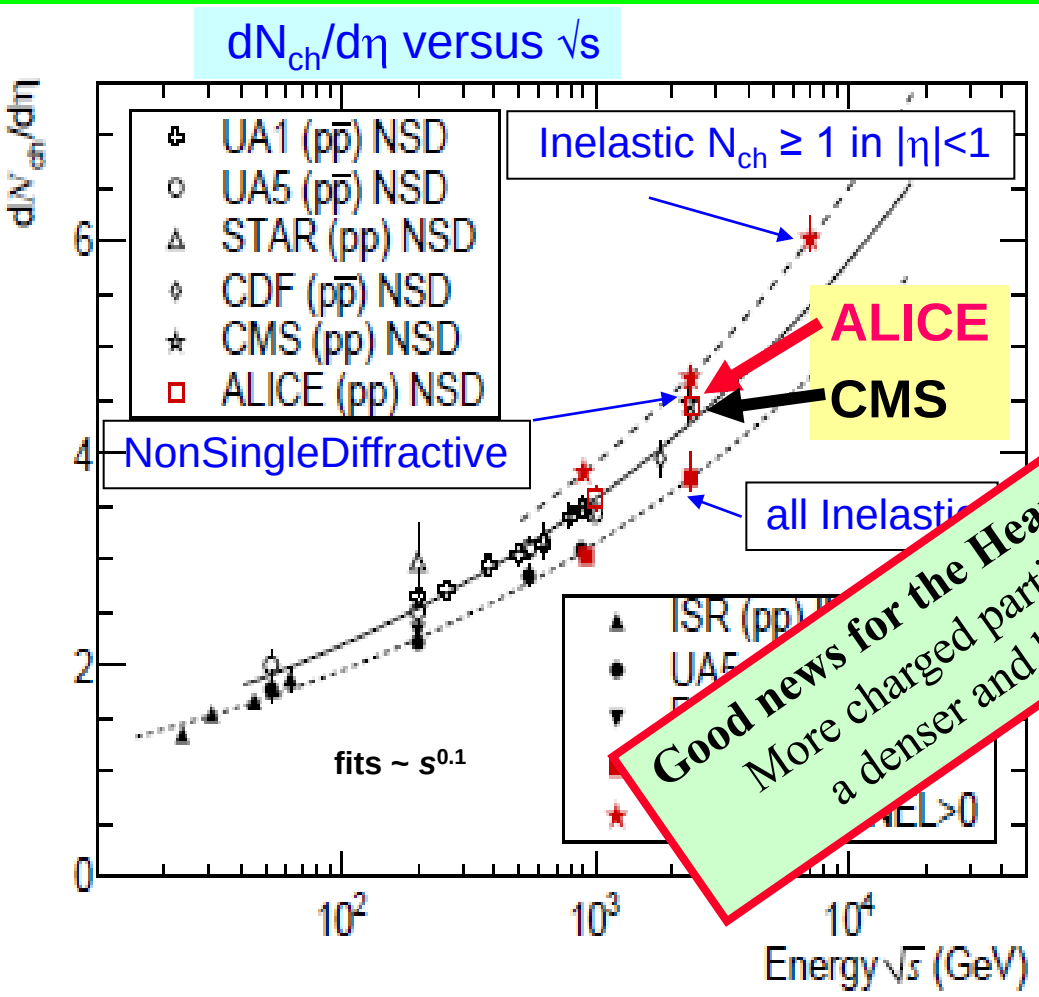
Inclusive jet cross-section

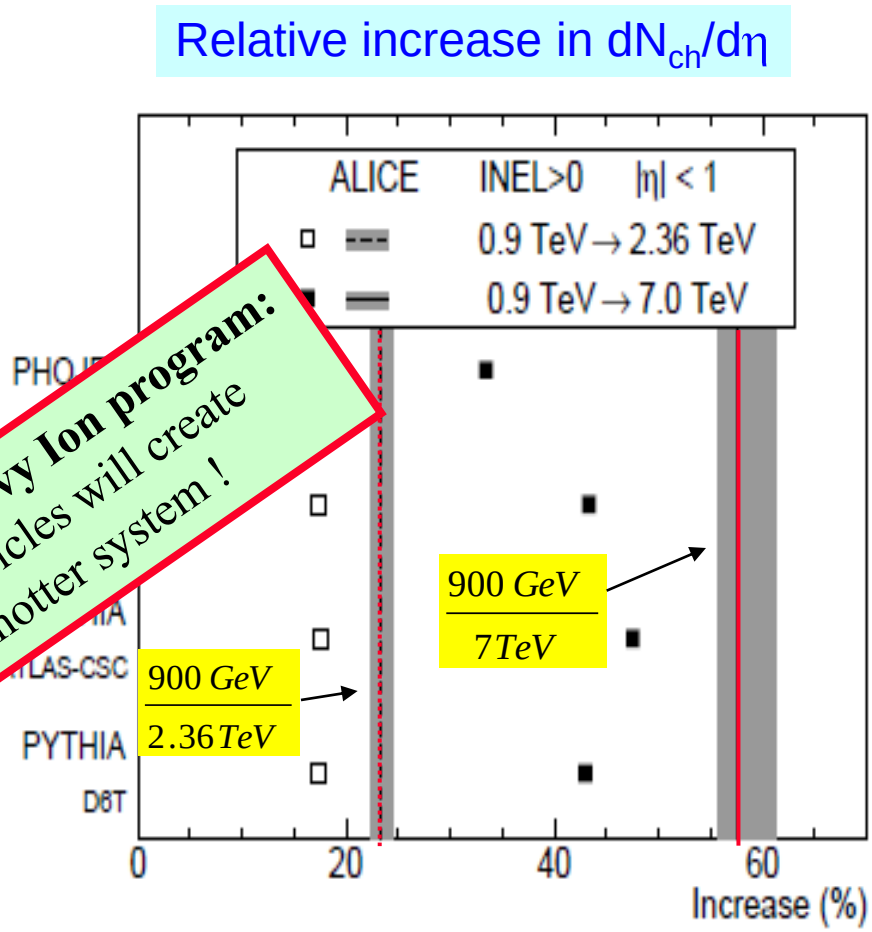




Good agreement data-NLO QCD over > 5 orders of magnitude
within ~ 40% experimental uncertainty (dominated by jet energy scale)

$dN_{ch}/d\eta$ versus $\sqrt{(s)}$





Good news for the Heavy Ion program:
More charged particles will create a denser and hotter system !

Results:

- $dN_{ch}/d\eta$ well described by power law $(\sqrt{s})^{0.2}$
- increase with energy significantly stronger in data than MC's
- Alice & CMS agree to within 1 σ (< 3%)

MC Scoreboard

	MC/TUNE	D6T	Perugia0	CSC	PHOJET
0.9 TeV	$dN_{ch}/d\eta$	-20%	-17%	+3%	-2%
	N_{ch}	N_{ch}>10	N_{ch}>5	N >15	N_{ch}>10
	p_t			eV	p_t>1GeV
	$<p_t>$				
2.36 TeV	η	-24%	-2	-2%	-8%
	N_{ch}	N_{ch}>10	N_{ch}>5	N_{ch} >20	N_{ch}>15
7 TeV	η	-27%	-24%	-4%	-17%
	N_{ch}			N_{ch} >30	

Stay tuned !

- MC << data
- MC >> data
- MC ≈ data

Conclusion:

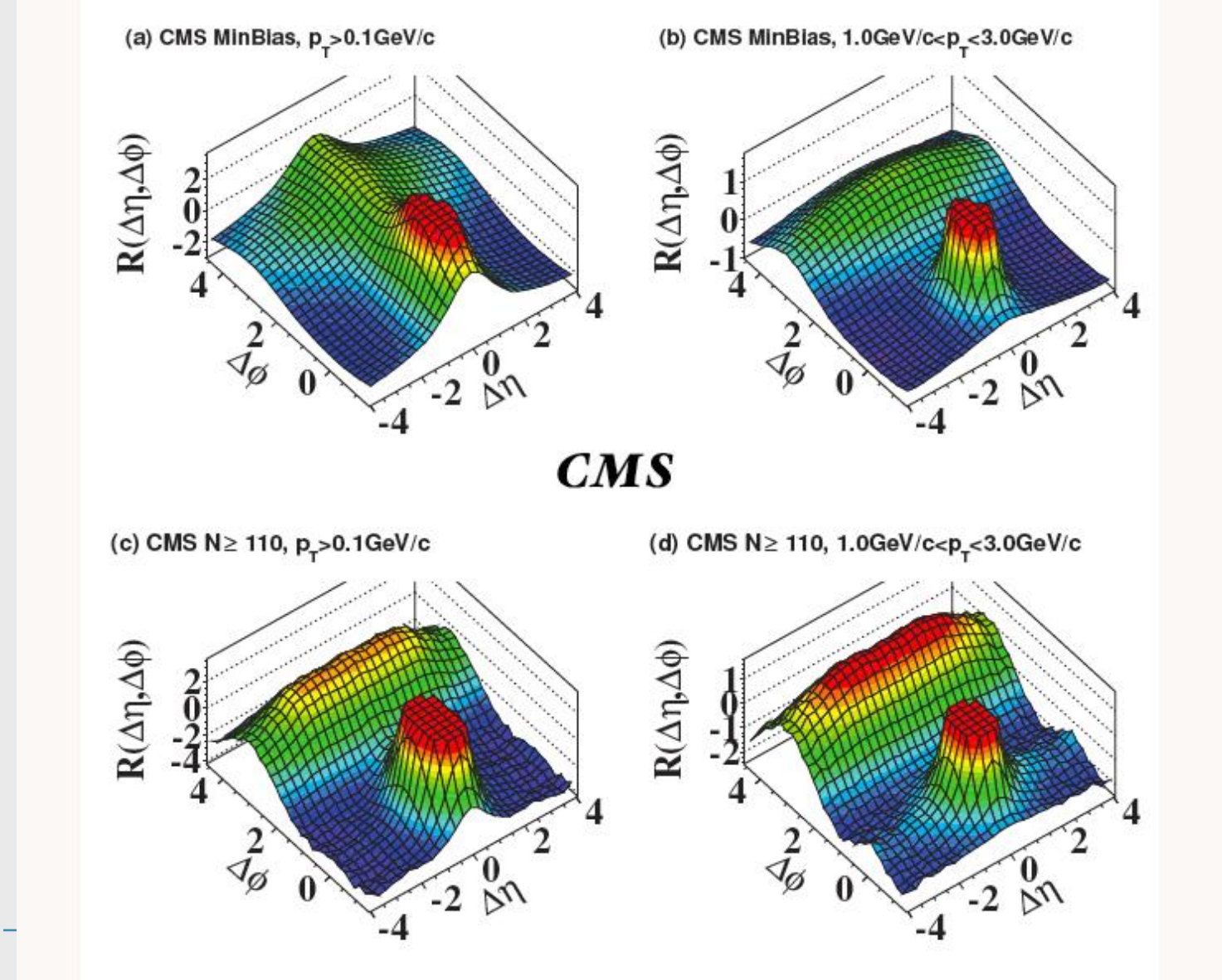
- none of the tested MC's (adjusted at lower energy) does really well
- tuning one or two results is easy, getting everything right will require more effort

(and may, with some luck, actually teach us something on soft QCD rather than only turning knobs)

Entering uncharted territories…

First signs of new phenomena?

“The ridge” in CMS



First searches for New Physics

Present goals:

- understand backgrounds by comparing MC to data for key search-sensitive distributions (→ complementary studies to Standard Model analyses)
- started to set competitive limits with Tevatron → two results shown here
- be prepared for discoveries when enough data available

Typically:

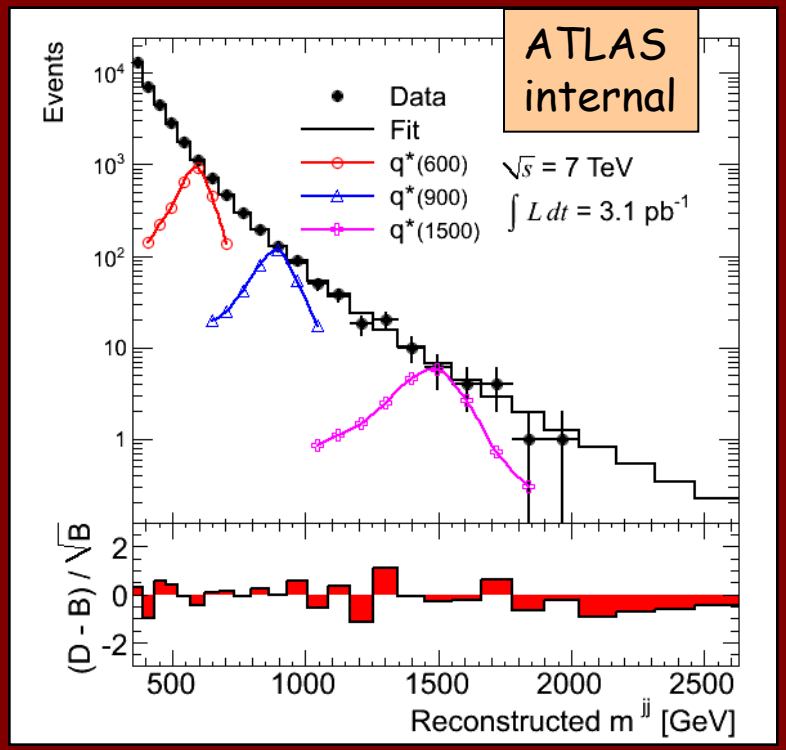
- few pb^{-1}: start to compete with Tevatron sensitivity
- O (100 pb^{-1}): discovery (5σ) potential (just) beyond Tevatron limits
- ~ 1 fb^{-1}: discovery potential extends into new territory, e.g.
  W' up to m~ 2 TeV
  SUSY up to m (squarks, gluinos) ~ 750 GeV

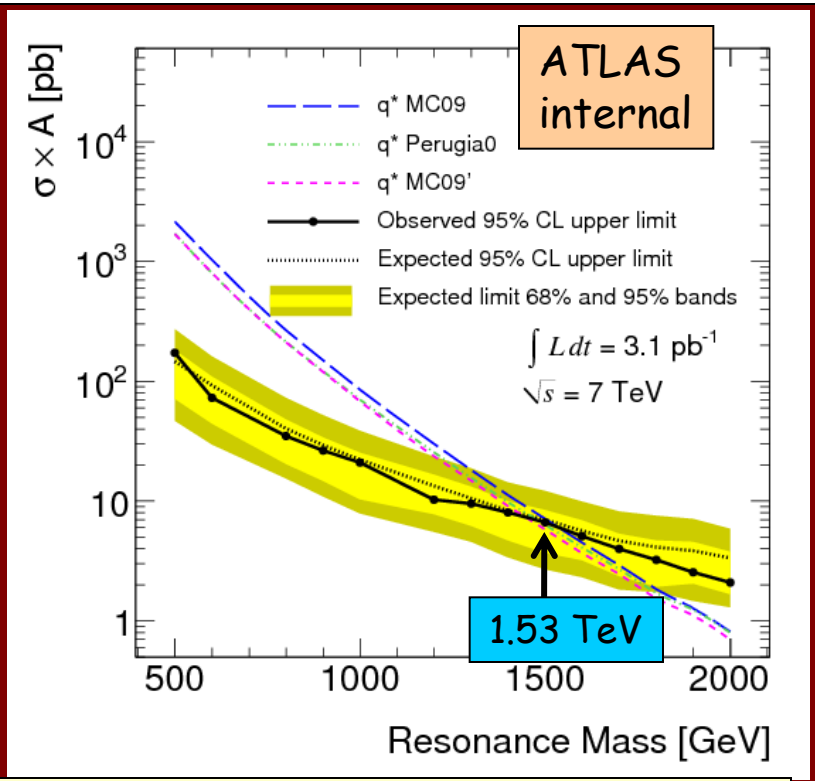
Searches for excited quarks: $q^* \rightarrow jj$

Latest published limit: CDF (1 fb^{-1}): 260 < M (q*) < 870 GeV

Look for di-jet resonance in the measured M(jj) distribution
→ spectrum compatible with a smooth monotonic function → no bumps

- August 2010: with 315 nb^{-1} : 0.4 < M (q*) < 1.26 TeV excluded at 95% C.L.
  - → beyond the Tevatron for the first time
  - → accepted for publication in Phys. Rev. Lett.
- Today: with 3.1 pb^{-1}: limit extended to ~ 1.5 TeV





- p_T (j_1, j_2) > 150, 30 GeV, $|\eta|$<2.5, $|\eta_1-\eta_2|$<1.3, m_{jj}> 350 GeV
- Experimental systematic uncertainties (luminosity, jet E-scale, background fit, …) included
- Impact of theoretical uncertainties (PDF, scale): < 100 GeV

Searches for quark contact interactions

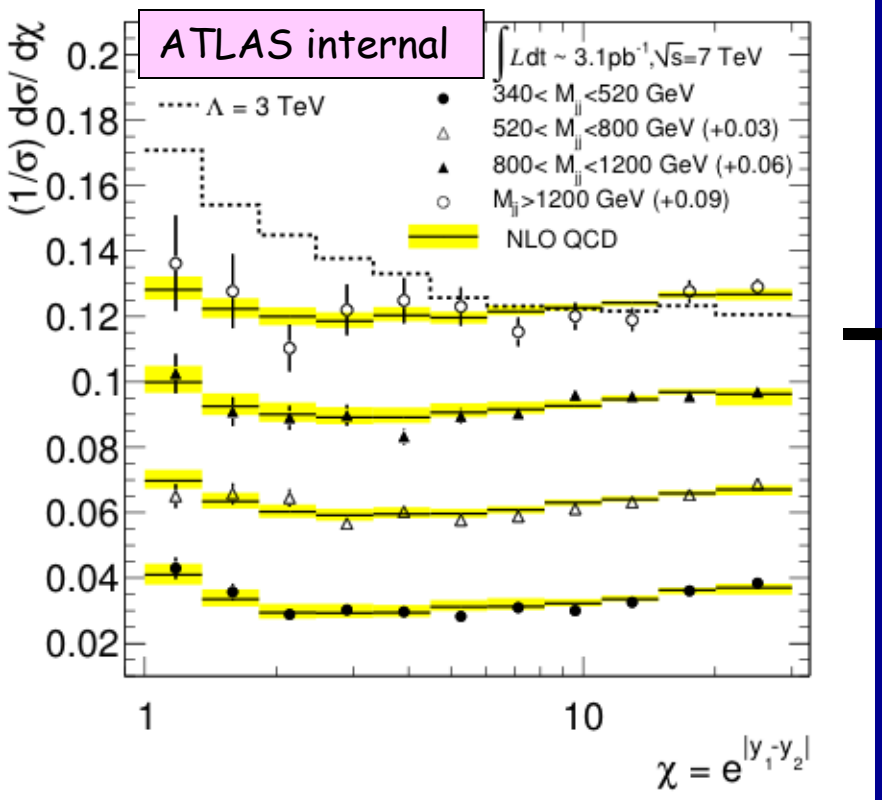
Full data sample: ~ 3.1 pb^{-1}

Look for deviations from QCD in dijet angular distributions

$$\chi = \exp(|y_1 - y_2|) = \frac{1 + \cos\vartheta^*}{1 - \cos\vartheta^*}$$

ϑ^* = polar angle of the dijet system

- QCD: χ distribution ~ flat (t-channel g-exchange dominates)
- Contact interactions (characterized by a scale Λ) or new massive physics: excess at low χ for large M(jj)



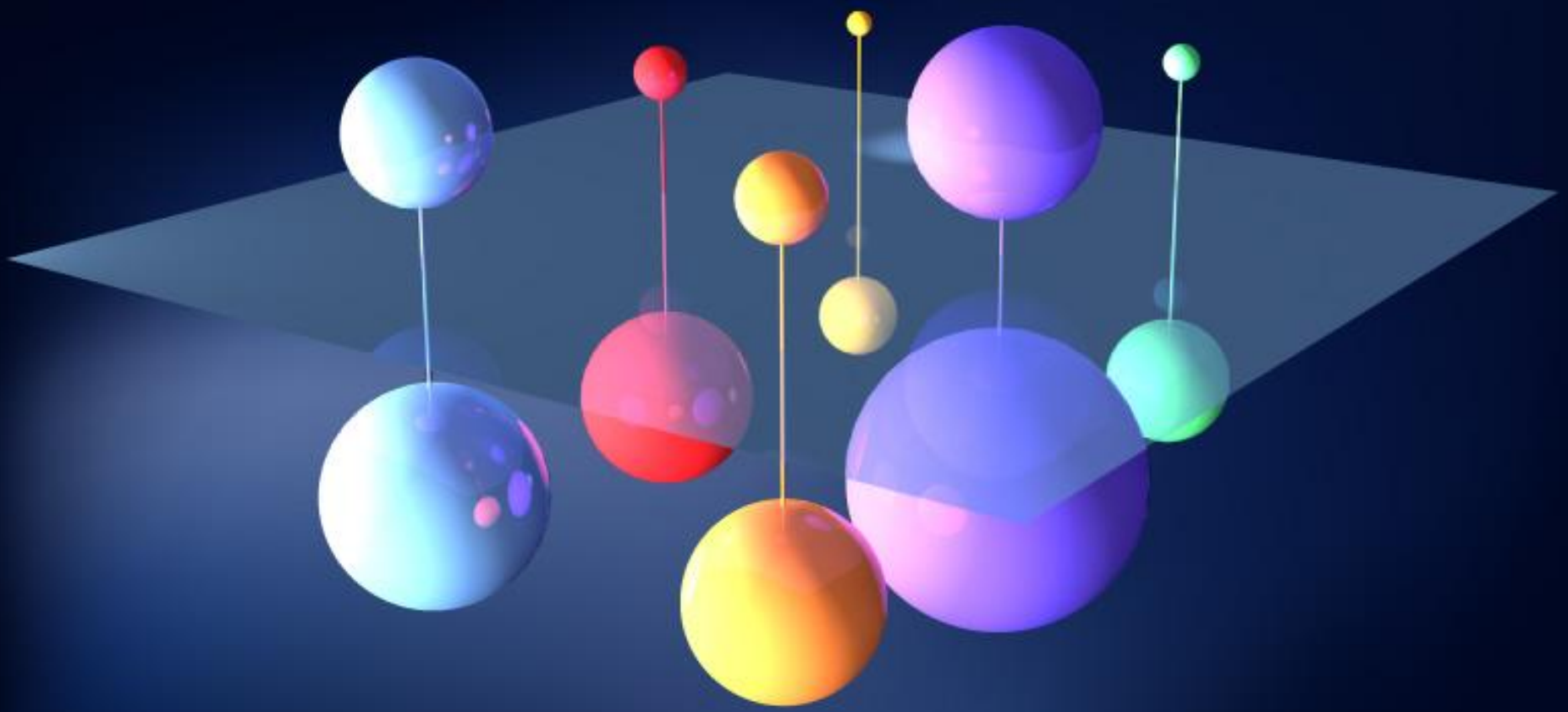
- p_T (j_1, j_2) > 60, 30 GeV, $|y_1+y_2|$<1.5, M(jj) >340 GeV
- Jet E-scale and PDF uncertainties included

Λ > 3.43 TeV at 95% C.L.

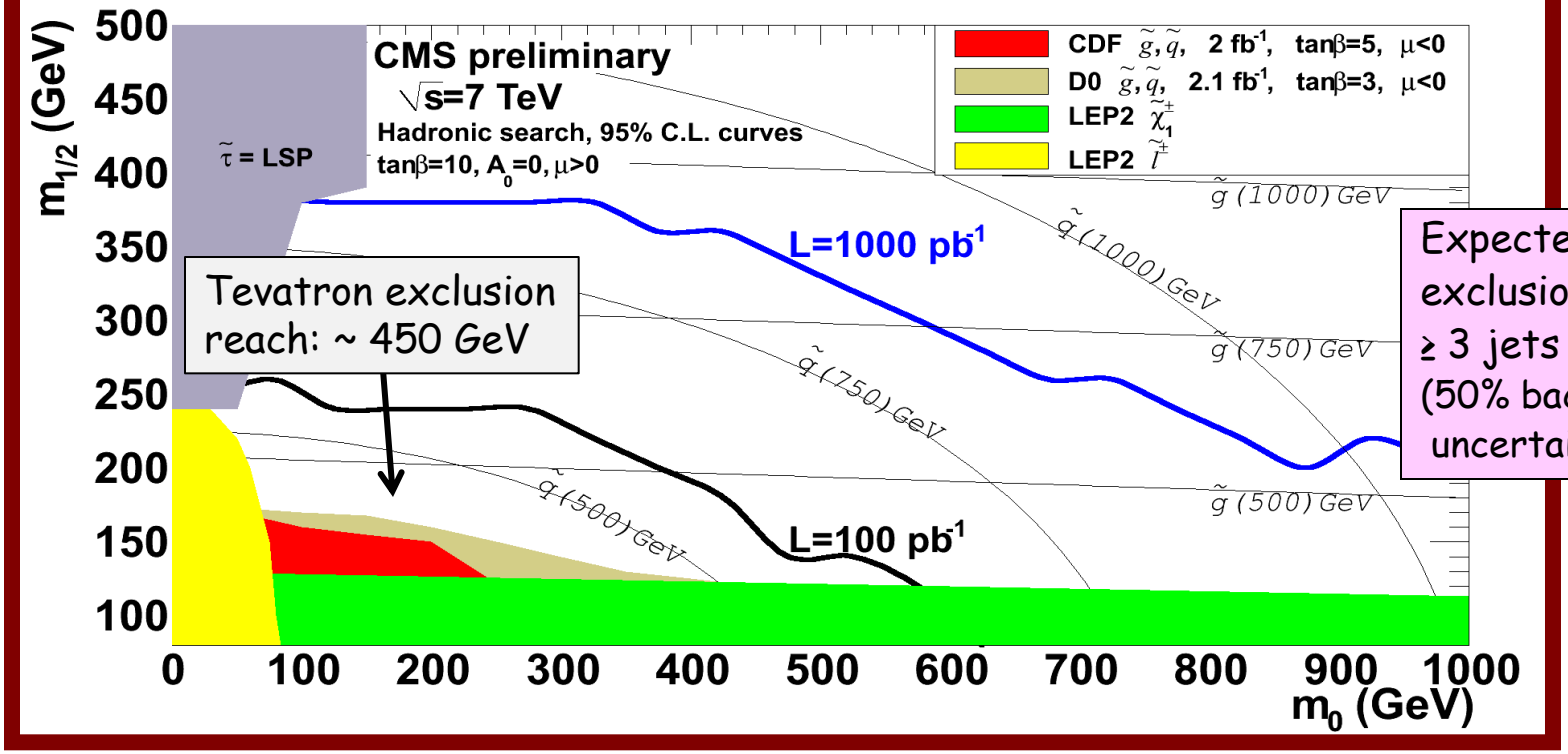
Expected limit: Λ > 3.49 TeV

Latest published limit:
D0 (0.7 fb^{-1}): 2.84 TeV

Supersimmetry



Search for Supersymmetry



Expected 95% C.L. exclusions from ≥ 3 jets + E_T^{miss} searches (50% background uncertainty included)

LHC discovery reach for $\tilde{q}$, $\tilde{g}$, 1 experiment

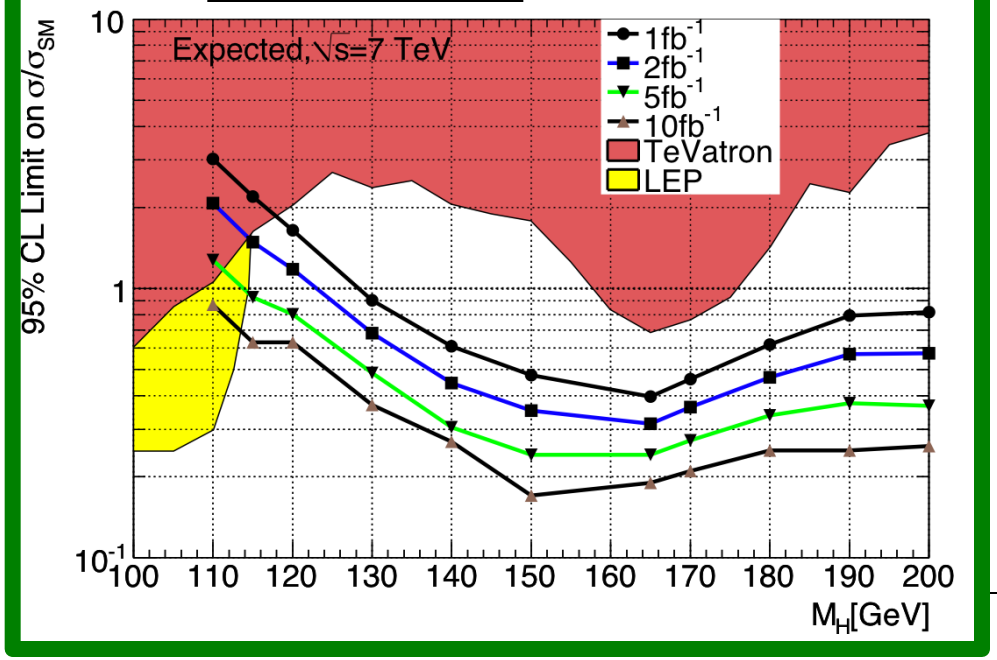
M (TeV)	1 fb^{-1}	2 fb^{-1}	5 fb^{-1}
√s=7 TeV	0.7	0.8	1
√s=8 TeV	0.8	0.9	1.1

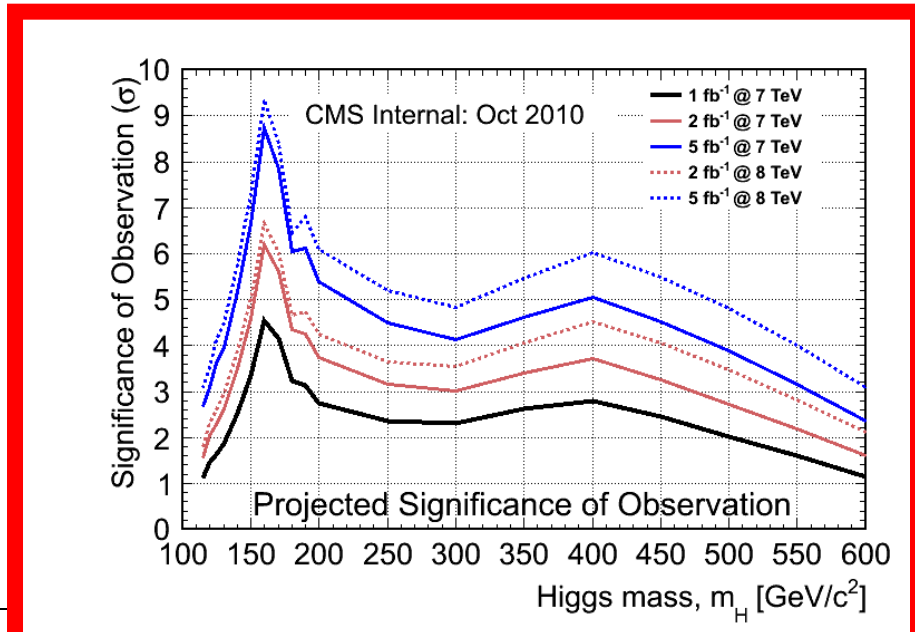
Expected Higgs mass coverage (GeV)

ATLAS and CMS internal and very preliminary

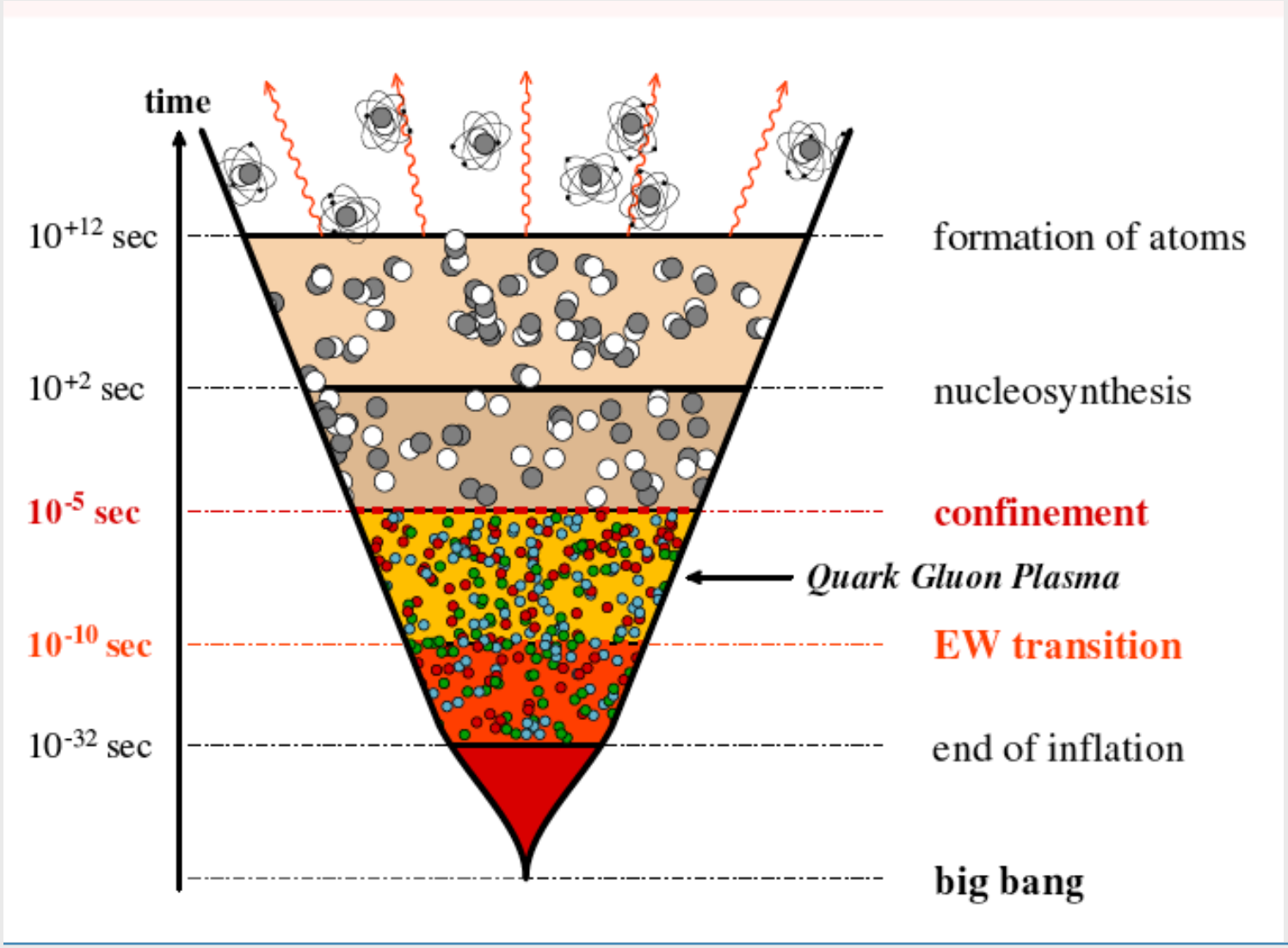
Luminosity per expt and √s	Comments	ATLAS+CMS 95% CL exclusion	ATLAS+CMS 3σ evidence	ATLAS+CMS 5σ discovery
1 fb^{-1} 7 TeV	2011	123-550 GeV	130-450 GeV	152-174 GeV
1 fb^{-1} 8 TeV	2011 (?)	120-570	127-500	150-176
2.5 fb^{-1} 7 TeV	2011 "aggressive"	114-600	123-530	138-220
5 fb^{-1} 7 TeV	2012 (if run)	114-600	114-600	124-510
5 fb^{-1} 14 TeV	2013			≥ 115
30 fb^{-1} 14 TeV	~2014			H→ bb at 4-5 σ ?

ATLAS internal





Ions and Quark-Gluon Plasma

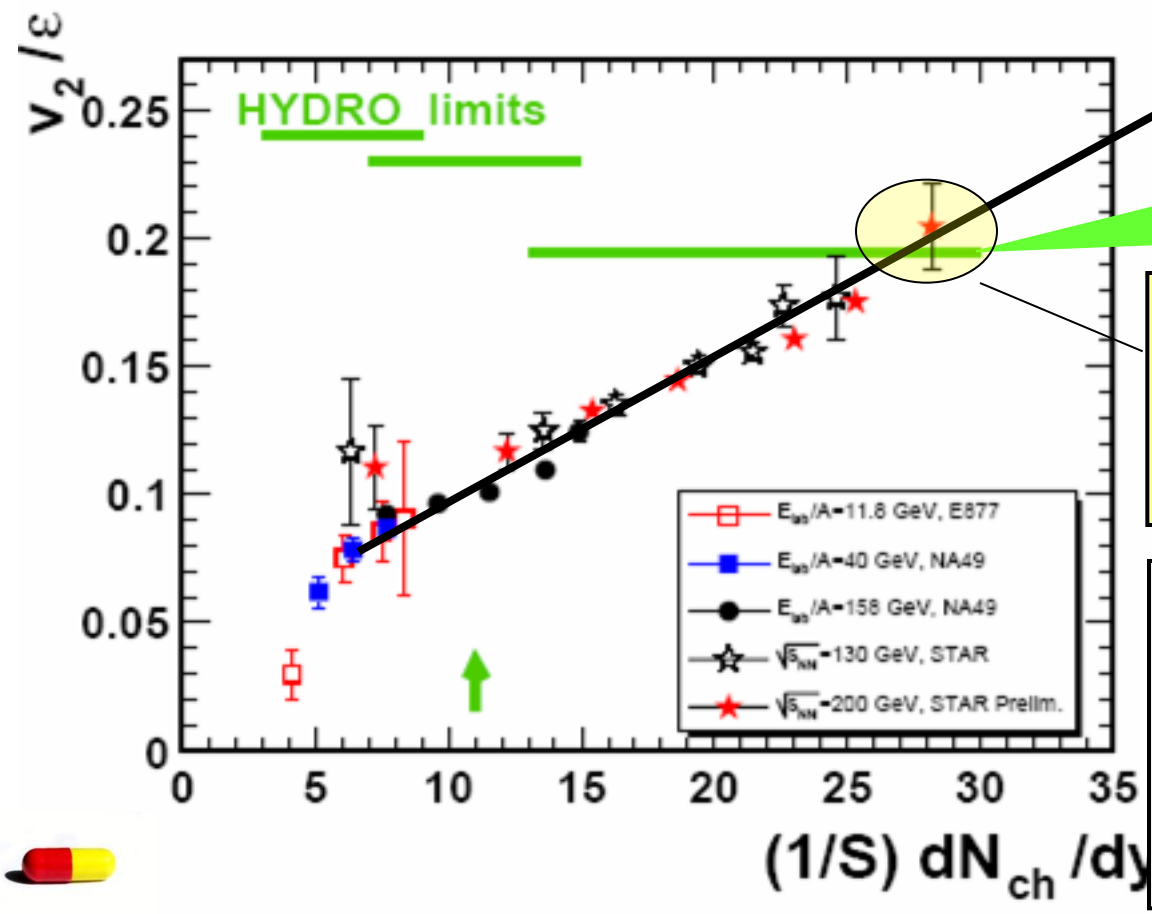


Heavy Ions: Flow at LHC

- one of the first and most anticipated answers from LHC
  - 2nd RHIC paper: Aug 24, 22k MB events, **flow surprise** (v_2)
    - Hydrodynamics: modest rise (Depending on EoS, viscosity, speed of sound)

LHC ?

increase of flow



BNL Press release, April 18, 2005:

Data = ideal Hydro

"Perfect" Liquid

New state of matter more remarkable than predicted – raising many new questions

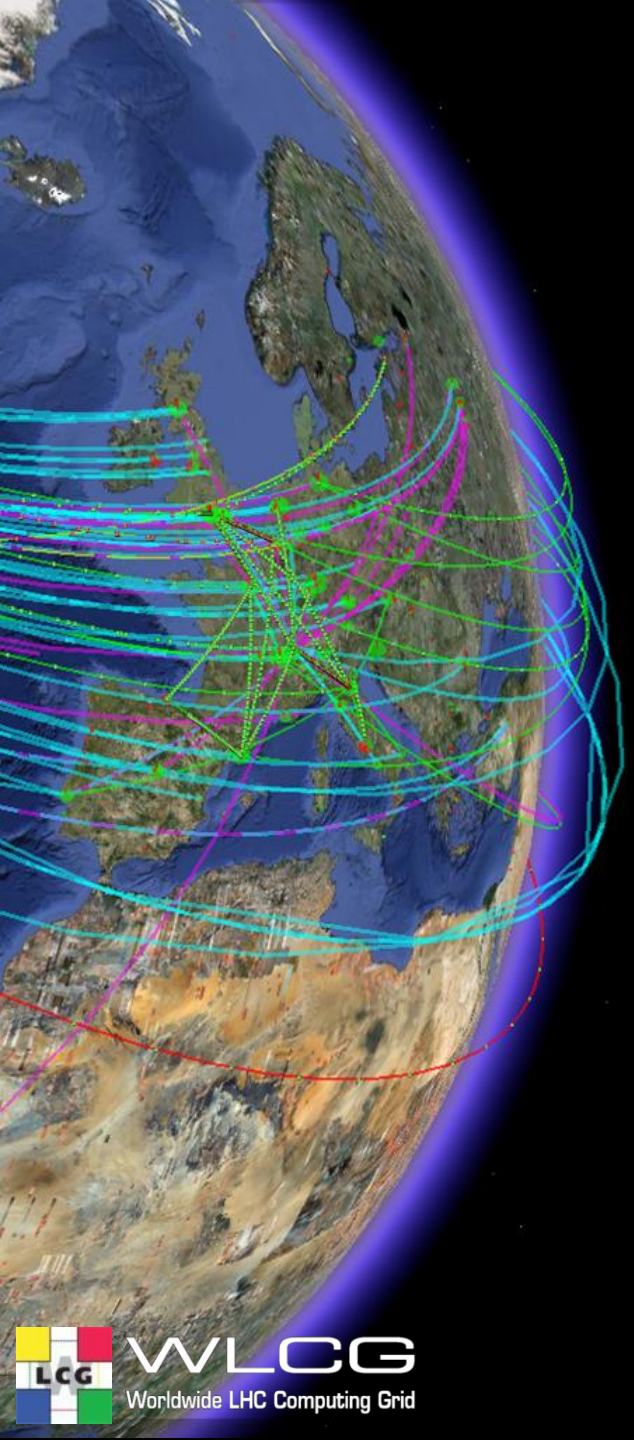
LHC will either

confirm the RHIC interpretation

(and measure parameters of the QGP EoS)

OR

……



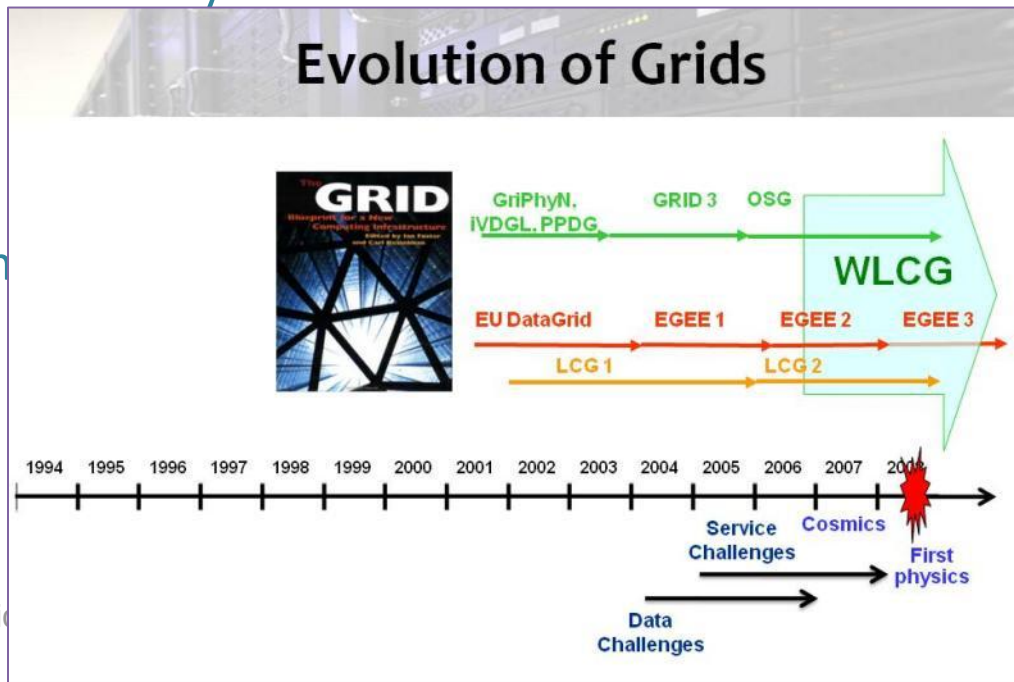
The LHC Computing grid today

- Distributed computing for LHC is a reality and enables physics output in a very short time
- Experience with real data and real users suggests areas for improvement
  - The infrastructure will evolve with the underlying technology and commercial offerings

WLCG
Worldwide LHC Computing Grid

Grids & HEP: Common history

- CERN and the HEP community have been involved with grids from the beginning
- Recognised as a key technology for implementing the LHC computing model
- HEP work with EDG/EGEE in Europe, iVDGL/Grid3/OSG etc. in US has been of clear *mutual* benefit
  - Infrastructure development driven by HEP needs
  - Robustness needed by WLCG is benefitting other communities
  - Transfer of technology from HEP
    - Ganga, AMGA, etc used by many communities now



Large scale = long times

- LHC, the experiments, & computing have taken ~20 years to build and commission
- They will run for at least 20 years
- We must be able to rely on long term infrastructures
  - Global networking
  - Strong and stable NGIs (or their evolution)
    - That should be eventually self-sustaining
  - Long term sustainability - must come out of the current short term project funding cycles

LHC is not alone

- HEP has been a leader in needing and building global collaborations in order to achieve its goals
- It is no longer unique – many other sciences now have similar needs
  - Life sciences, astrophysics, ESFRI projects
  - Anticipate huge data volumes
  - Need global collaborations
- There are important lessons from our experiences,
  - HEP was able to do this because it has a long history of global collaboration; missing from many other sciences
- We must also collaborate on common solutions where possible

Long times require constant progress

- … on technology follow-up
- … on paradigm changes
- … on organization
- … on inclusion of wider communities
- … on expansion to wider sectors of the society

In short:

MORE BRAINWARE


Jul 20, 2010 12:52:57 pm
Running jobs: 87412.0
Transfer rate: 7.44 GiB/sec
Thank you!
CERN
CMS
LHCb
shboard
Google
© 2010 Europa Technologies
US Dept of State Geographer
© 2010 Google
© 2010 Tele Atlas
49°23'04.71" N 6°19'55.14" E elev 331 m
Eye alt 4625.07 km