Running experiments in hadron physics

ECFA Meeting

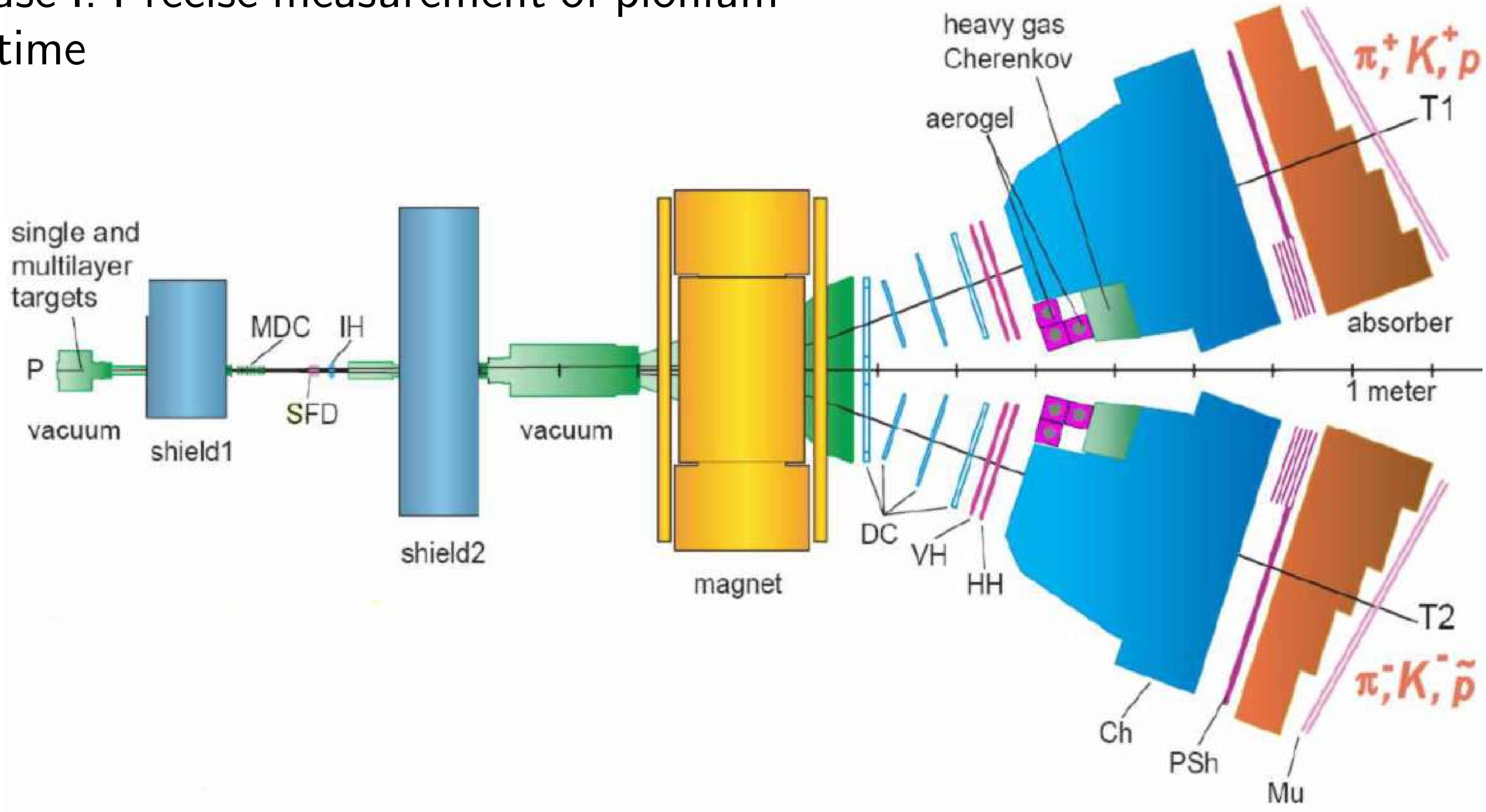
March 9 – 10, Prague

Alexander Kupčo

Institute of Physics, Center for Particle Physics, Prague

DIRAC experiment

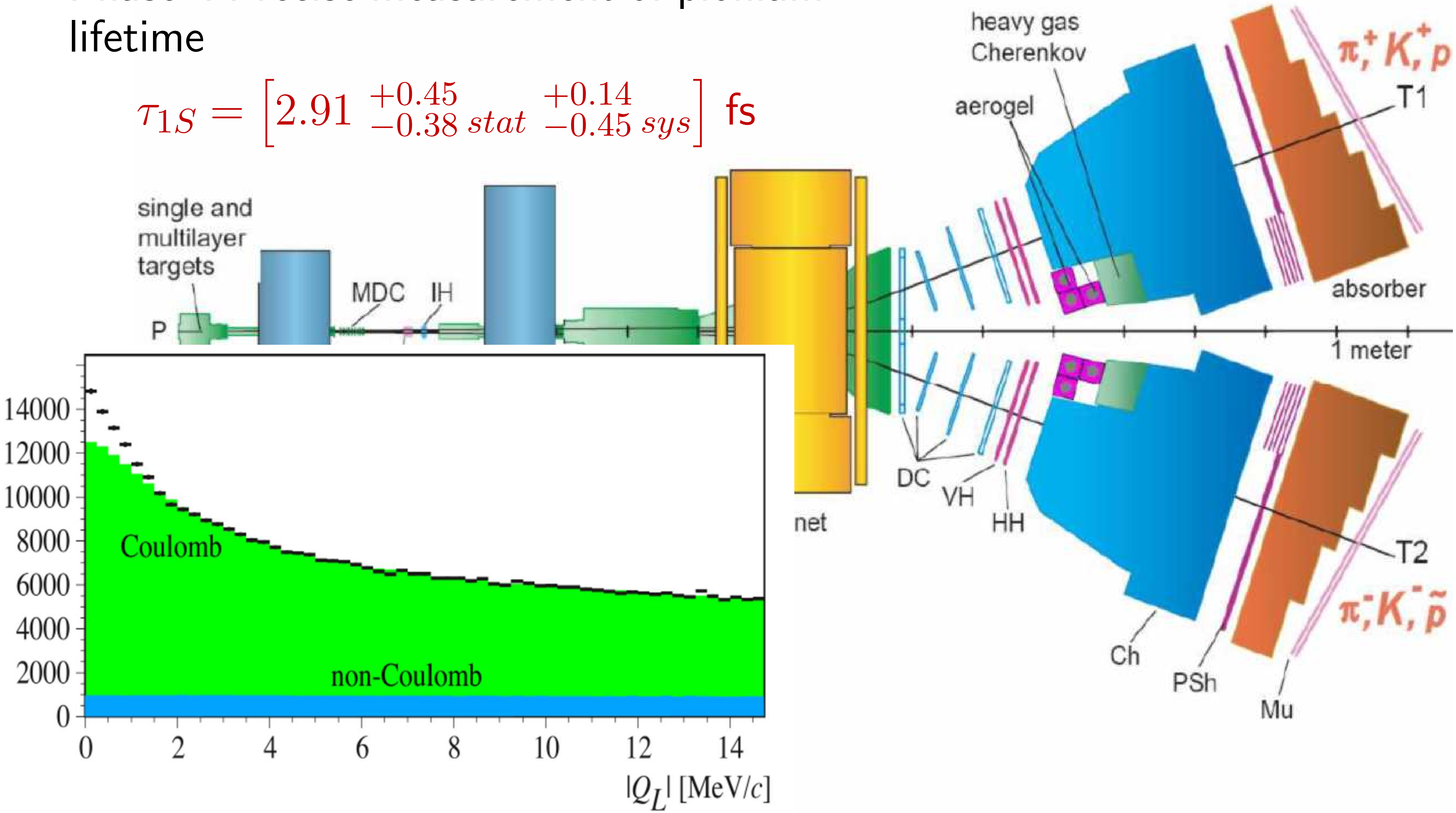
- Phase I: Precise measurement of pionium lifetime



DIRAC experiment

- Phase I: Precise measurement of pionium lifetime

$$\tau_{1S} = \left[2.91\ {}^{+0.45}_{-0.38}\,stat\ {}^{+0.14}_{-0.45}\,sys\right]\ \text{fs}$$



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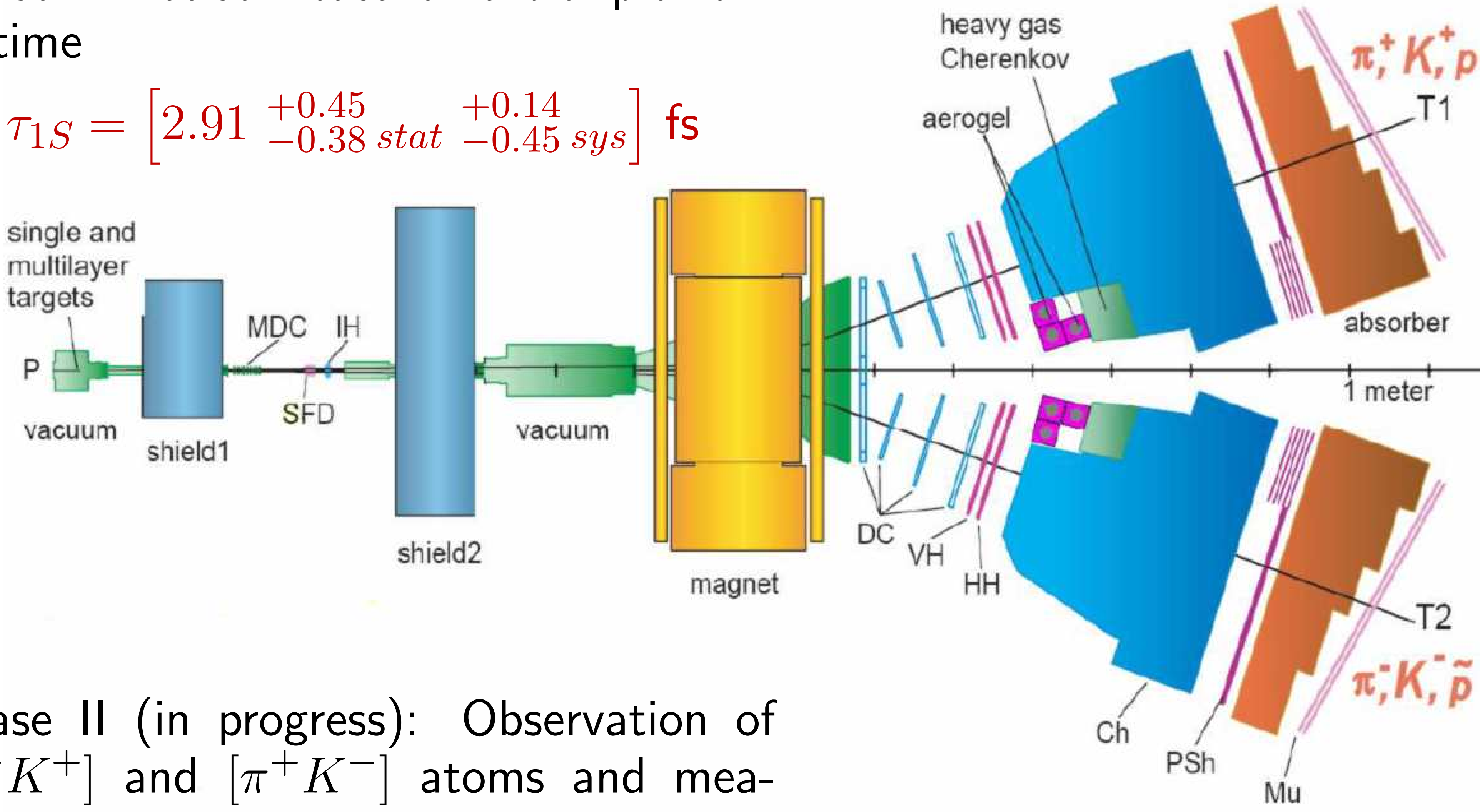
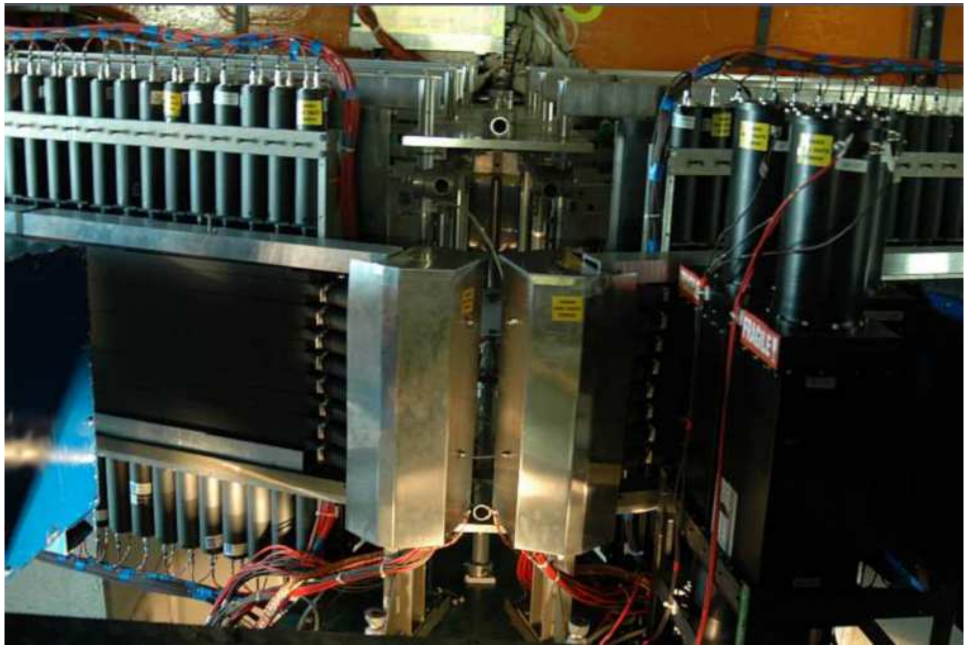


- Phase II (in progress): Observation of $[\pi^- K^+]$ and $[\pi^+ K^-]$ atoms and measurement of their lifetimes

Czech contribution to DIRAC

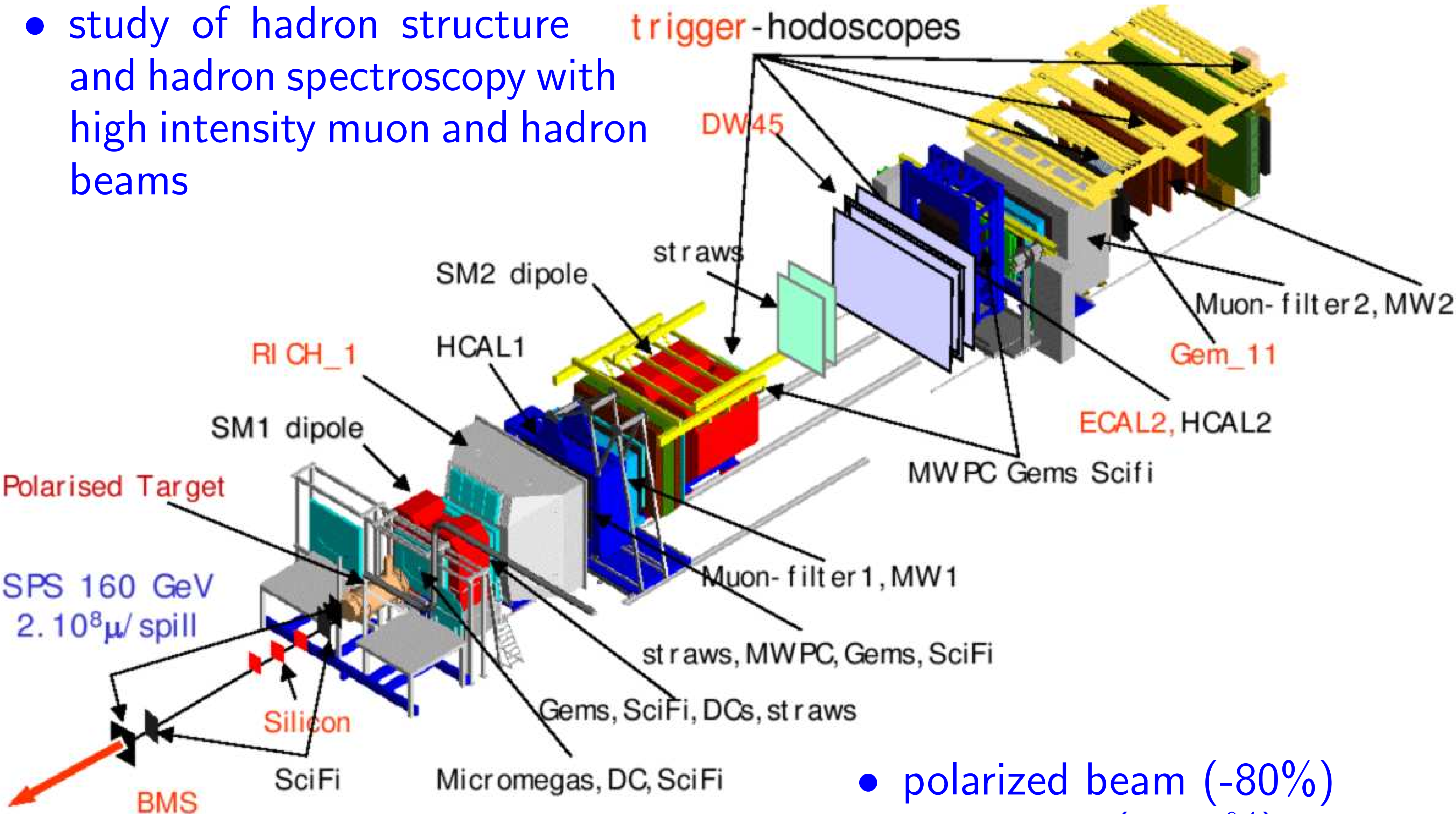
- Czech group lead by prof. Čechák (6 physicists + 1 engineer + 1 PhD student + 1 undergrad. student)
  - Faculty of Nuclear Sciences and Physical Engineering, CTU
  - Institute of Physics ASCR
  - Nuclear Physics Institute ASCR

- Horizontal Hodoscopes for Trigger system
- Mirrors for Cherenkov detectors
- Dosimetry measurements of radioactive expositions in the detector
- Physics: one PhD thesis
  - study of correlation of particles with small relative velocities



COMPASS

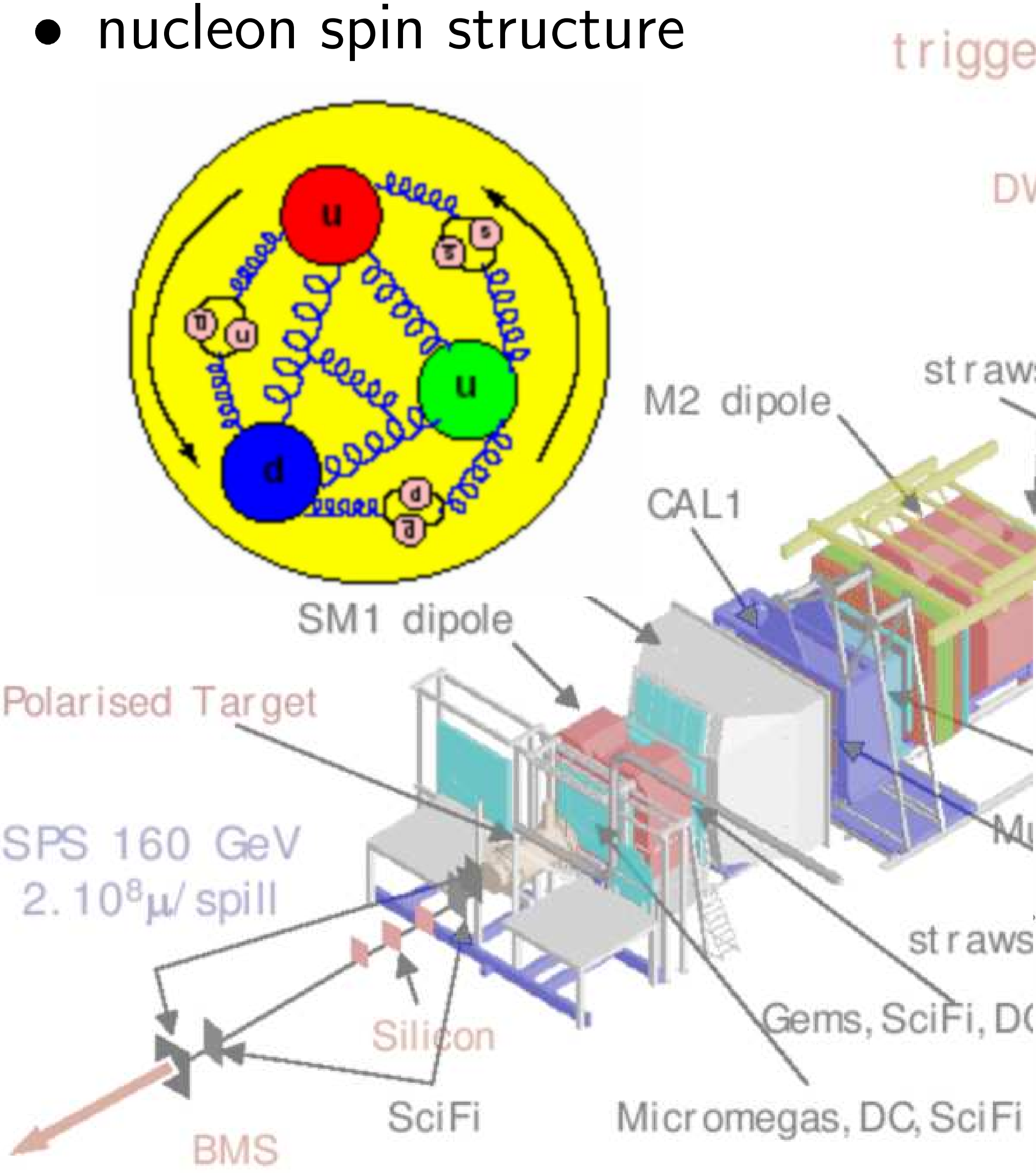
- study of hadron structure and hadron spectroscopy with high intensity muon and hadron beams

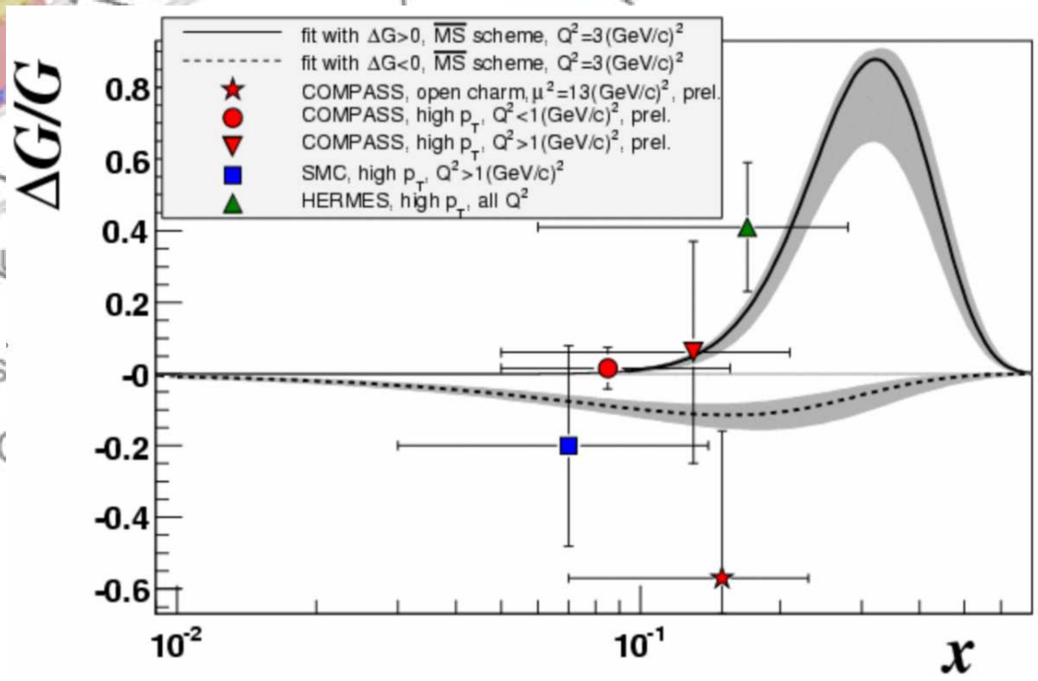


- polarized beam (-80%) and target ($> 50\%$)

COMPASS

- nucleon spin structure





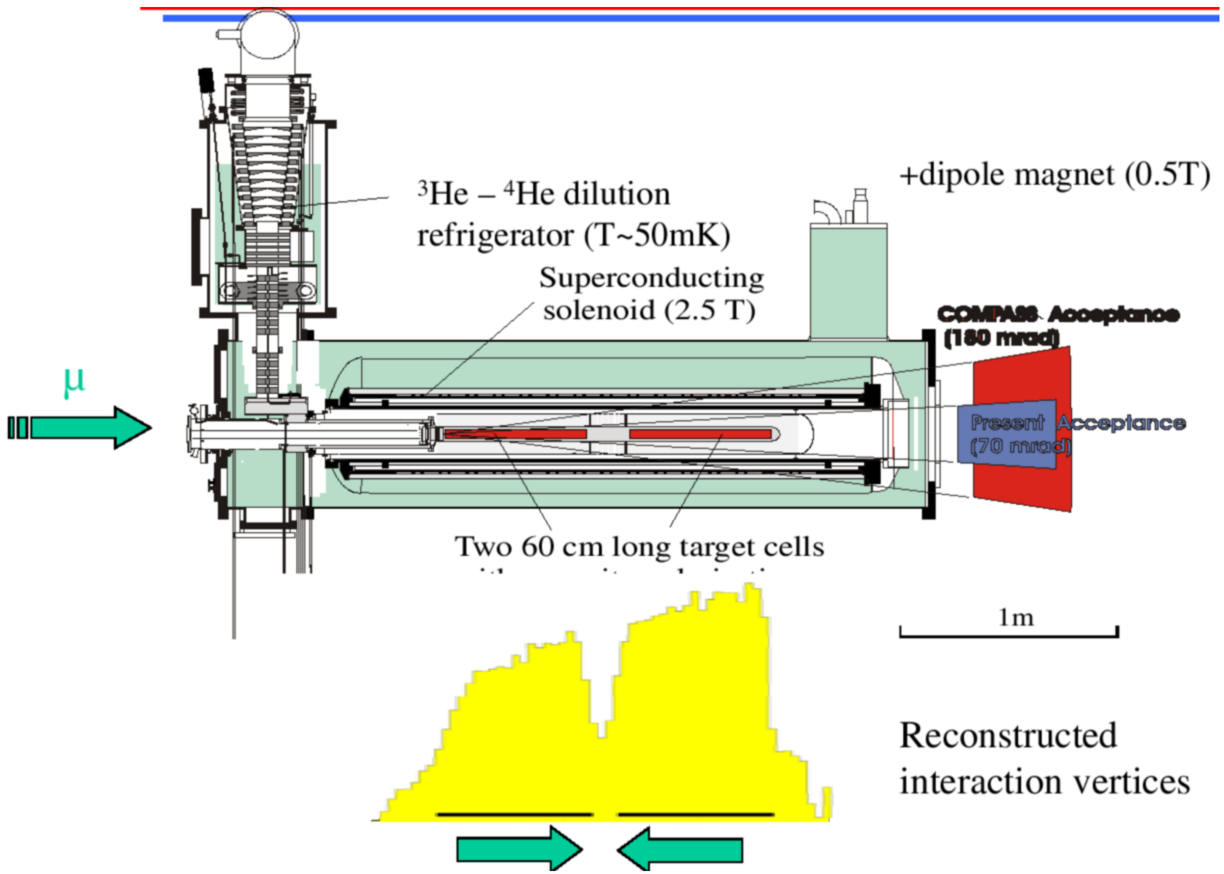
Joint Czech Group in COMPASS

- lead by prof. Finger
- 18 physicists and engineers, 10 graduate and 8 undergrad. students
  - Faculty of Mathematics and Physics, Charles University
  - Faculty of Mechanical Engineering, Czech Technical University
  - Faculty of Nuclear Sciences and Physical Engineering, CTU
  - Technical University in Liberec
  - Institute of Scientific Instruments, ASCR, Brno

Joint Czech Group in COMPASS

Commitments

- Polarized Target
  - upgrade in 2006 which increased the acceptance
- RICH detector for particle identification
  - design of optical imaging system
- development of multi-channel scintilator detectors for beam monitoring
- Central data recording
  - coordinators for muon-beam program



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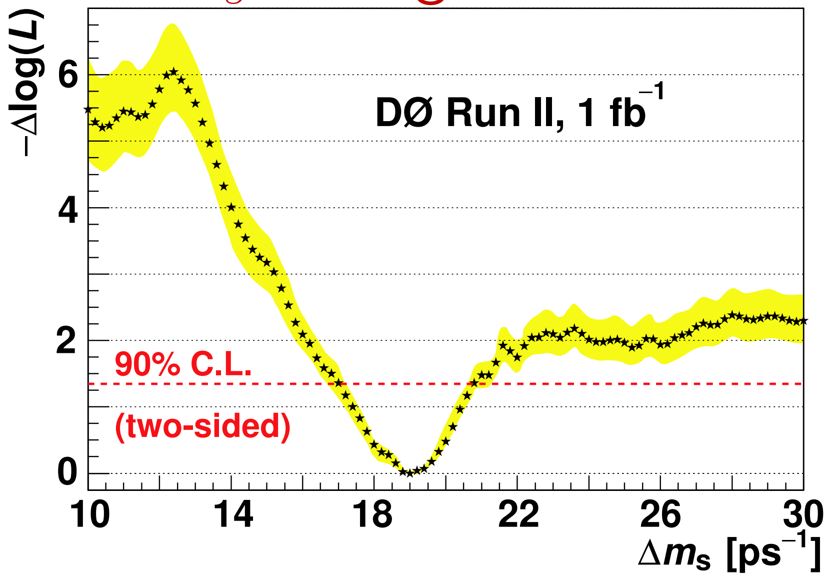
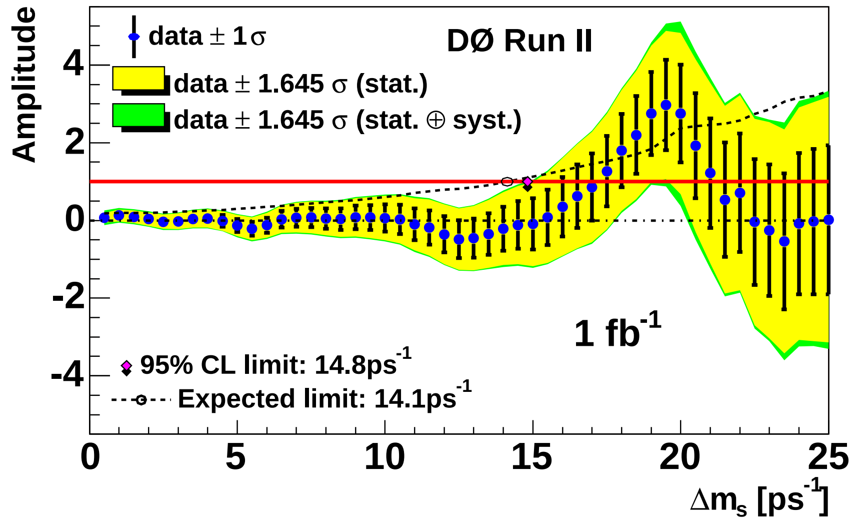
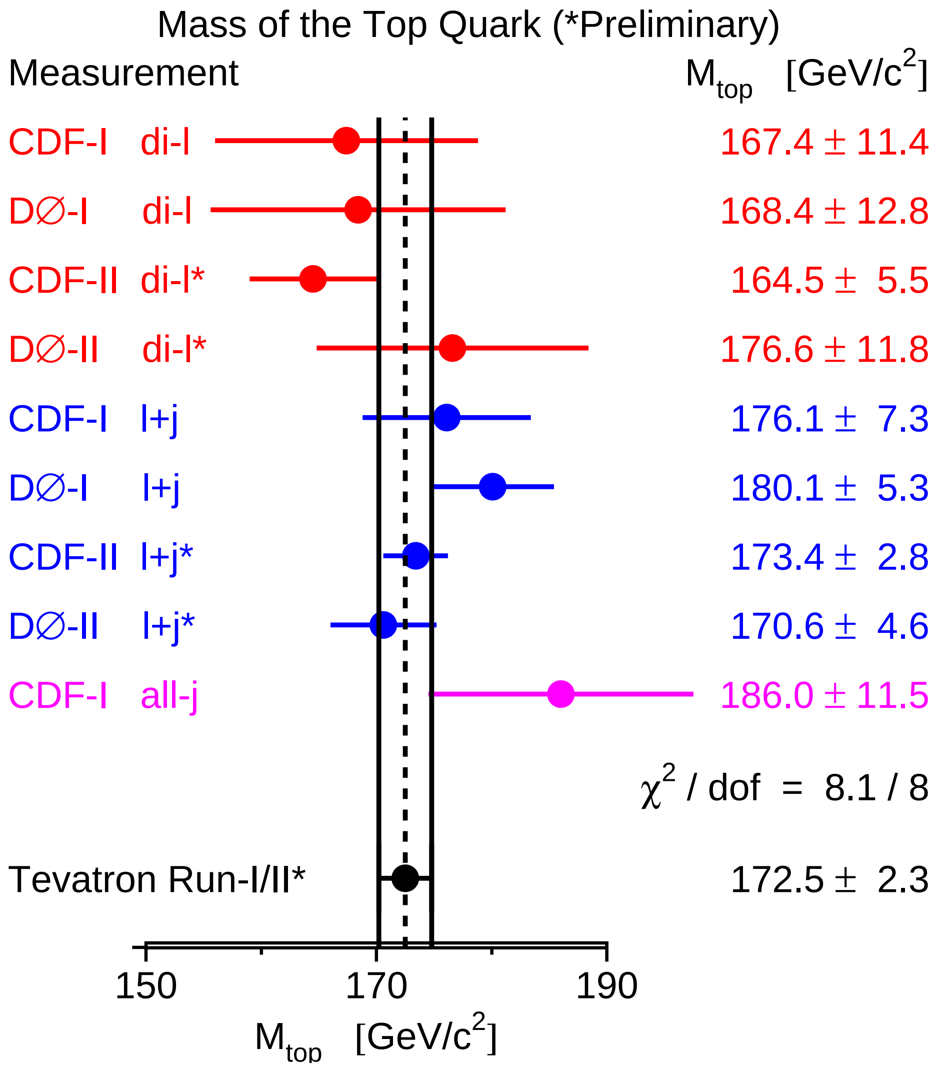
DØ experiment

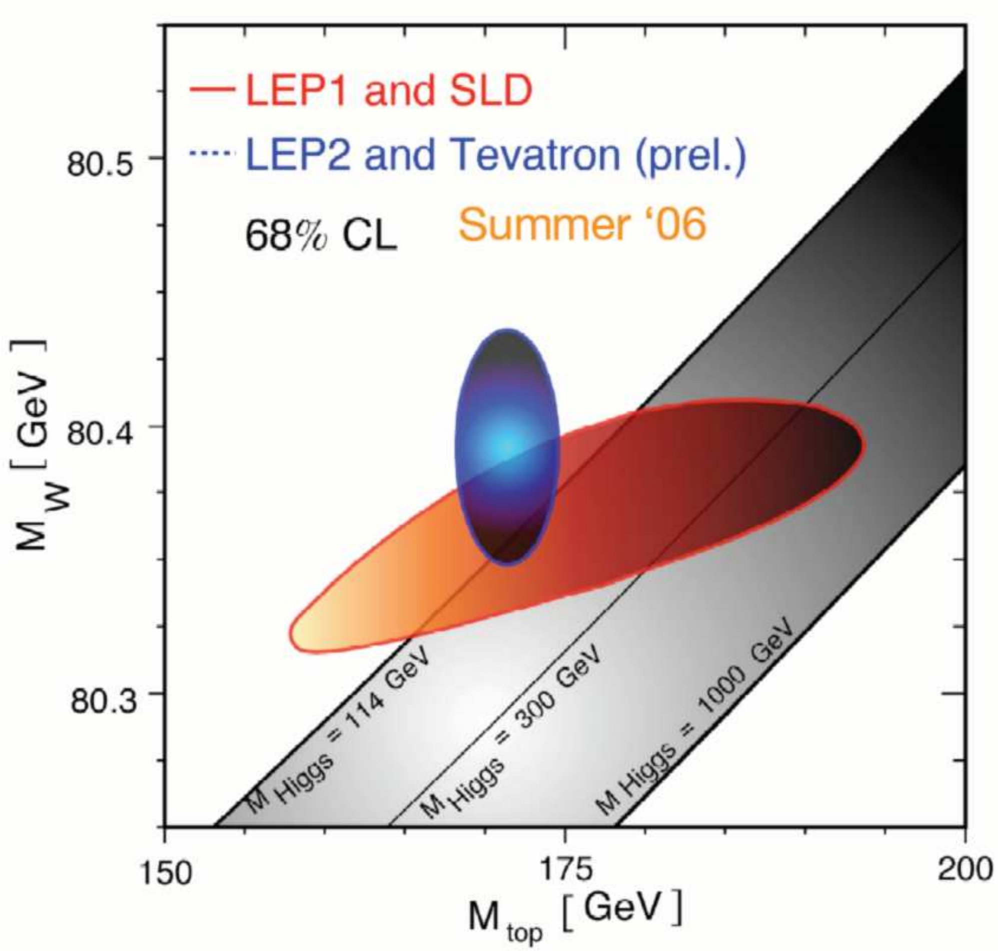
B_s mixing



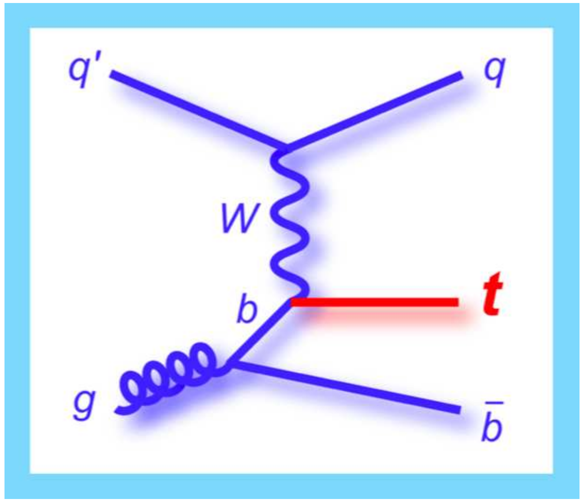


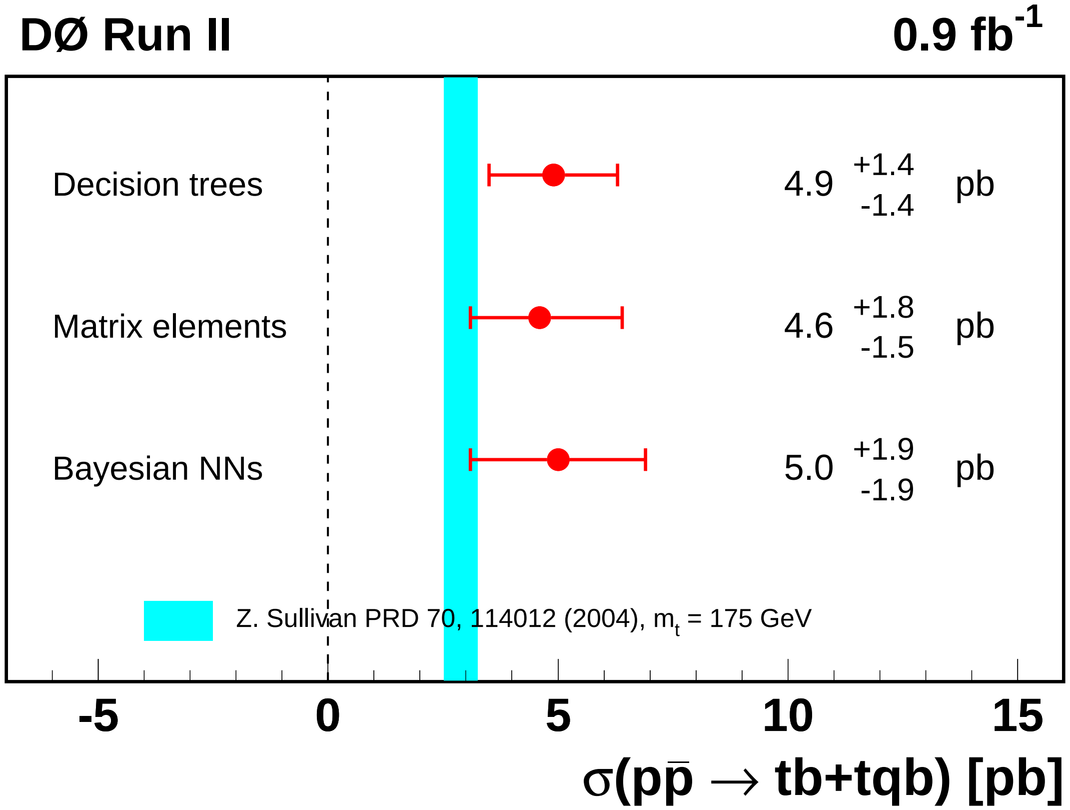
DØ experiment - top mass

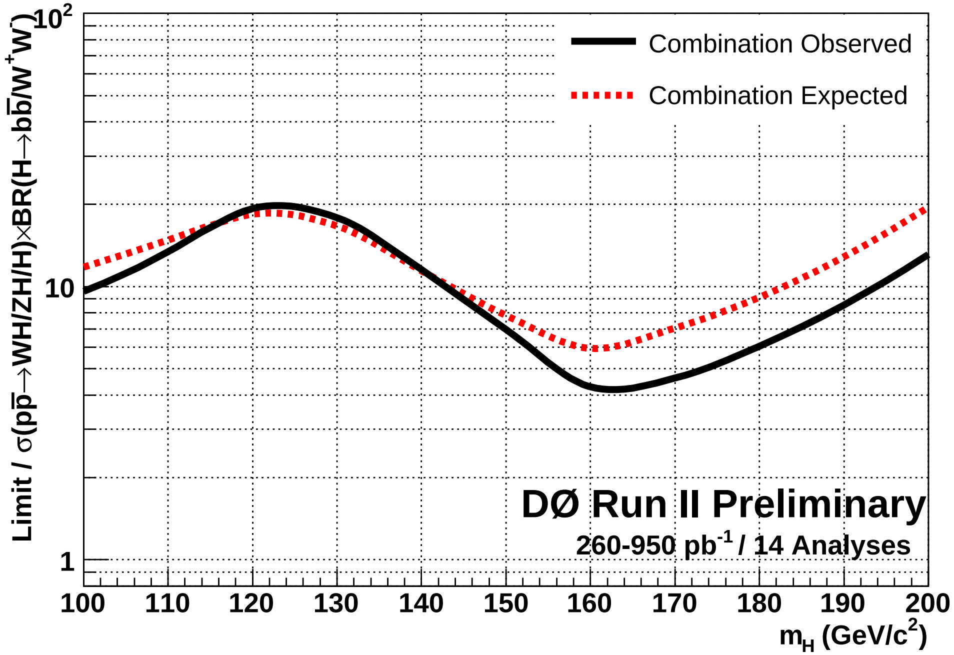




Single top and Higgs search







- first evidence of single top production
- Higgs is even more challenging

DØ Collaboration

- As of today we are:
  - ~ 670 physicists from 91 institutions
  - $\sim 50\%$ from non-US institutions

    (note strong European involvement)
  - ~ 100 post-docs, ~ 140 graduate students

Czech Group

- members of the DØ Collaboration since 1997
- lead by M. Lokajíček and V. Šimák (6 physicists, 5 graduate student, 4 computer specialists, and 1 technician)
- 8 of us qualified as DØ authors
- 2 PhD and 1 diploma theses
- Financed by grants from Ministry of Education and by Center for Particle Physics

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Our contributions in past

- Run II Upgrade
  - HV distribution boxes for muon detectors built here in Prague
  - calibration system for muon trigger (Light Mixing Boxes)
  - 1 year of silicon detector tests
  - contribution to the building of Forward Proton Detectors (Roman Pots)

- Software: code for accessing luminosity information and for normalization of the data

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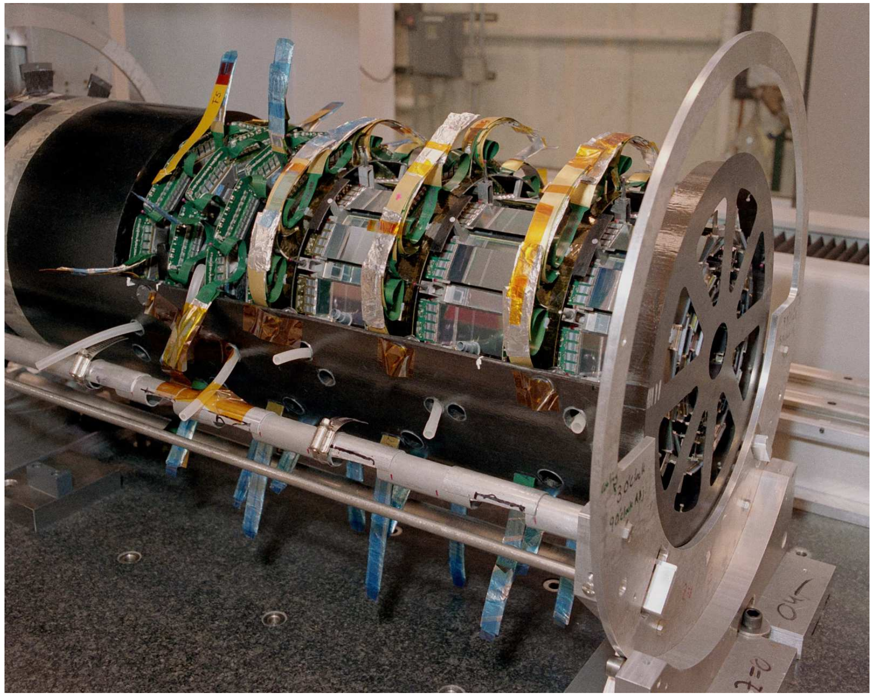

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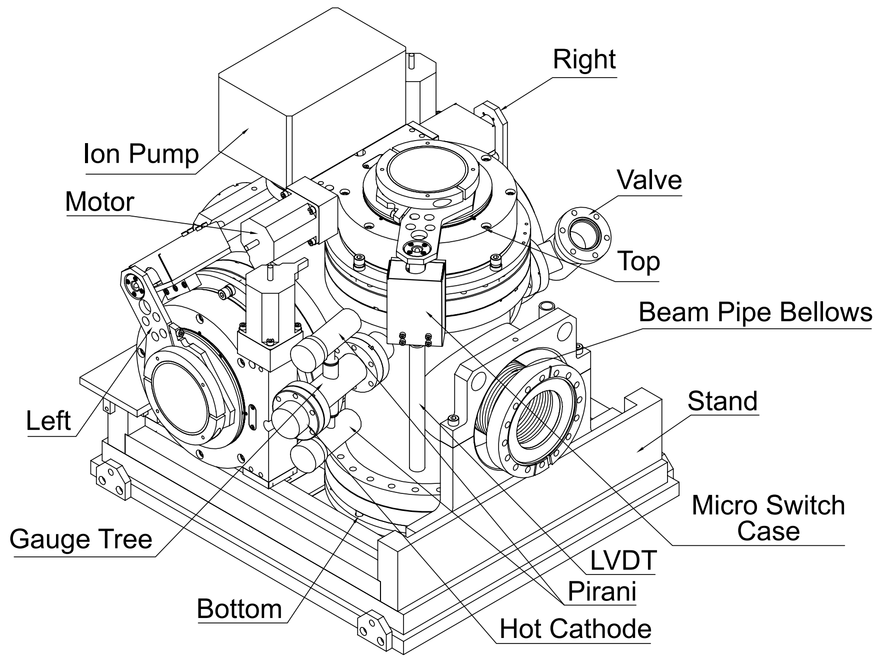

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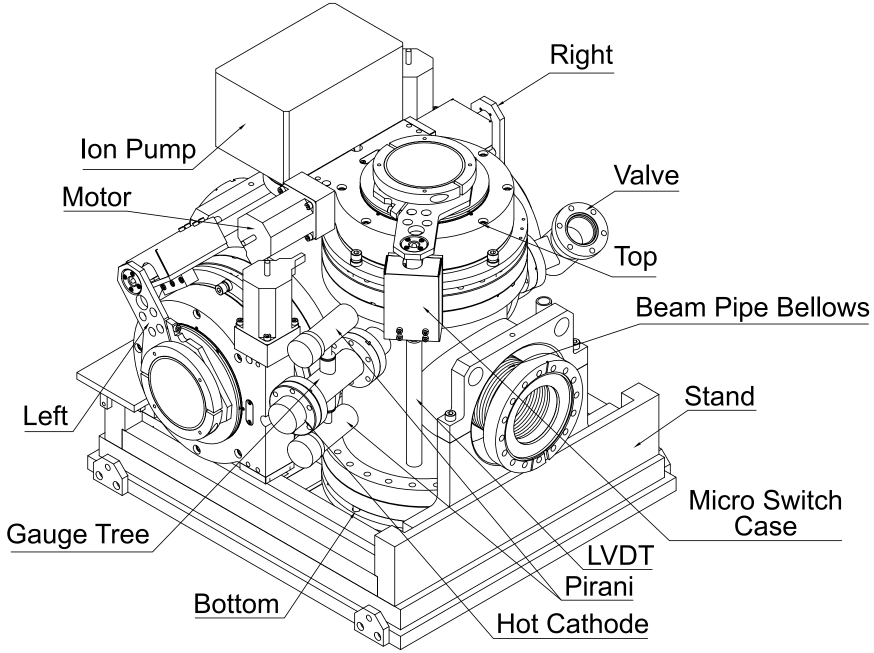
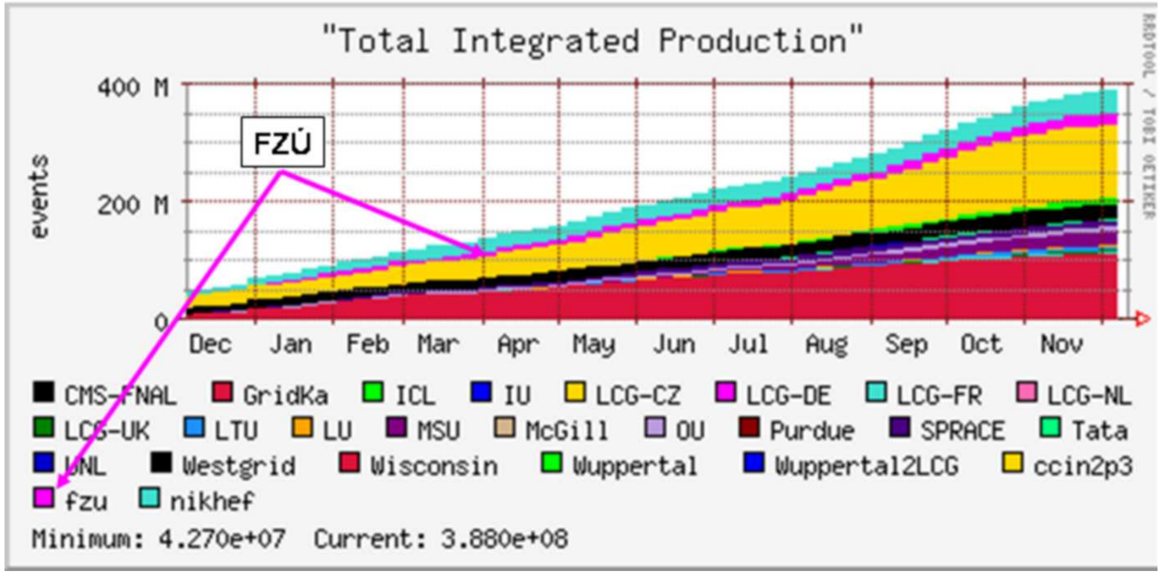


- Software: code for accessing luminosity information and for normalization of the data

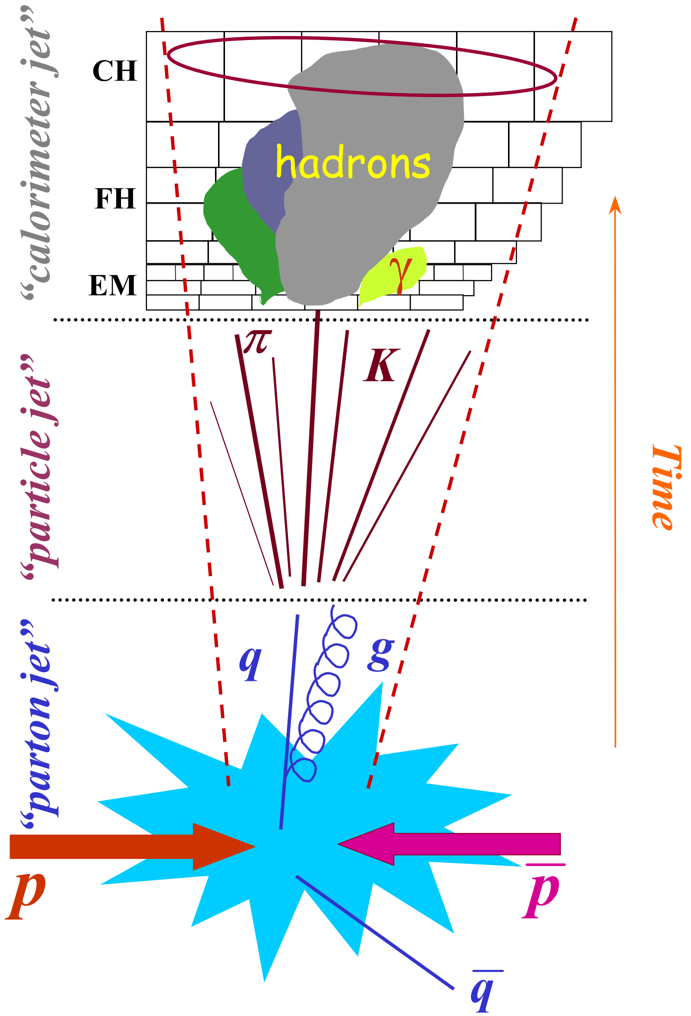
Computing

- distributed computing: reconstruction on-site, MC simulation off-site
- currently, 20 farms provide computing services for DØ
- DØ computer center in Prague since 1999 (In the beginning, we were using CESNET farms. Currently, we have our own farm built in Institute of Physics)
- we provide about 5% of total MC production (21M out of 400M events in 2006) which is usually the 4^{th} to 5^{th} largest contribution



- our annual financial contribution to DØ is paid with provided computer services

Jet energy calibration



Motivation: good jet energy calibration is crucial for precision measurements at hadron-hadron colliders where most of the final states involve jets

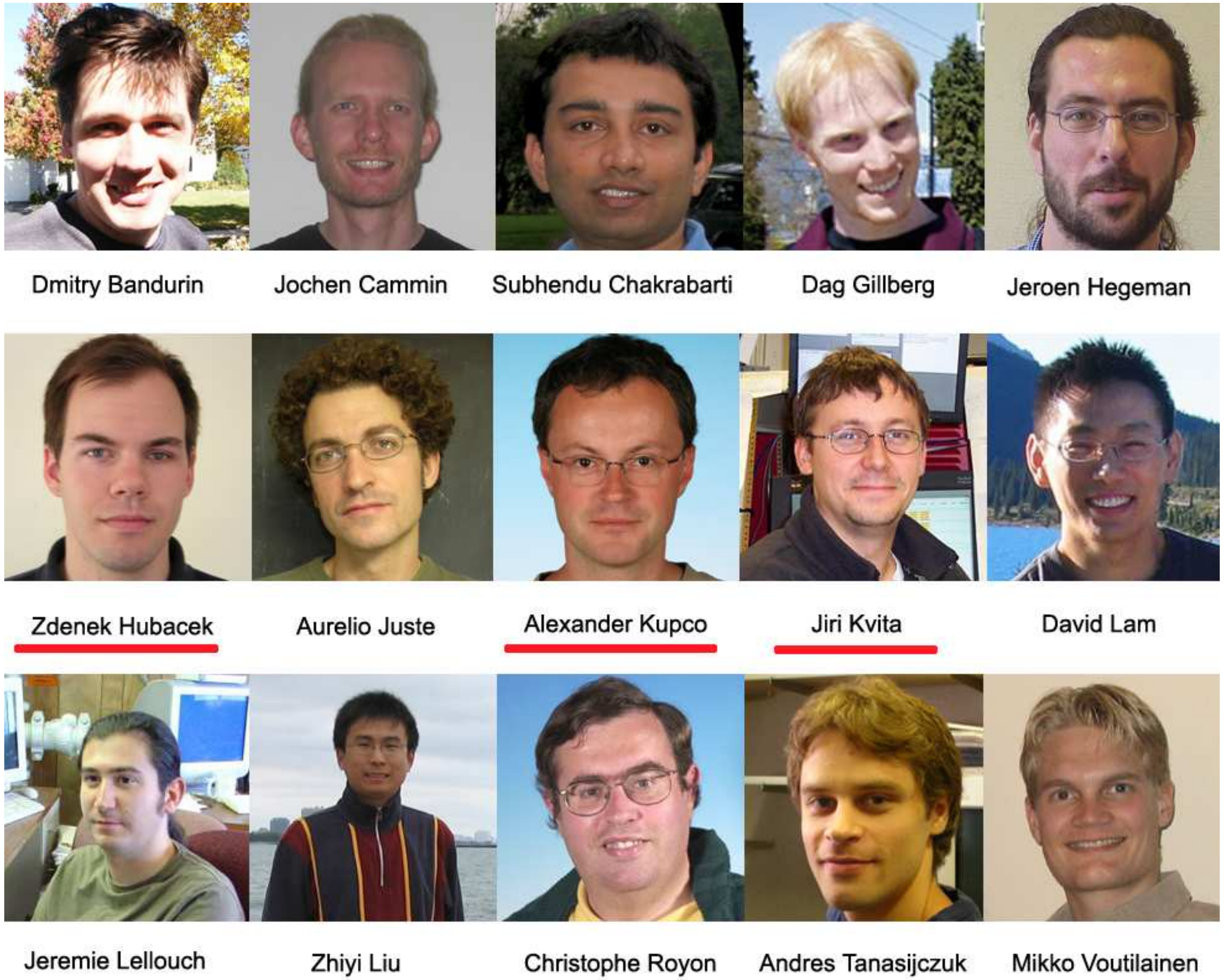
$$E_{ptcl}^{jet} = \frac{E_{det}^{jet} - \mathcal{O}}{R_{jet}\, S}$$

Offset $(\mathcal{O})$ - energy not associated with the hard interaction (U noise, pile-up from previous crossings, additional $p\bar{p}$ interactions)

Response (R_{jet}) - calorimeter response to jet

Showering (S) - losses due to showering the energy in the calorimeter out or into the jet cone

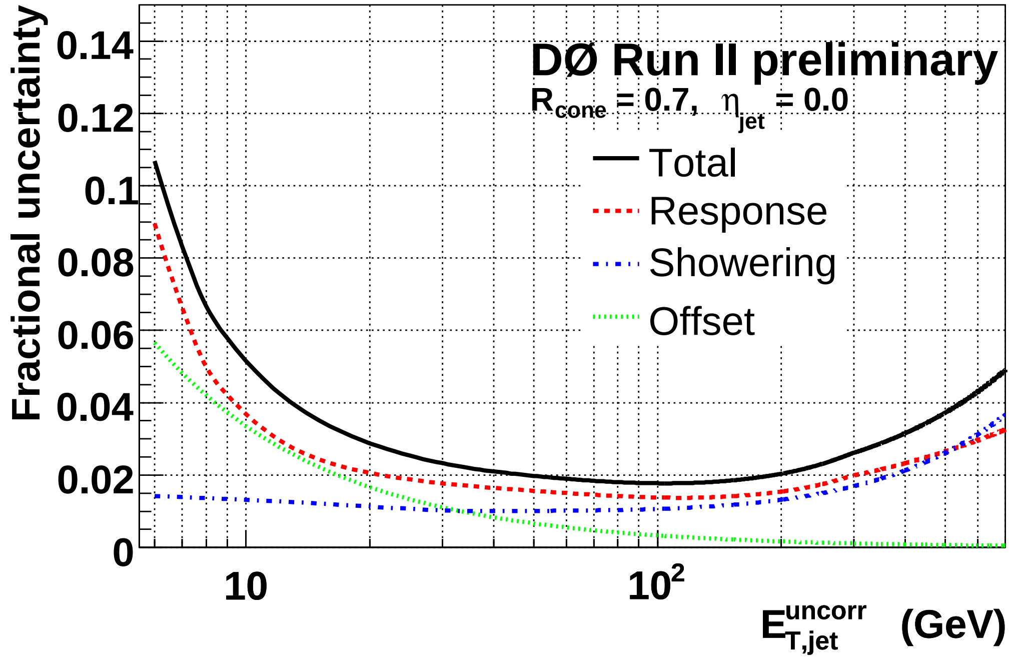
JES Group



- Our responsibilities
  - offset correction
  - determination of absolute scale using $\gamma + \text{jet}$ events
  - closure tests
- AK is convener of JES group since autumn 2006

JES Status

- DØ preliminary JES based on $100\,\mathrm{pb}^{-1}$ sample
- approved in the end of Feb 2006
- first JES version in Run II certified in large enough kinematic range ($|\eta| < 2.5$), and reaching uncertainties competitive with Run I



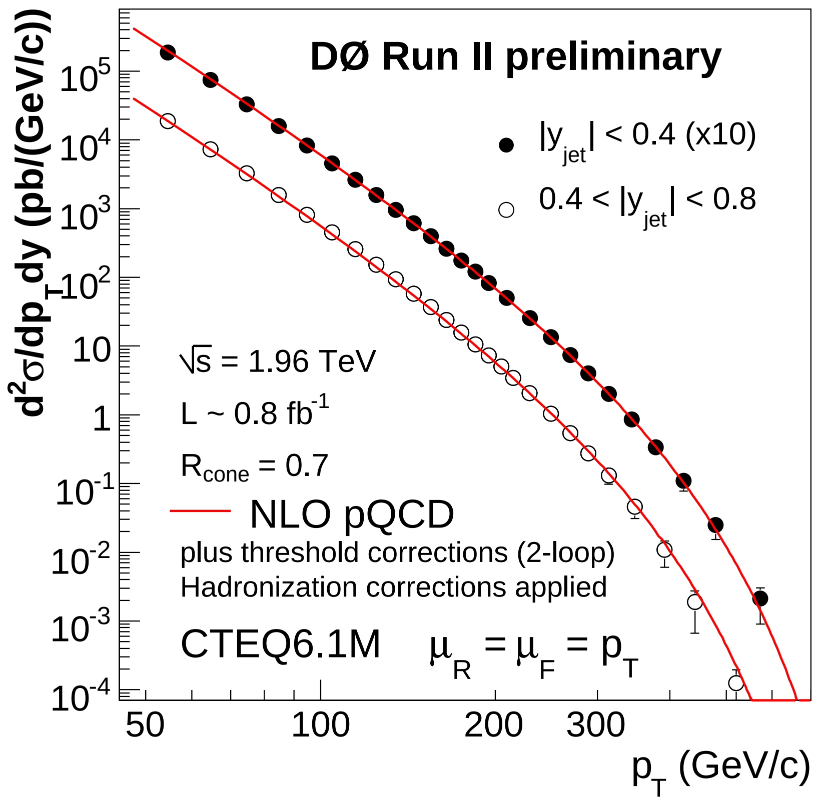
Final JES for Run IIa

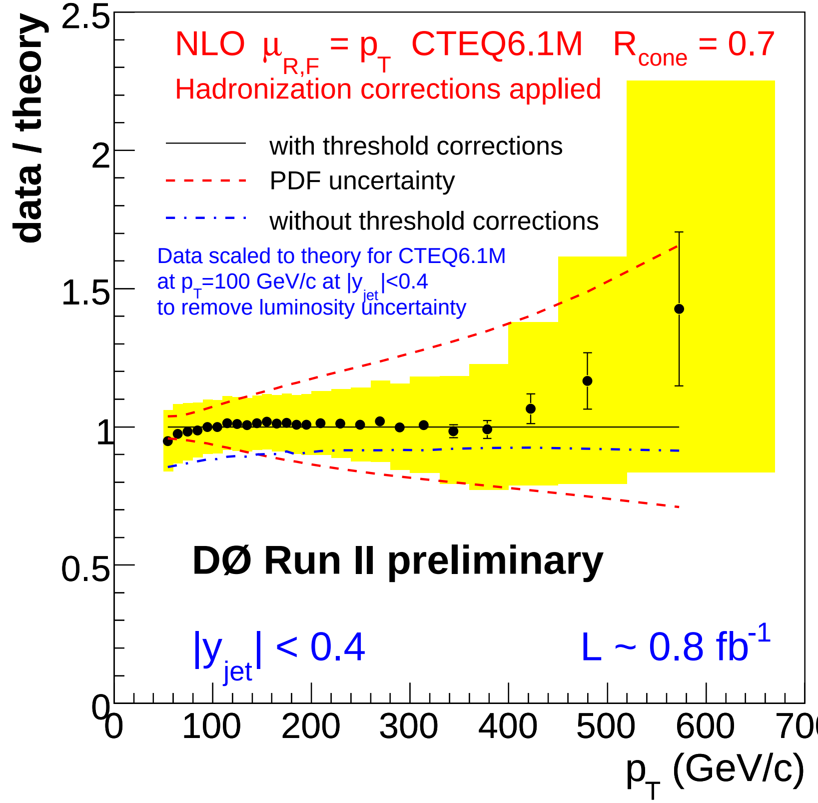
- will be based on full Run IIa sample of $\sim 1\,\mathrm{fb}^{-1}$

- goal: to improve our understanding of the jet energy calibration and to further reduce the uncertainties

Physics

- QCD
  - high p_T jets
  - multijet final states
  - diffraction
- Top physics
  - top mass in 6-jet channel
  - $t\bar{t}$ kinematic properties (p_T spectrum)

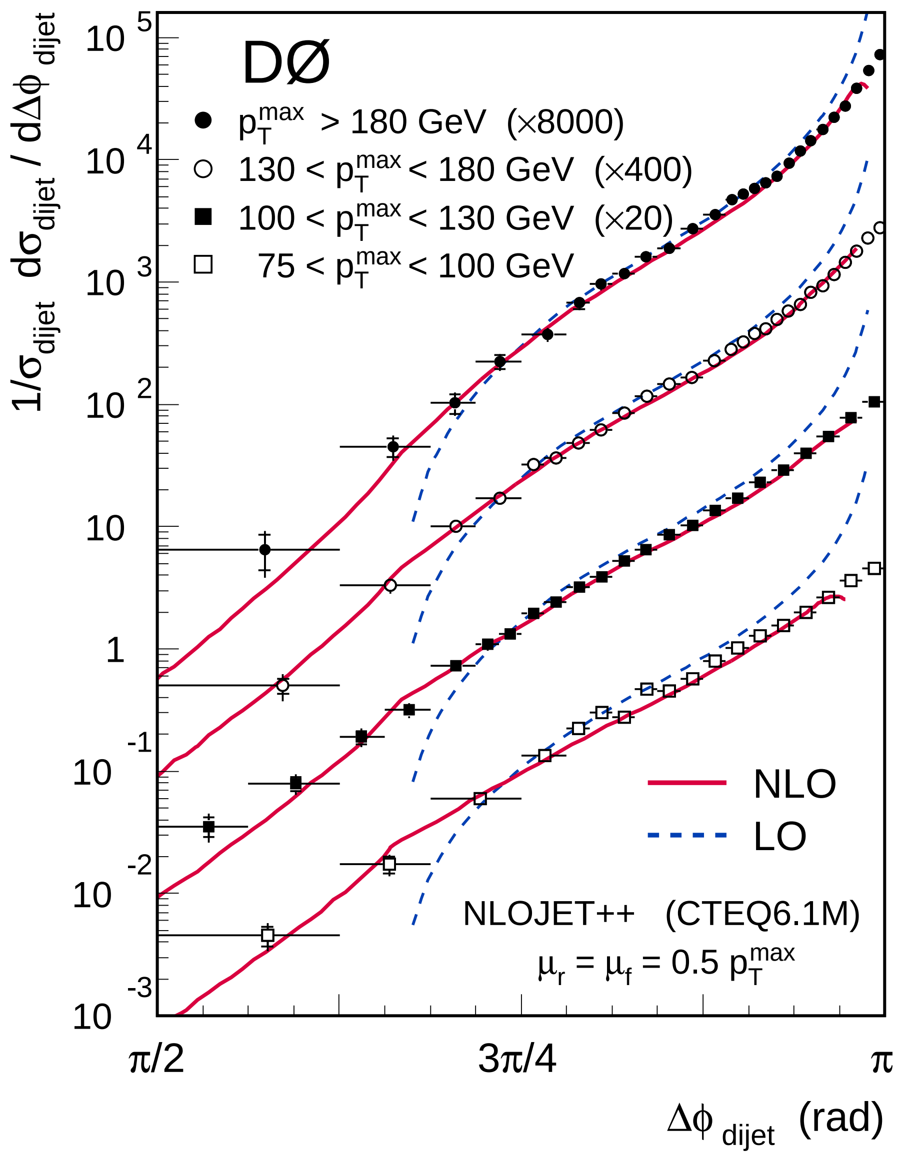


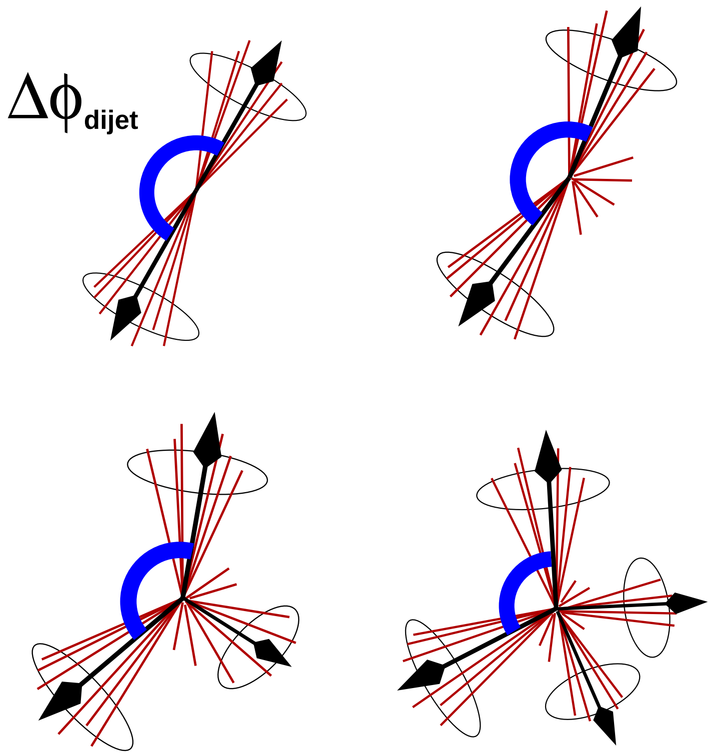


- lumi $8\times$ higher than in RunI $\Rightarrow$ reach in p_T increased from about 450 GeV up to 600 GeV
- good agreement with QCD predictions (no compositeness is seen)
- systematics (dominated by the JES uncertainty) is smaller than the PDF errors

$\Rightarrow$ we can learn about gluon structure functions in proton at large x

Dijet angular decorrelations

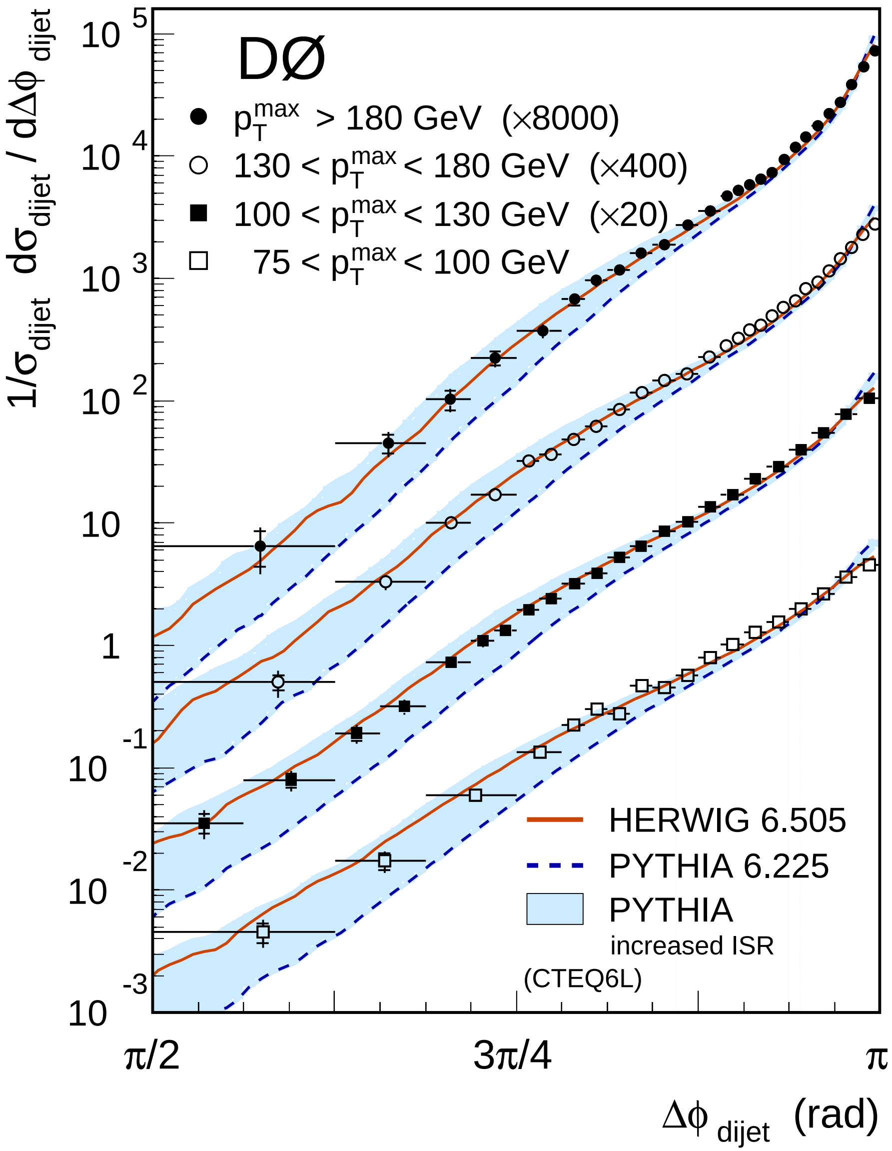




Phys.Rev.Lett.94:221801,2005

- $\Delta\Phi_{dijet}$ sensitive to the additional radiation in the event
- first Run II QCD paper
- first comparison with $2 \to 3$ NLO QCD calculation at Tevatron

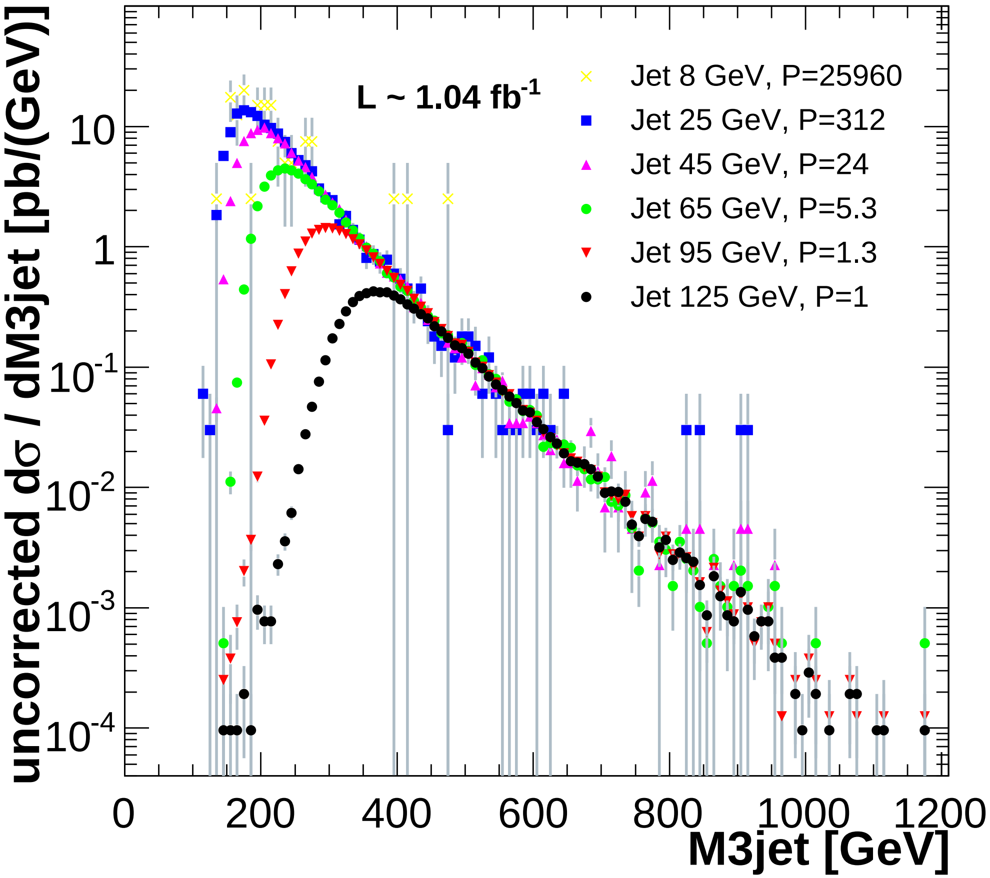
Dijet angular decorrelations



Phys.Rev.Lett.94:221801,2005

- data also provide tests of parton shower models in MC event generators
- CDF Run I tunes of Pythia could not disentangle perturbative effects (represented by parton shower models) from actual non-perturbative contribution from soft underlying event
- found value of `PARP(67)=2.5` used in new Pythia tune (DWT) which is used also at LHC

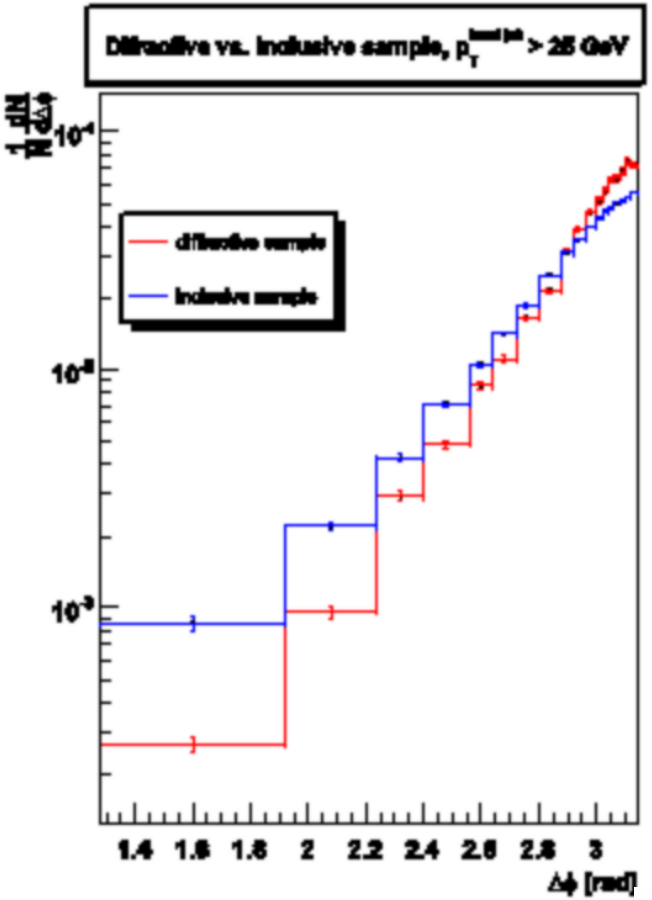
Three-jet final states



- subject of one PhD thesis
- complete description of three jet final state by measuring all 3-jet observables (M_{3jet}, jet energy fractions in CMS, angular distributions)
- tests of 3-jet NLO QCD predictions (NLOJET++)
- studies of gluon jet properties (3^{rd} leading jet is mostly a gluon one)

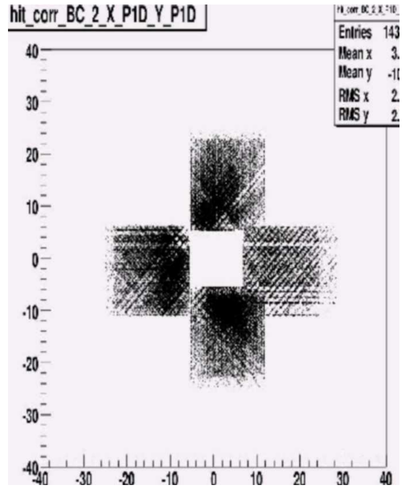
- improved experimental knowledge about multi-jet final states which are background for various measurements and searches of new physics (top mass, Higgs, $\cdots$)

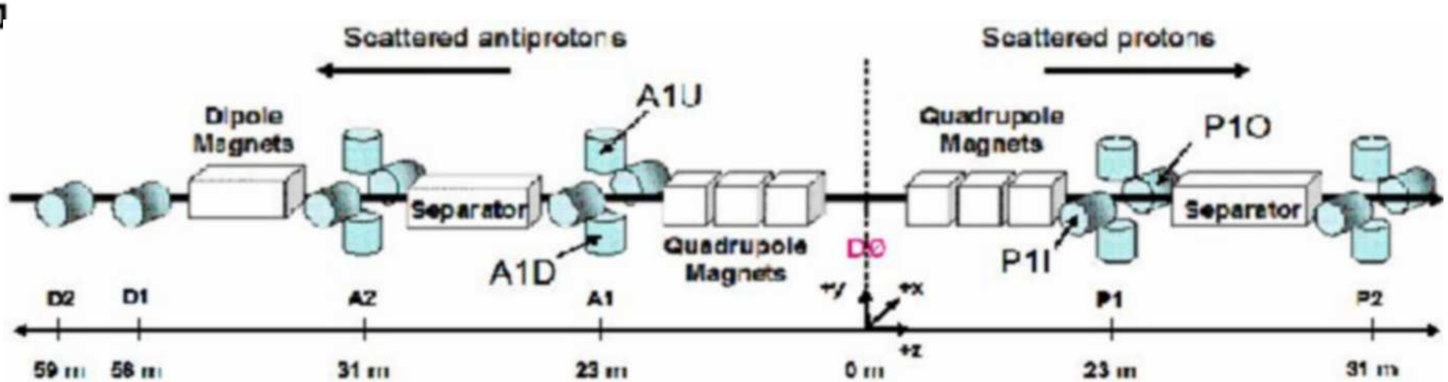
Diffractive physics



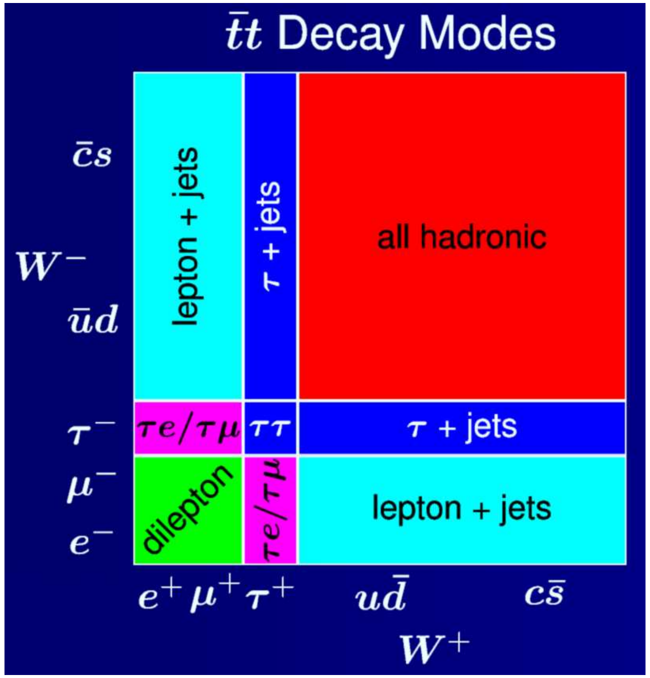
- Diffractive dijets
  - diffractive dijets more correlated in ϕ
  - due to different nature of pomeron induced ISR
  - thesis finished and will be defended soon
- Elastic slope dN/dt
  - dedicated low lumi runs
  - pots can be moved very close to the beam

$\Rightarrow$ access to small values of t





Top mass in 6-jet channel



- Advantages: statistics, full reconstruction of event (no neutrinos)
- Disadvantages: no lepton (trigger + significant QCD background), combinatorial ambiguity
- Run I thesis ($m_t = 179 \pm 14_{(stat)} \pm 8_{(sys)}$ GeV)
- Run II: vertex b-tagging $\Rightarrow$ improved event selection and reduced combinatorial background
- increased luminosity $\Rightarrow$ difficult triggering

(kinematic peak of m_{3jet} near the top mass)

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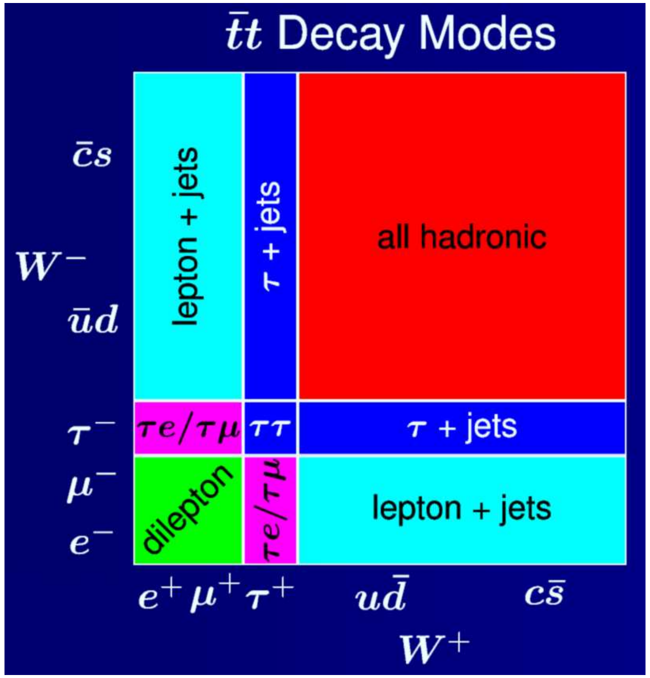

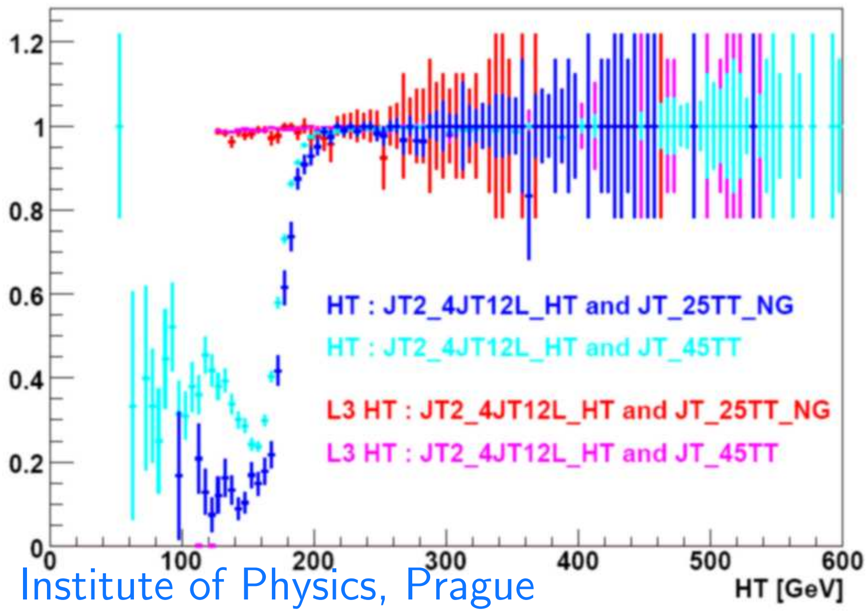

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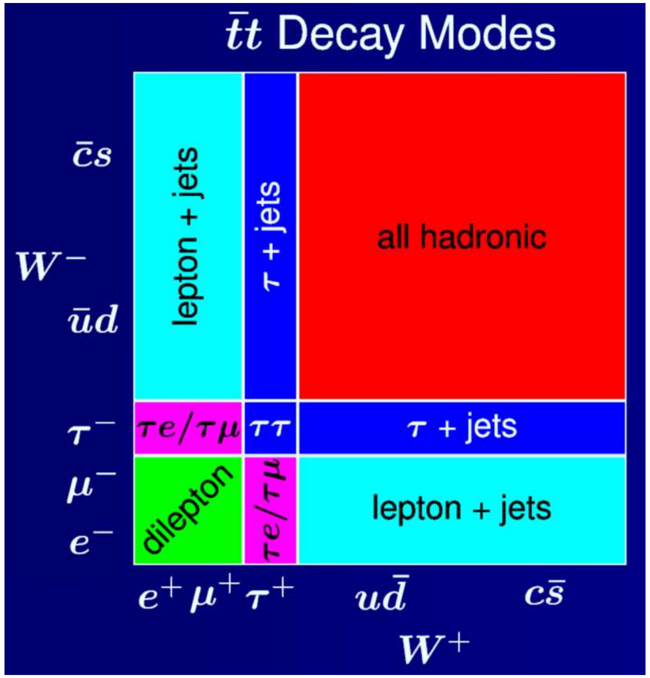

- large instantaneous luminosity $\rightarrow$ several $p\bar{p}$ interactions per bunch X-ing
  - design of algorithms for jet vertex finding to confirm that all 6-jets are coming from the same $p\bar{p}$ interaction
- Top properties
  - measurement of kinematic properties of $t\bar{t}$ pairs in $l +$ jets channel