The Analysis Centre

of the Helmholtz Alliance “Physics at the Terascale”

Thomas Schörner-Sadenius

DESY „Wissenschaftlicher Ausschuss“
Hamburg, 10 November 2009

HELMHOLTZ GEMEINSCHAFT

PHYSICS AT THE TERA SCALE Helmholtz Alliance

DESY

… SOME 3 YEARS AGO …

… AND RECENTLY …

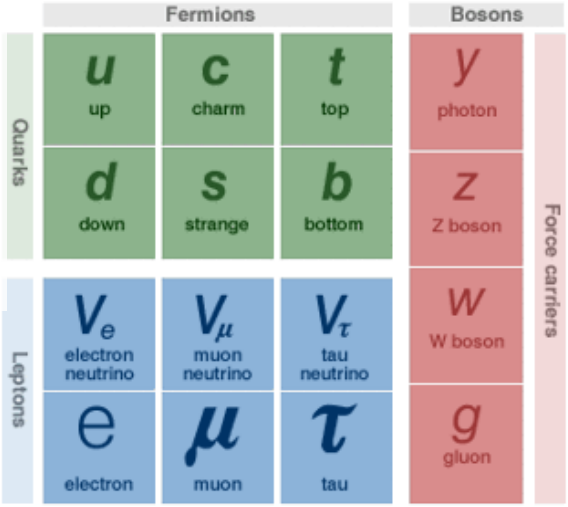
OUTLINE

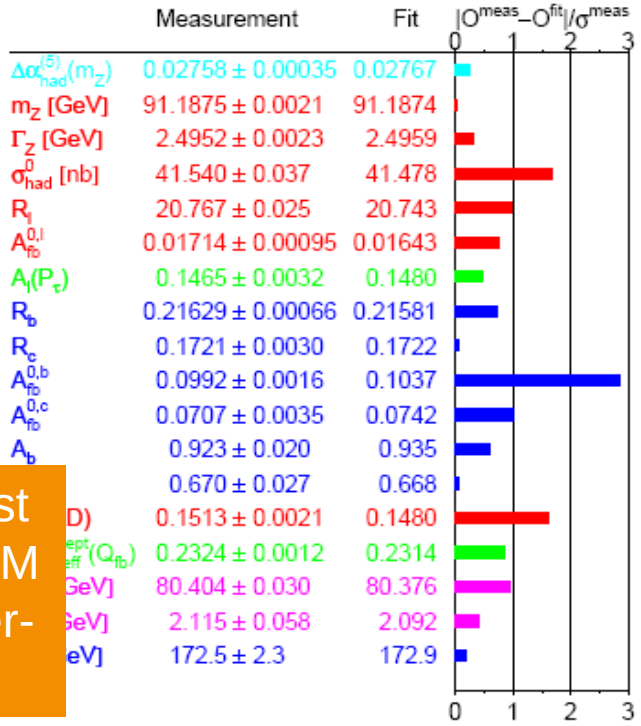
- The status and challenges of particle physics
- The LHC and the worldwide organisation of LHC research
- The Helmholtz Alliance “Physics at the Terascale”
- The Analysis Centre
  - Mission and structure
  - Education
  - Monte Carlo generators, Parton Distribution Functions, and Statistics Tools
  - Further aspects, challenges and plans
- Summary

STATUS AND FUTURE OF PARTICLE PHYSICS

> The Standard Model of particle physics has found numerous confirmations.

- Precision up to 10^{-5} in electroweak sector, 1% in QCD / strong interactions!
- Beautiful results: LEP, TEVATERON, HERA …



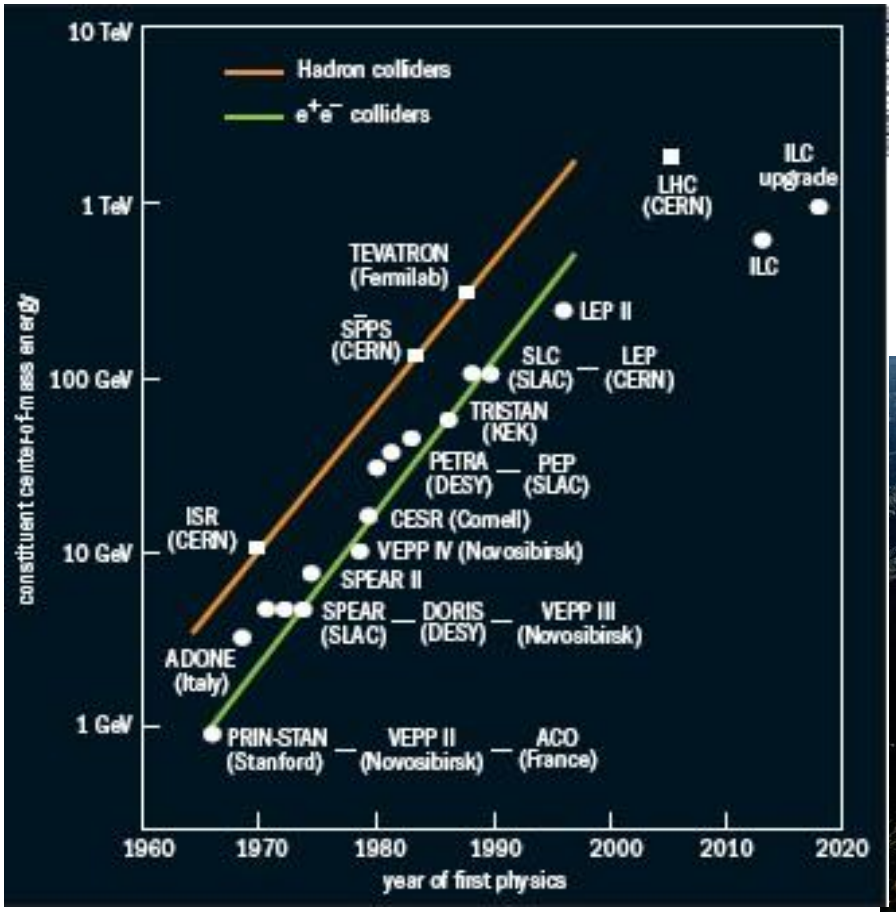


Pulls of most important SM model observables.

> But: Standard Model not complete / satisfactory.

- Missing explanation of EW symmetry breaking / mass generation → Higgs?
- Other problems: Dark matter, divergencies, gravitation, free parameters, …

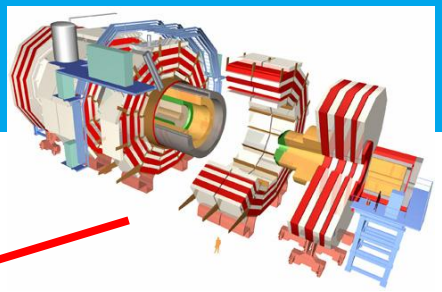
THE STRIVE FOR EVER HIGHER ENERGY …

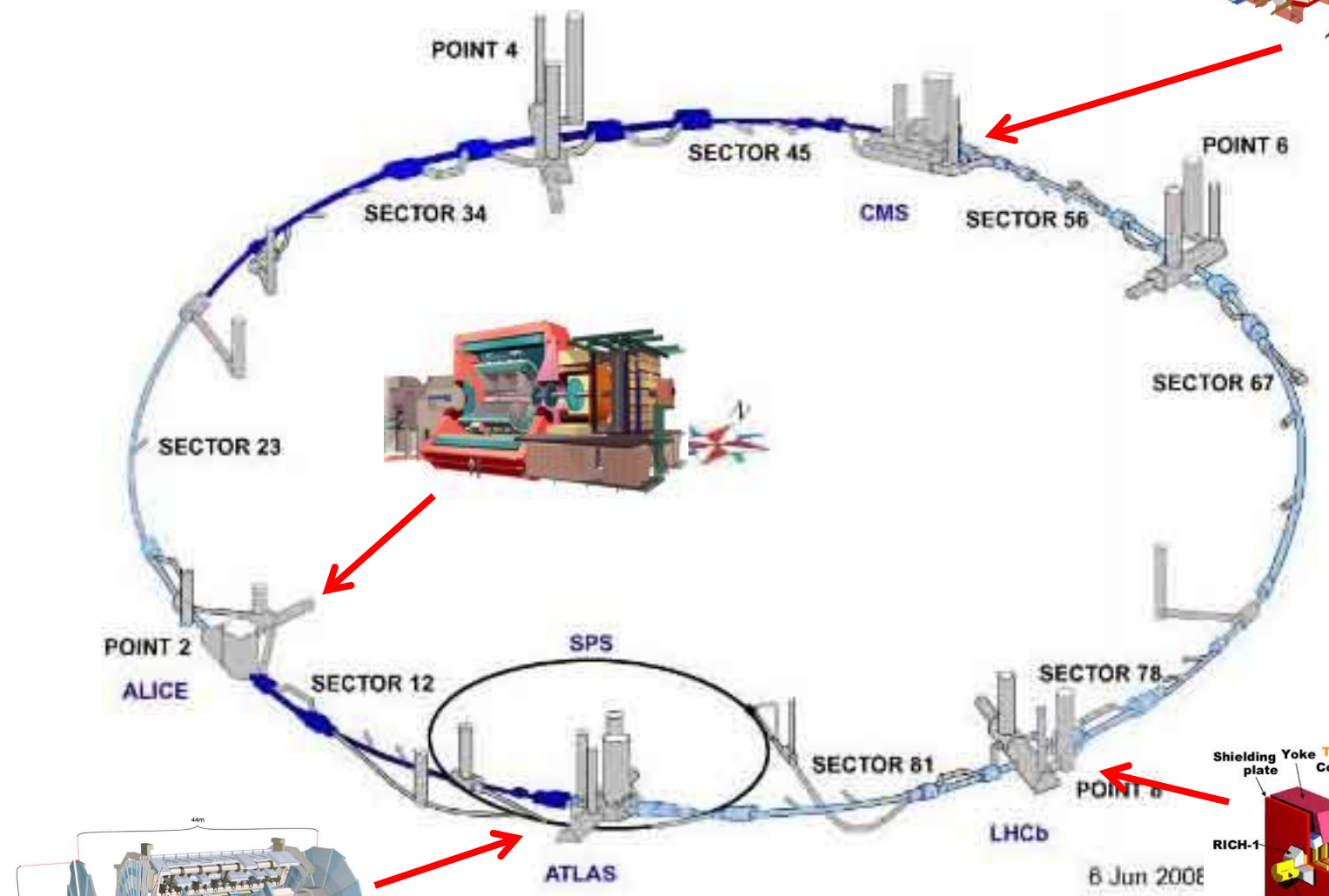


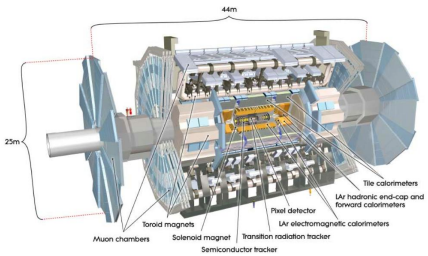
> Aims: Creation of heavy objects (Higgs etc.) and resolution of small structures
➔ highest energies / momenta !

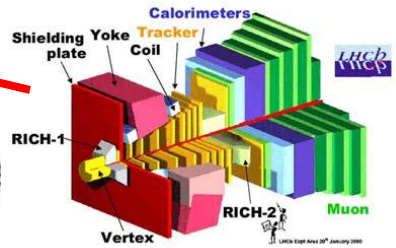
Large Hadron Collider: proton-proton collisions at 14 TeV!

THE LARGE HADRON COLLIDER (LHC)



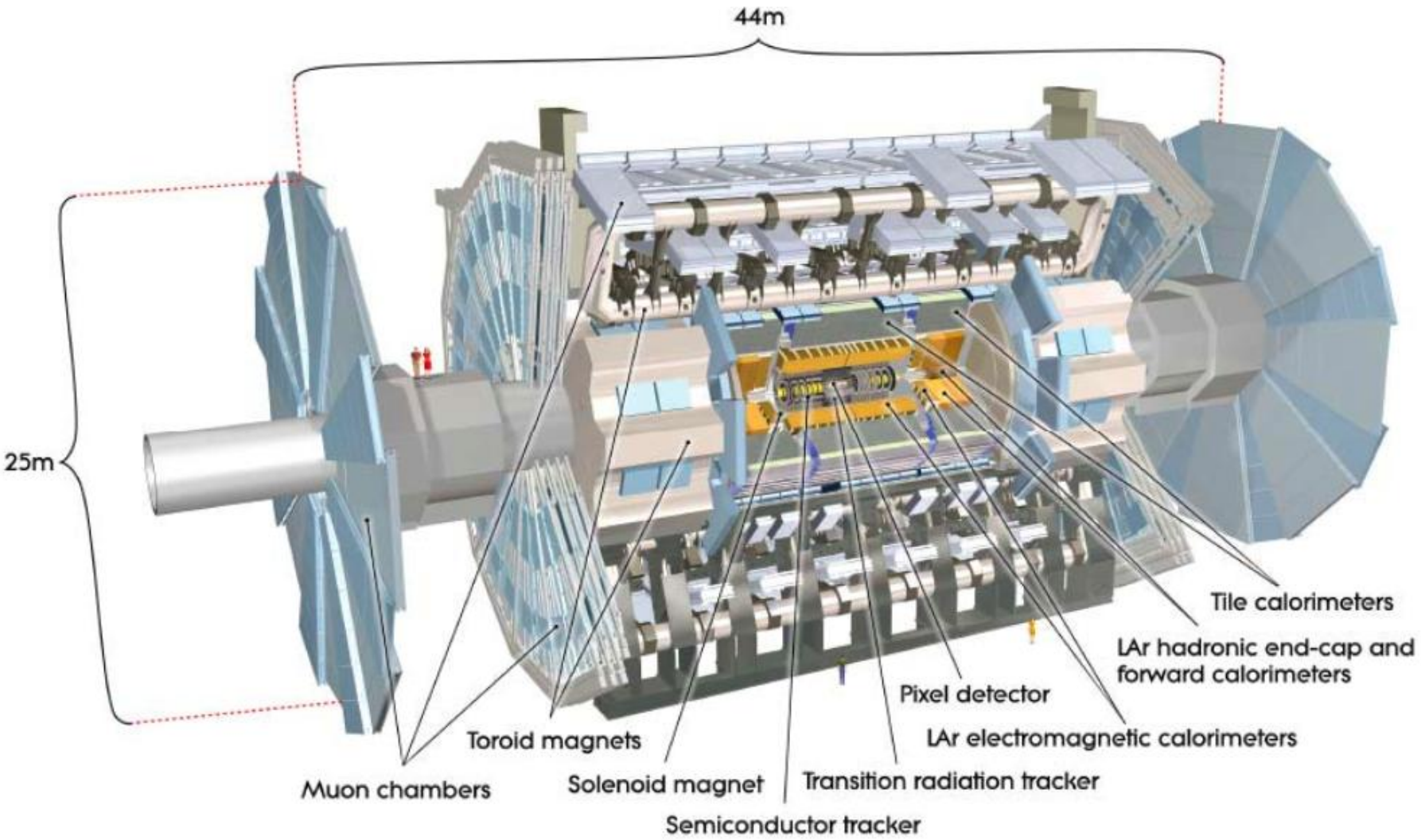




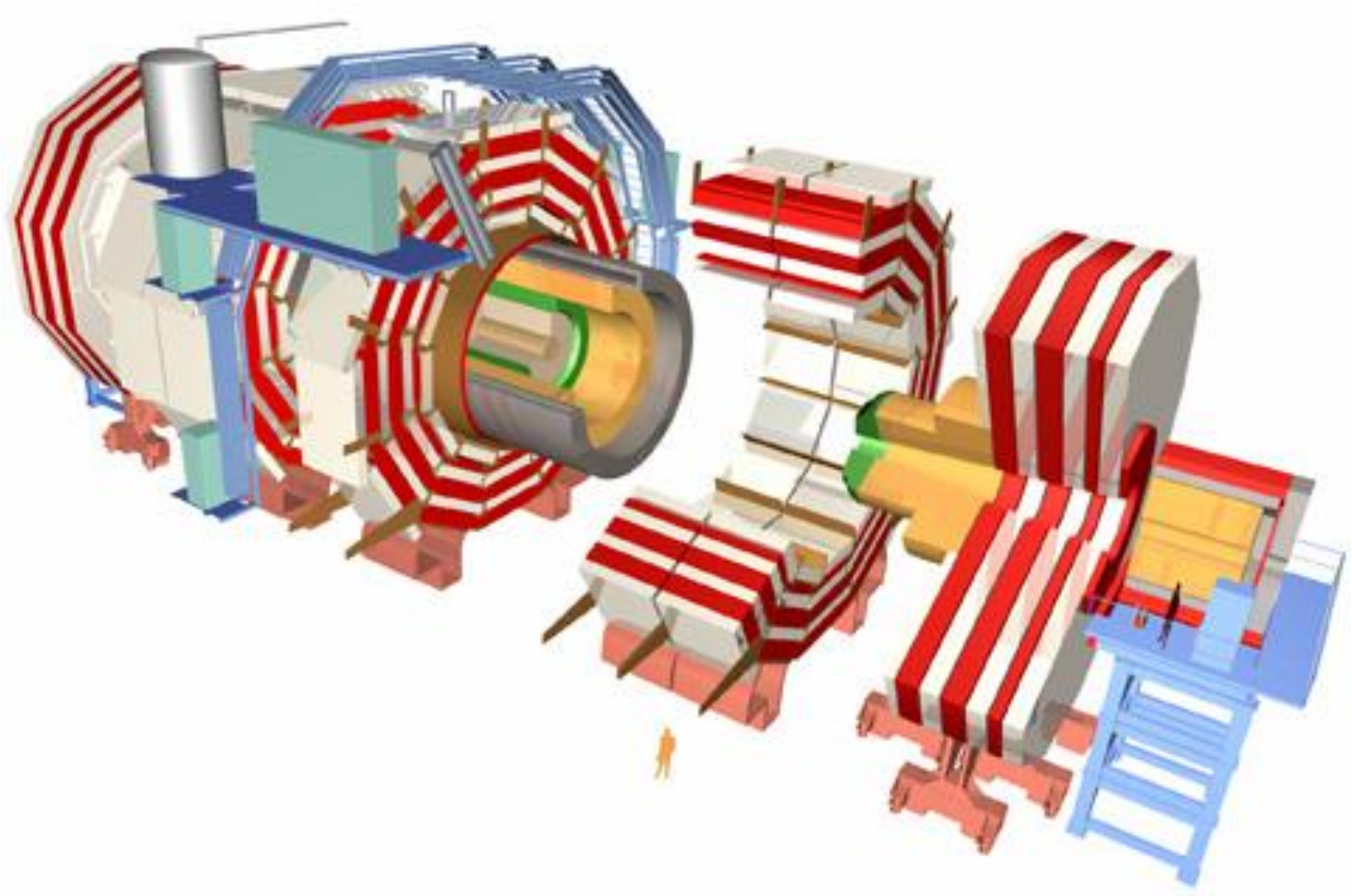


THE LARGE HADRON COLLIDER (LHC)

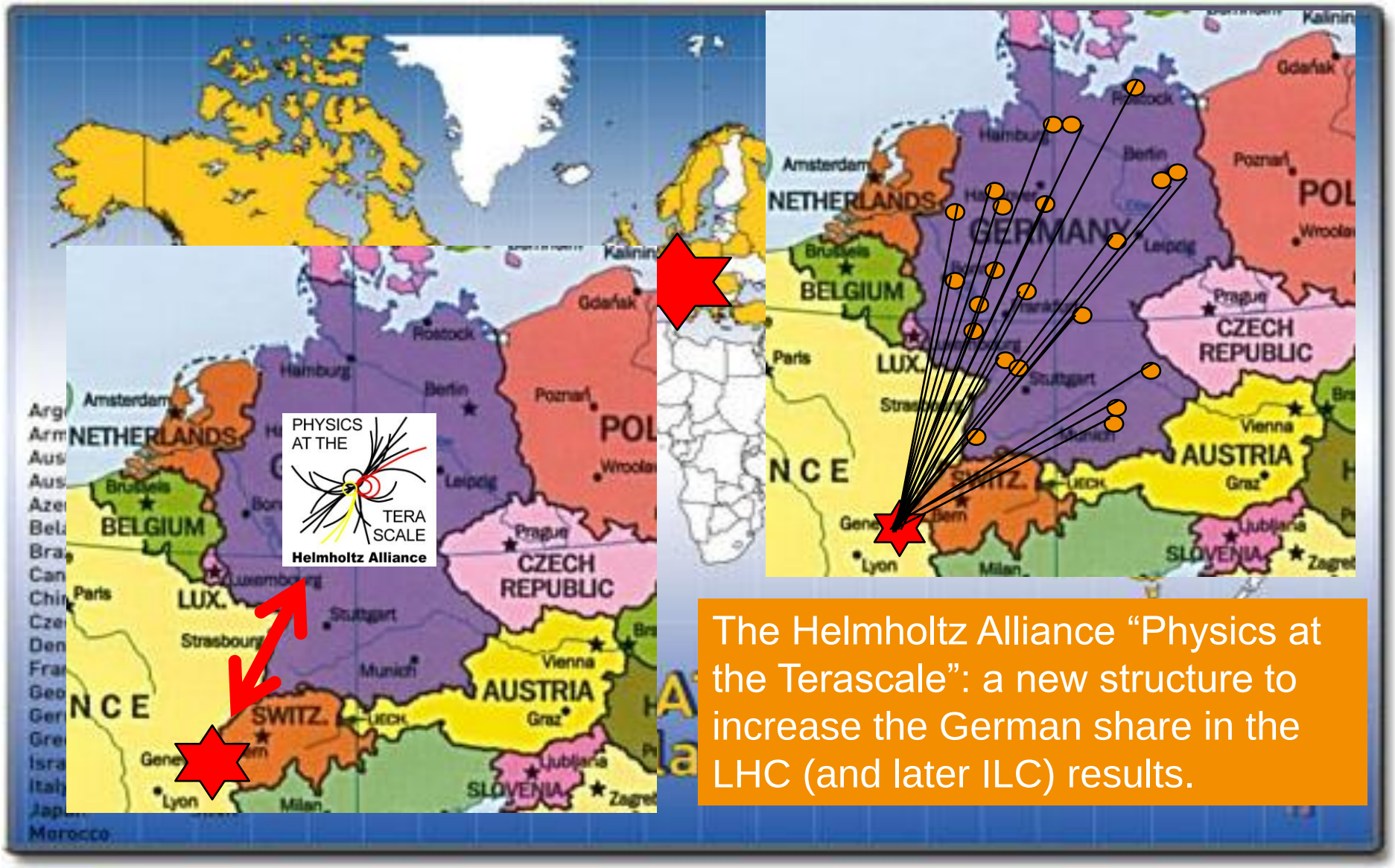
THE ATLAS EXPERIMENT



THE CMS EXPERIMENT

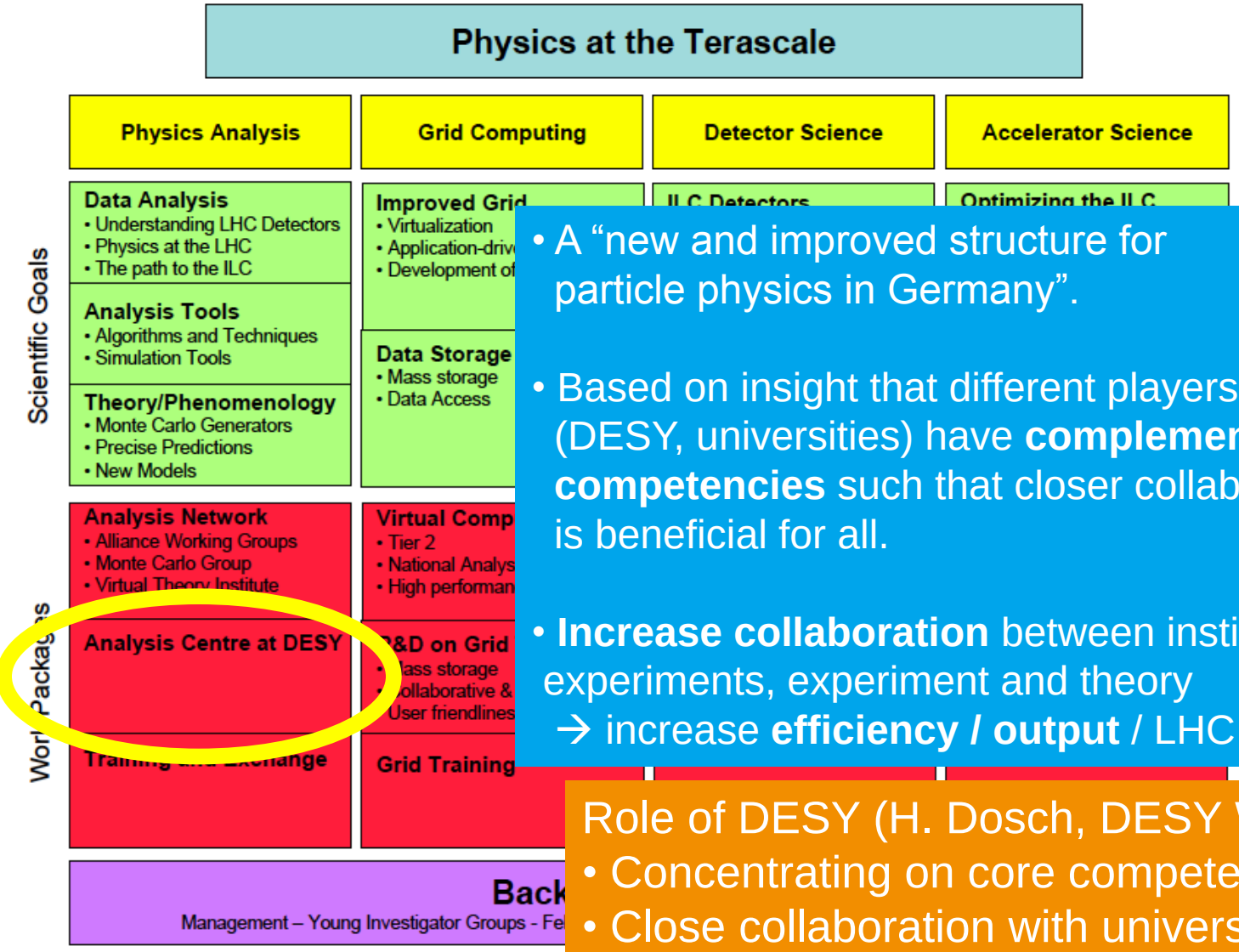


THE LHC: A WORLD-WIDE ENTERPRISE



The Helmholtz Alliance “Physics at the Terascale”: a new structure to increase the German share in the LHC (and later ILC) results.

THE ALLIANCE "PHYSICS AT THE TERASCALE"



- A "new and improved structure for particle physics in Germany".
- Based on insight that different players (DESY, universities) have **complementary competencies** such that closer collaboration is beneficial for all.
- **Increase collaboration** between institutes, experiments, experiment and theory
  → increase **efficiency / output** / LHC share.

Role of DESY (H. Dosch, DESY WA):
- Concentrating on core competencies
- Close collaboration with universities!

MISSION OF THE ANALYSIS CENTRE

The mission of the Analysis Centre is to enhance the physics potential of the German LHC / ILC community by providing analysis infrastructure and by supporting analysis-related issues of general relevance.

- ***Education and training*** (schools, workshops, documentation, …).
- **Basic research, tools development** and user support in central fields.
  - Software, algorithms, methods, papers, talks, …
- LHC / ILC ***analysis support*** (to be developed).
- ***Networking***.
- Fields of general relevance ➔ three ***dedicated working groups***:
  - Monte Carlo generators (MC),
  - Parton Distribution Functions (PDFs), and
  - Statistics Tools.
  - Needed by everybody at LHC, building on large HERA/DESY expertise, experiment independent!

THE ANALYSIS CENTRE …

- … is the Analysis Centre ***of the Alliance*** (located at DESY)
  - Everybody doing analysis in D is by definition part of the Analysis Centre!
  - All partners are invited to contribute – and profit → maximise the added value.
- … will become the ***focus of LHC and ILC analysis*** at DESY
  - All are expected to contribute; already now DESY pushes the centre massively, both on the organisational and the project side.
- … aims at having ***major impact*** on important projects / programs relevant for the LHC / ILC. That requires
  - … interesting projects! ✔ (see later)
  - … good connections to LHC / ILC! ✔
  - … sufficient manpower to keep the promises! ✔
- Currently ***close to 20 people*** (not: FTE) involved in the centre at `core' level.
  - Attracting reasonable numbers of DESY fellows (typically 0.2FTE) to our projects.

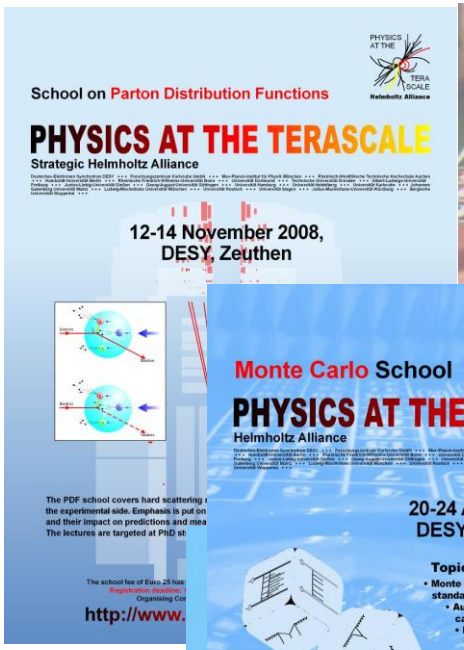
EDUCATION AND TRAINING: 2009

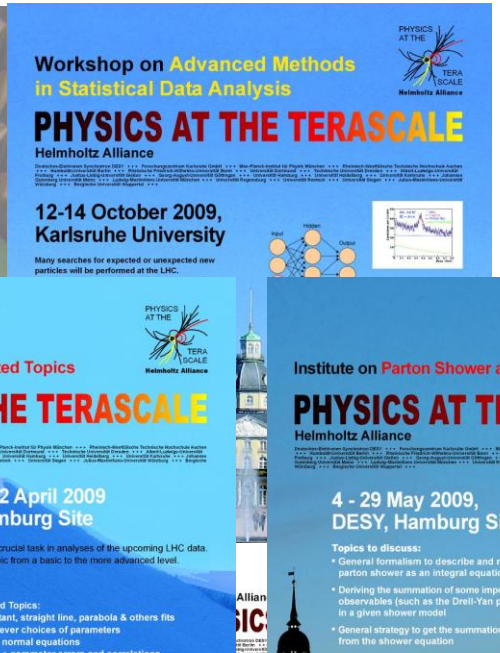
- Education and training events organised by the Analysis Centre in 2009

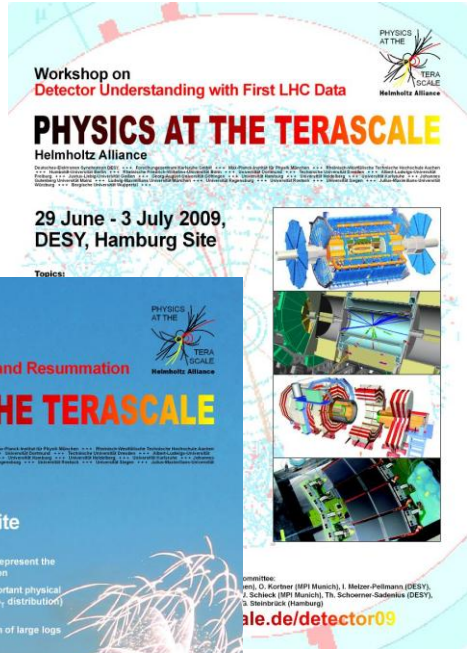
Name	Date, place	Participants
CAPP09	March, DESY	30
Fitting 2009	April, DESY	90
MC 2009	April, DESY	75
IPSR 2009	May, DESY	
Detector Understanding	June, DESY	65
Single top	September, DESY	25
Advanced Statistics	October, Karlsruhe	40
PDF 2009	October, DESY	30

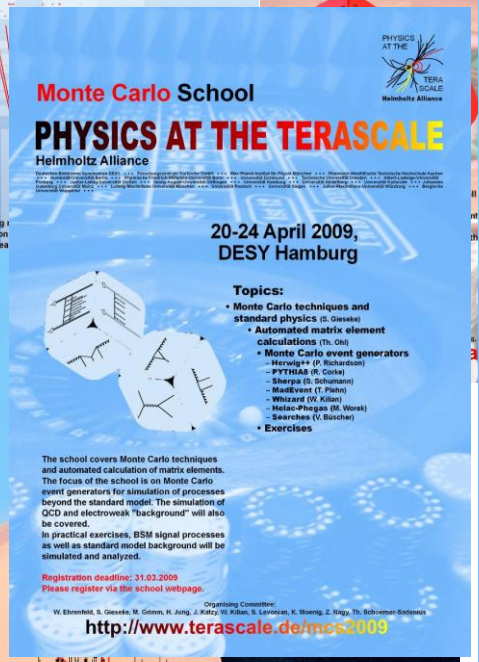
- Overall ***excellent feedback***; develop and adapt to user needs. One of the strong points of the Alliance!
- Very similar programme in 2010, with some modifications.

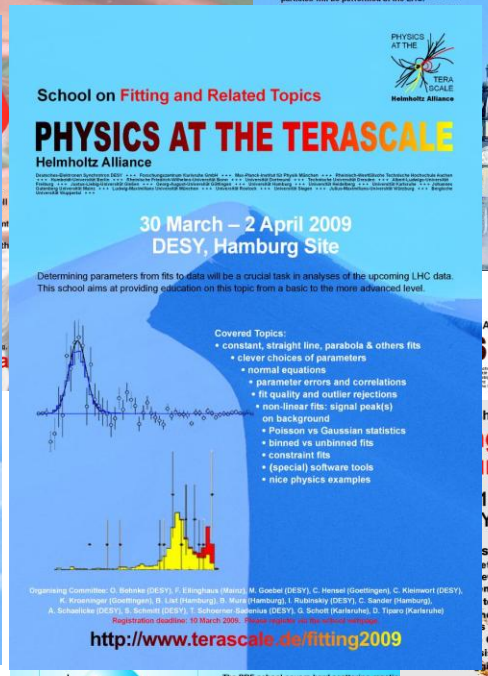
EDUCATION AND TRAINING

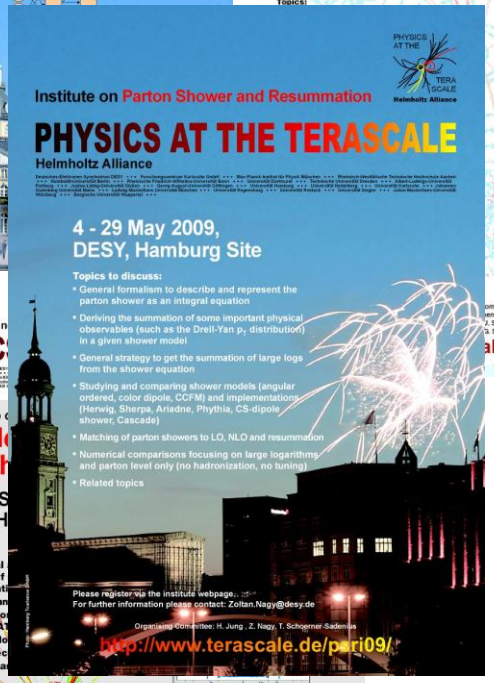


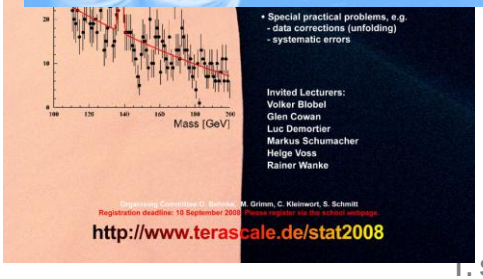


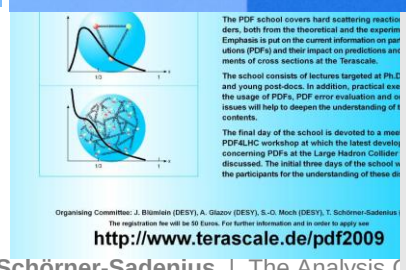


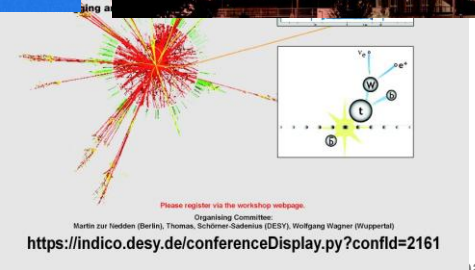












EDUCATION AND TRAINING: PLANS FOR 2010

- Education and training events intended for 2010:

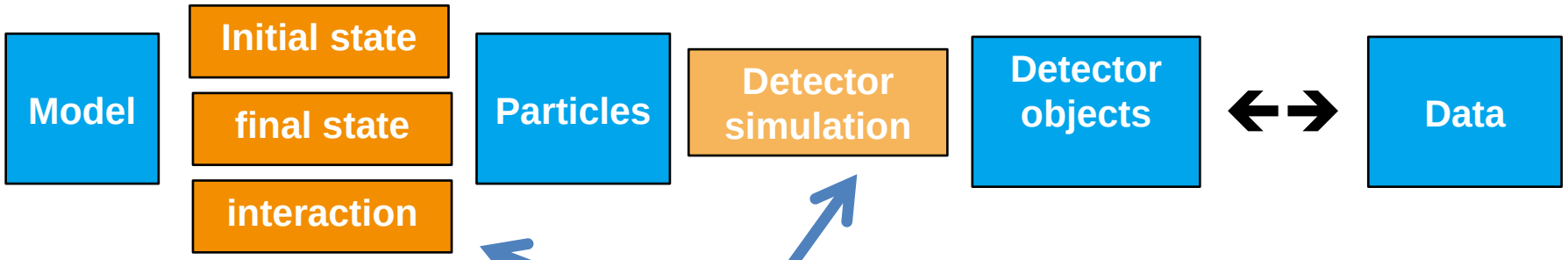
Name	Date, place	Participants
Statistics 2010	Spring, DESY	40
Introduction to Terascale	March, DESY	40
CTEQ-MCNet School*	June, Black Forrest	
“Detector Understanding”	unclear	
PDFs, MC, NLO	?, Freiburg	60
Advanced Statistics	October, Göttingen	40
PDF 2010	Autumn, Zeuthen	40
C++	?, DESY/Bonn	40
OO Design course	Dresden, Spring	25

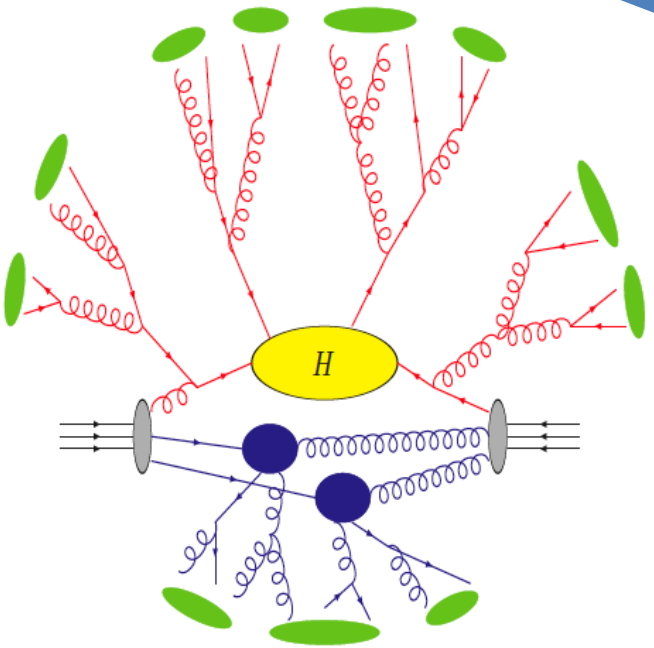
- Awaiting funding decision from Alliance Management Board.

*Contributions from Analysis Centre MC group.

ANALYSIS CENTRE GROUPS: MC

- Monte Carlo models: Central for all measurements in high-energy particle collisions: ***data corrections, detector understading, etc.***

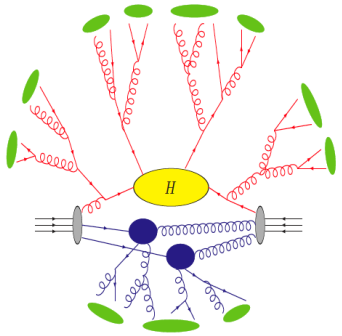




Simulated / evaluated using samples of MC generated events with
- beam particles / PDFs
- hard interactions
- parton showers
- hadronisation
- multi-parton interactions / UE
- …

ANALYSIS CENTRE GROUPS: MC

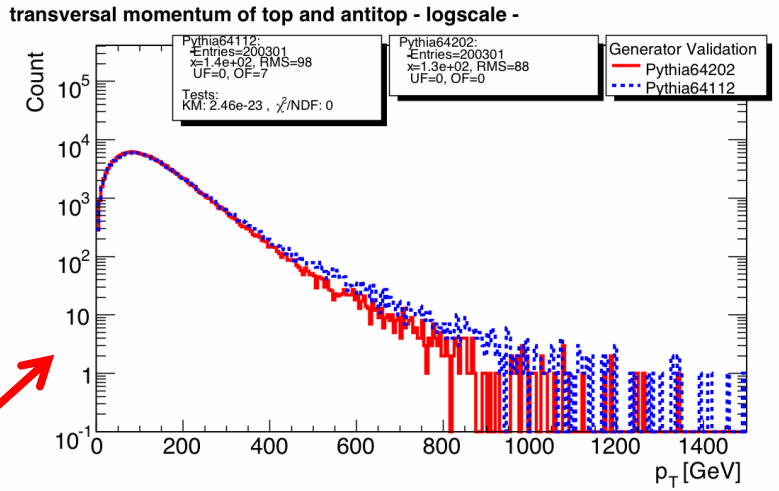
- Mission: **Data = PDF ⊗ (hard part ⊗ shower + MPI/UE ⊗ shower) ⊗ hadronisa**
  - ***systematic understanding of (QCD) LHC events***, including parton shower, PDF, hard scattering etc.
  - ***Tuning*** of Monte Carlo generators.
  - ***Software projects*** and support.

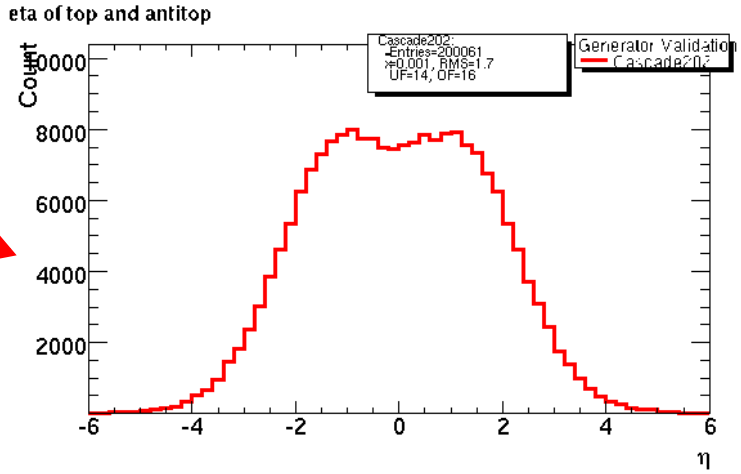


- Education:
  - Yearly MC school (2010: contribution to CTEQ/MCNet School) plus typically one or two QCD/MC block courses.
- Concrete projects (details on next slides):
  - Important point: ***projects as offers and invitations for feedback + contribution***!
  - CASCADE MC generator, unintegrated PDFs, framework for non-collinear MC generators and new parton shower developments, PDF4MC project.
  - PDF framework OOPDF (replacement for LHAPDF?)
  - Tuning efforts within ATLAS (and CMS), and across the experiments (PROFFIT tool).
  - Validation efforts and tools (HEPMCAnalysis), application to GENSER validation.

MC GROUPS: EXAMPLES (1)

- HEPMCAnalysis: a tool for ***generator validation and comparisons***
  - Developed in the Statistics Tools group
  - Extremely useful and light-weight.
  - Used for validation of the GenSer (GeneratorService) library of all generators used by LHC collaborations
    → usable for all LHC generators!
  - Example 1: validation of different PYTHIA versions (predictions for top-antitop pair transverse momentum).
  - Example 2: top-antitop pseudorapidity distribution with CASCADE generator.





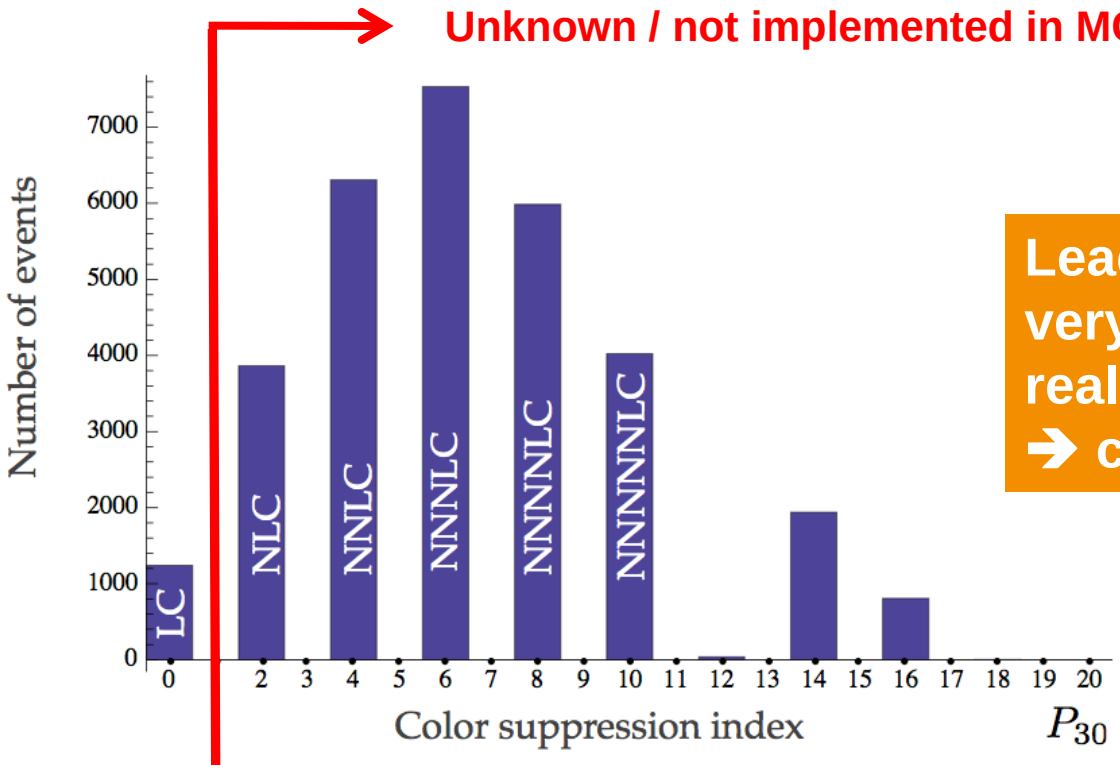
MC GROUPS: EXAMPLES (2)

- Theoretical studies of parton showers (THE ingredient to all MCs):
  Estimate, with simple “color shower”, the ***importance of subleading color contributions***

$$N_m(P) = \frac{1}{N}\sum_{i=1}^{N} \langle \{c_i'\}_m | \{c_i\}_m \rangle \, \delta(P - P_m(\{c_i', c_i\}_m))$$

$$\langle \{c'\}_m | \{c\}_m \rangle = \frac{c_P(m)}{N_c^{P_m}} \left\{ 1 + \mathcal{O}\left(\frac{1}{N_c^2}\right) \right\}$$

  - Relative contributions of different color configurations to full parton shower:



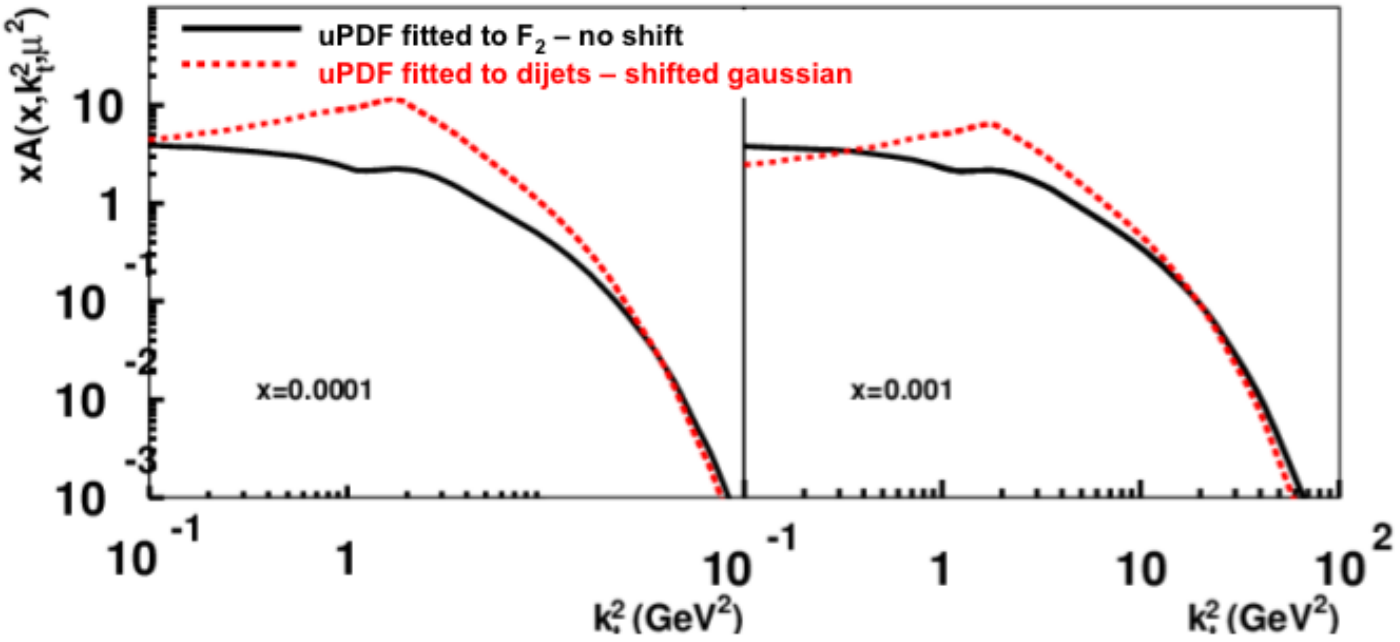
Leading color is at best very crude estimate of real size of parton shower ➔ central field of activity!

MC GROUPS: EXAMPLES (3)

- Determination of parameters of unintegrated PDFs (uPDFs):
  - Defined at some starting scale and evolved to higher scales by emissions of gluons according to CCFM evolution (CASCADE MC gen.)

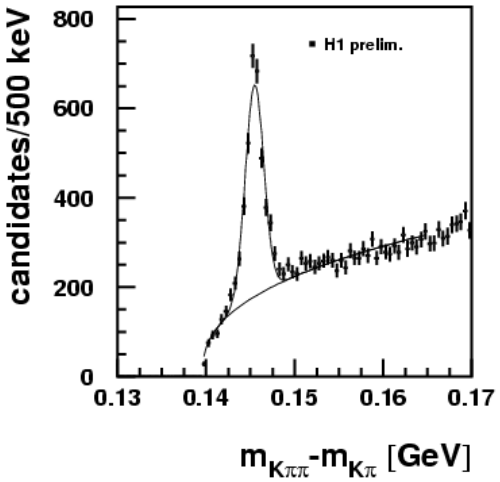
$$xA_0(x, k_T) = N \cdot x^{-B} \cdot (1-x)^C \cdot exp(-\frac{(k_T - \mu)^2}{2\sigma^2})$$

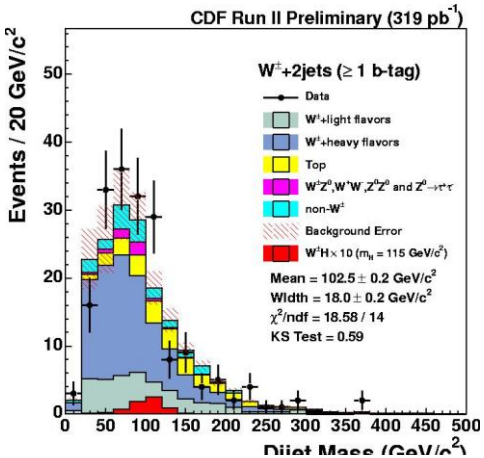
  - Fitting the MC to dijet data suggests a ***gluon PDF*** which is suppressed at low k_T (shifted Gaussian).

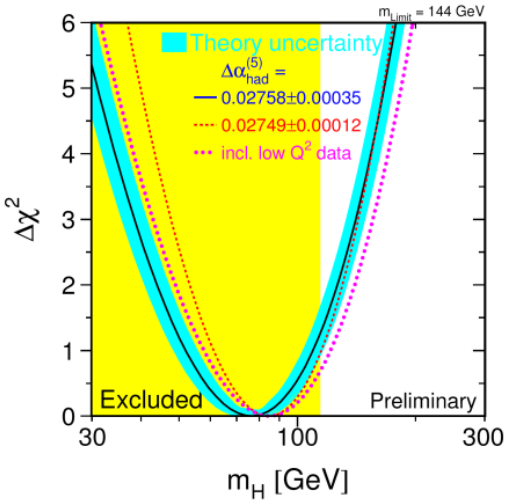


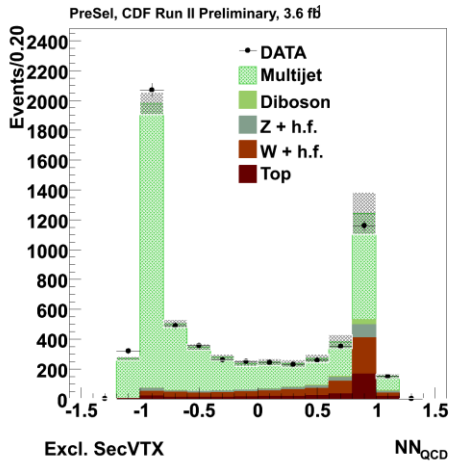
ANALYSIS CENTRE GROUPS: STATISTICS TOOLS

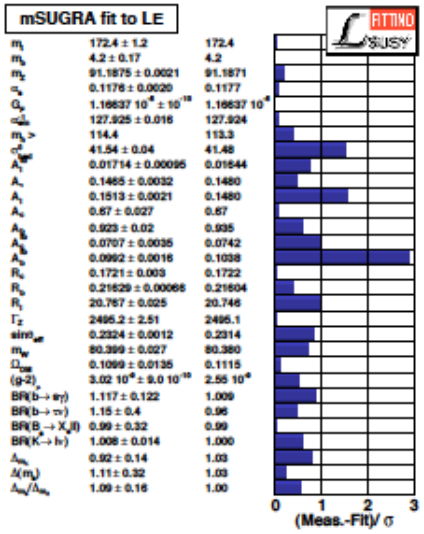
- Fitting of signal peaks, fitting of signal+background, derivation of limits on model parameters, separation of signal and background, etc.

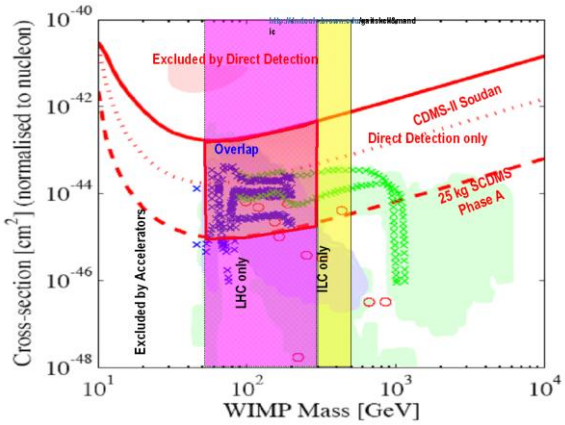










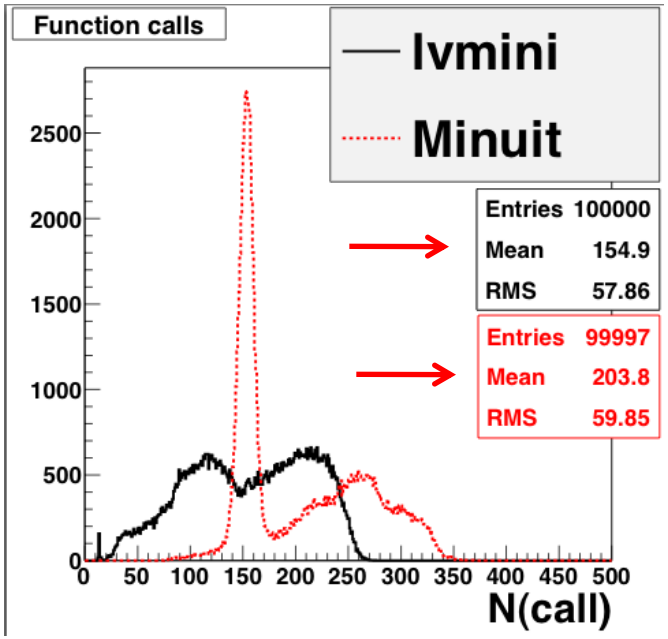


ANALYSIS CENTRE GROUPS: STATISTICS TOOLS

- Mission: ***Education*** / training (schools), community ***support*** (details to be put into place), ***tool development*** and support for them (contacts!).
- Topics: signal/background separation with multivariate methods, searches and limits, fitting, unfolding and other practical problems.
- Education: typically two schools / year (one basic at DESY, one advanced elsewhere), informal statistics meetings, software review meetings, installation of discussion forums (to come).
- Projects (details next slide, ***invitation for contribution / feedback***):
  - Millepede support, development and maintenace (taken over from V. Blobel) (DESY)
  - LVMINI and APLCON porting to the ROOT / C++ / LHC world (DESY)
  - Core contributions to TMVA starting now (two DESY fellows)
  - Efforts on unfolding starting (DESY / Mainz)
  - Numerous connected projects (BAT, ROOSTATS, FITTINO, GFITTER, …)
- Outcome: Significant (contributions to important) statistics projects.

STATISTICS TOOLS GROUP: EXAMPLES (1)

- LVMINI (V. Blobel): Porting from FORTRAN world to ROOT and benchmarking
  - Prel. Result with non-tuned settings: clear ***reduction of function calls***.
  - Further tests needed. Applications for example in calorimeter calibration etc.

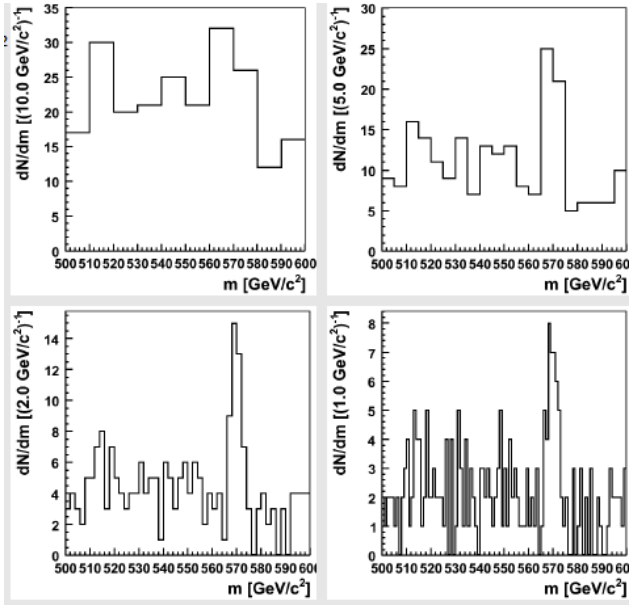


- In general many tools for HERA purposes not yet available at LHC!Other examples:
  - Porting of the APLCON constrained fit tool (also V. Blobel) to the C++ world.
  - Unfolding and data correction procedures / software.
- Implementation of broken line fit in Millepede: Applied for example in multi-parameter CMS tracker alignment:

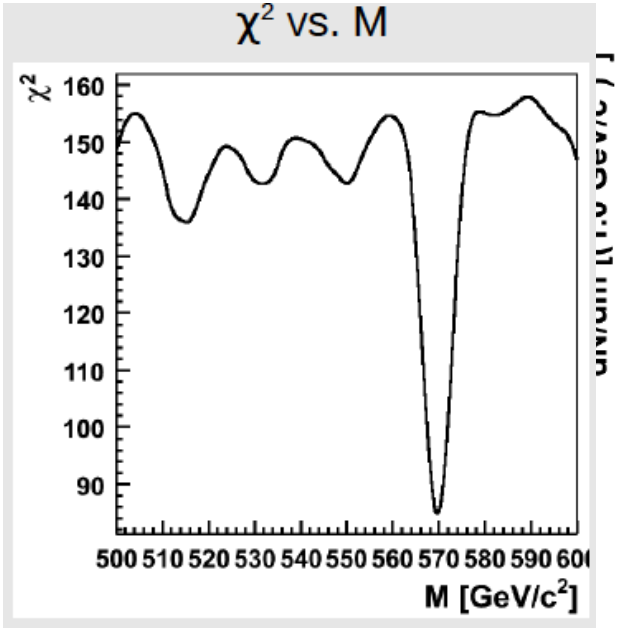
Clear improvement in alignment parameter resolution.

STATISTICS TOOLS GROUP: EXAMPLES (2)

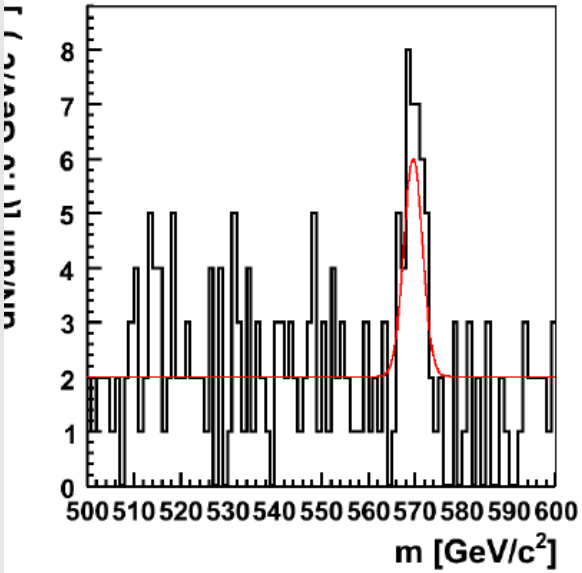
- Exercise from fitting school: Search + fit new particle with unknown mass!



Choose Binning



Signal scan

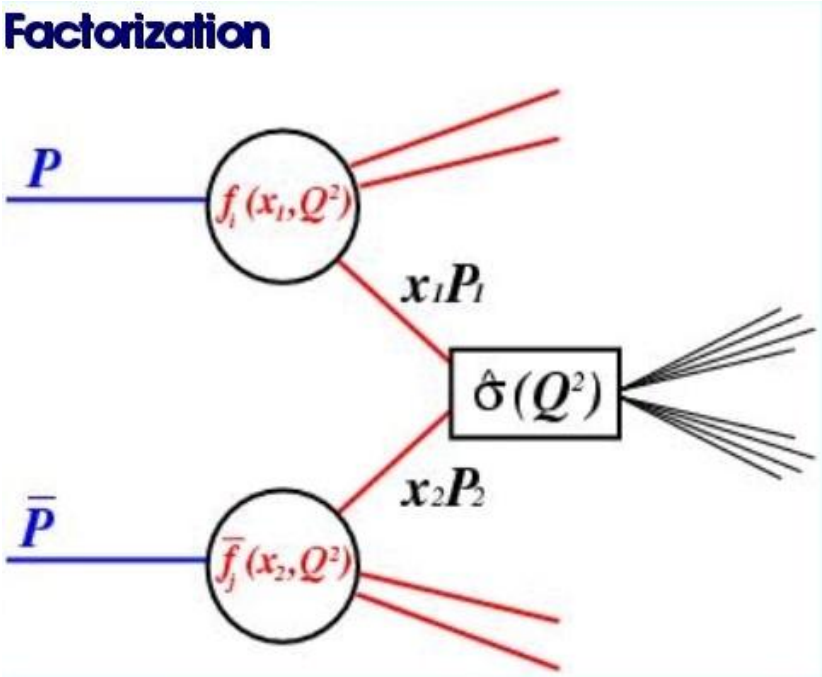


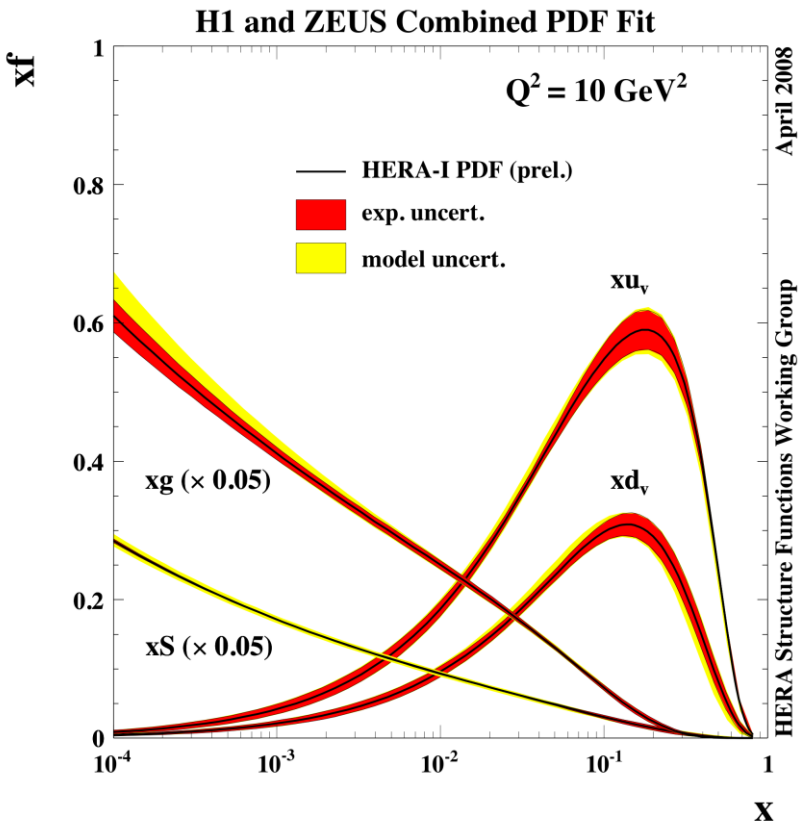
Final fit

Evaluate background fluctuation probability: ~4x10

- Many more nice and useful fit lectures and interactive exercises:
  https://indico.desy.de/conferenceTimeTable.py?confId=1582

ANALYSIS CENTRE GROUPS: PDFs



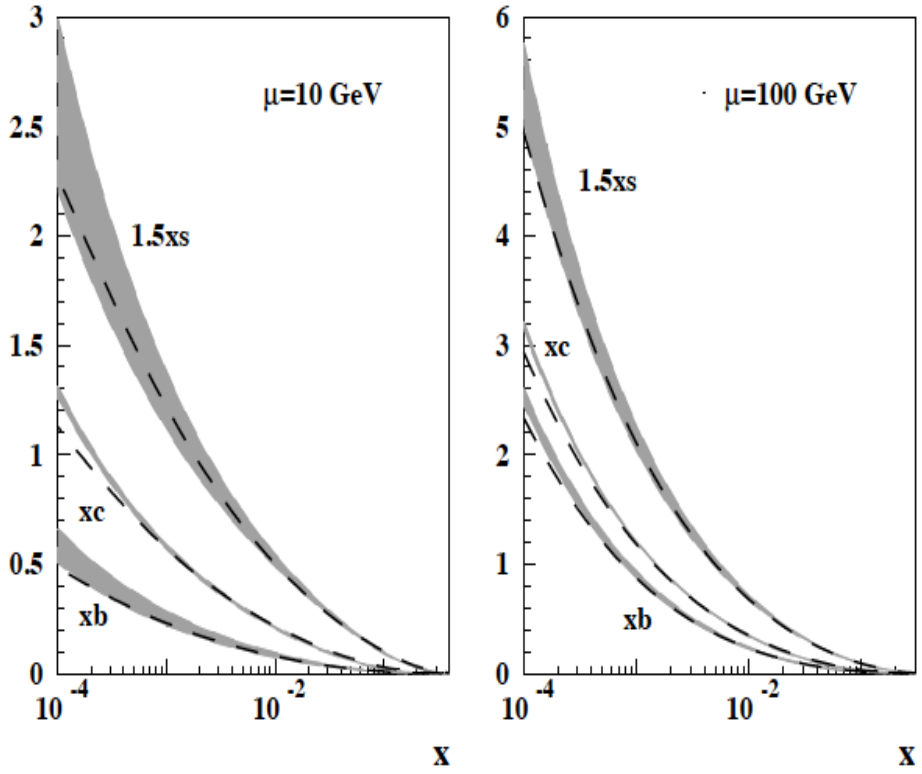


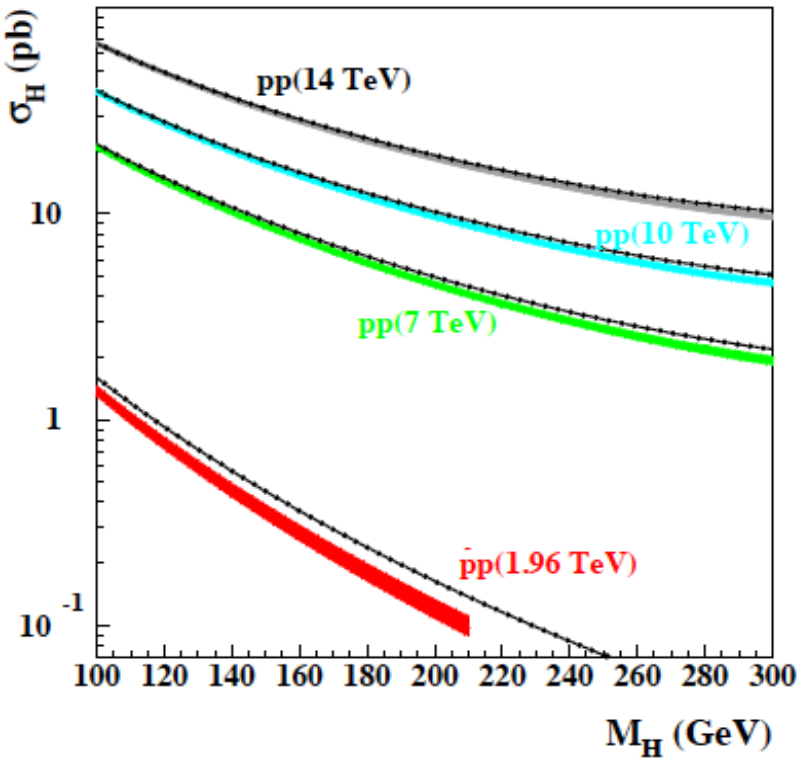
ANALYSIS CENTRE GROUPS: PDFs

- Mission:
  - ***Support final analyses of HERA data*** w.r.t. to the extraction of PDFs; detailed data systematics and parameterization studies.
  - ***Comparisons of different PDF analyses*** (MSTW, CTEQ, NNPDF, Dortmund, ABMK) to refine the understanding of PDFs and their errors, including alpha_s.
  - ***Theoretical calculations*** needed to improve ongoing ep and pp analyses.
  - Platform for ***analysis of inclusive hard scattering data at the LHC*** (DY, ttbar, Higgs) to refine the understanding of the PDFs.
- Education: annual PDF school with lectures and exercises
  - All PDF aspects and inclusive hard scattering processes.
- Outcome:
  - Theoretical results, improved errors on PDFs and alpha_s, determination of realistic theory errors, papers, talks
  - ***Open-source code for NNLO structure function evolution*** and pp inclusive hard scattering process analyses to extract PDFs.
  - ***Final HERA PDFs*** and (maybe) a new global fit (Alliance contribution?)

PDF GROUP: EXAMPLES

- Complete theoretical treatment of heavy flavour in PDF fits with meaningful error treatment:
  - Comparison with MSTW08.





- Application to collider phenomenology: Higgs production in pp(bar) collisions.
  - Large potential for ***gluon determination*** in pp

NETWORKING, ANALYSIS WORKING GROUPS

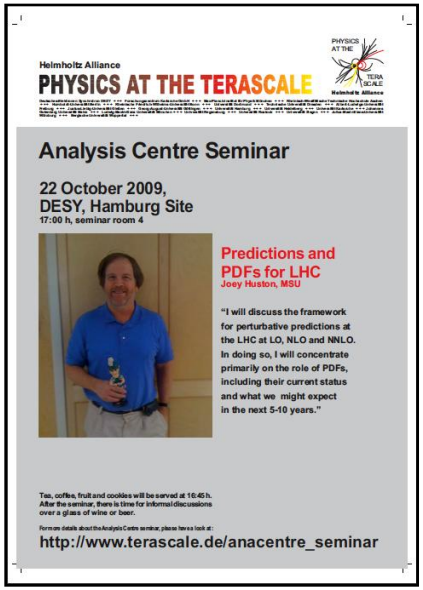
- ***Network idea*** is one of the strong points of the Analysis Centre!
  - Bringing people together, setting up a large `knowledge / expertise' database.
- Examples ***MC network*** and ***network of statistics projects***:
  - MC network of MC group in the Analysis Centre and projects at different Alliance locations (annual meetings of all projects, contributions to regular MC meetings etc.).
  - Many statistics projects in German HEP, connected through contributions to schools, personal contacts. Annual software review meetings.
- ***Analysis Working Groups***: Bringing together institutes, experiments, experimentalists and theorists!
  - Existing examples: Mtautau working group between ATLAS and CMS.
  - 2009: One new Analysis working group: “Neutrinos and LFV at LHC”.
  - Topical workshop on “Single-top production / fourth-generation quarks”
  - Some more ideas around. Will organise more topical workshops to trigger such activities.

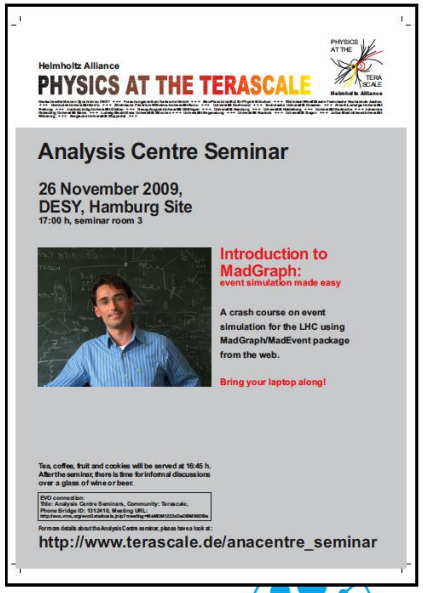
CHALLENGES

- Timescales!
  - Alliance ends (?) in 2012; two positions (of four) filled only recently → very little time to build up structure, make it know and accepted, and to be productive.
  - Experience from LPC@FNAL: 5 years from first project to fully developed centre.
- Relation to LHC data analysis activities
  - So far not involved in LHC data analysis issues, and connection to NAF computing rather weak.
  - Analysis mostly experiment-specific → more difficult to define potential activities.
  - Need better communication with and more input / wishes / requests / ideas from the experimental collaborations.
- Manpower and support from university institutes and DESY
  - Significant output requires people contributing to the projects and defining new ones.
  - Consequently, we could still (and always) do with more people getting involved, both from DESY and the other Alliance partners.

PLANS FOR 2010 – VISION FOR >2011

- Keep up, adapt and broaden ***education programme*** and ***research and development*** in the groups.
- Increase number ***of topical workshops*** (seeds for Analysis Working Groups?).
- Work towards efficient ***support of LHC data analysis***
  - How? Need input from the experimental groups and close(r) collaboration with NAF!
- Start ***Studentship programme***
- Further activities and plans:
  - ***"Knowledge" database***,
  - Modern Science Information System,
  - Analysis Centre seminar,
  - theorist of the week,
  - visitors, …





SUMMARY AND CONCLUSIONS

- Analysis Centre:
  - A useful structure with a somewhat slow start, already good output and large potential.
  - A challenge to meet the needs of the community.
- The centre, to fully exploit its potential, requires more contributions from all Alliance partners.
  - The Analysis Centre is (also) a `service organisation' …
  - … but the goal is to achieve larger added value.
- Especially needed: "analysis" efforts in the Analysis Centre.
  - Requires input from the experimental groups: ATLAS and CMS have to tell the centre
  - … what they want and need (in the relevant fields).
  - … whether what the centre does is useful, or not.

… because it will pay!