

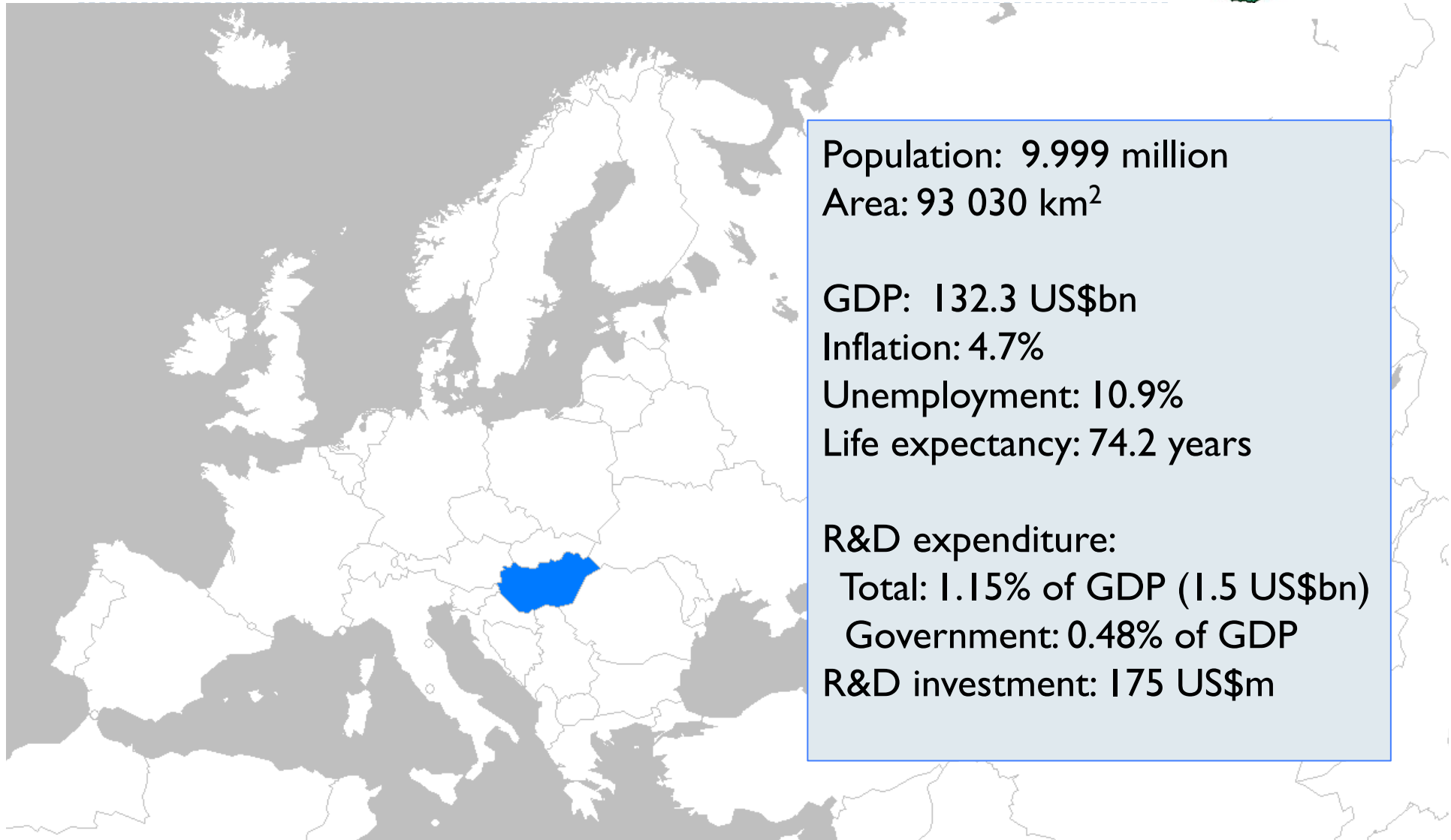
The background of the slide is the Hungarian flag, which consists of three horizontal stripes of red, white, and green. The red stripe is at the top, the white stripe is in the middle, and the green stripe is at the bottom.

Midterm report: Hungary

Gabriella Pásztor

Plenary ECFA, 26 November 2010

Hungary in numbers



Population: 9.999 million

Area: 93 030 km²

GDP: 132.3 US\$bn

Inflation: 4.7%

Unemployment: 10.9%

Life expectancy: 74.2 years

R&D expenditure:

Total: 1.15% of GDP (1.5 US\$bn)

Government: 0.48% of GDP

R&D investment: 175 US\$m



Higher education

- ▶ **Institutes:** 69
- ▶ **Teaching personnel:** 21934
- ▶ **Students** full-time (total): 242701 (370331)
- ▶ **BSc+MSc** full-time (total): 222564 (328075)
 - ▶ Women: 116981 (52.6%)
 - ▶ Foreigner: 14290 (6.4%)
 - ▶ 1st year: 61948 (27.8%)

- ▶ **Workforce** (women): 3781900 (1737000 ~ 45.9%)
- ▶ With higher education degree (woman): 908500 (493500)
 - ▶ 24.0% (28.4%)
- ▶ With university degree (woman): 358900 (158500)
 - ▶ 9.5% (9.1%)



University education

Complies with Bologna Treaty

Typically 3 years BSc, +2 years MSc, +3 years PhD

- ▶ 26 universities
- ▶ 12 offering science or engineering degrees
- ▶ 5 offering physics degrees
- ▶ 2 offering particle physics specialization
 - ▶ ELTE - Eötvös University, Budapest
 - ▶ University of Debrecen, Debrecen
- ▶ Registration and tuition fees but most students are “state-funded” and also scholarships are available both from the government and from industry



Particle Physics Funding

- ▶ **Foreign Ministry**
 - ▶ CERN membership
- ▶ **National Office for Research and Technology (NKTH), Research and Technology Innovation Fund**
 - ▶ M&O for main CERN experiments (CMS+ALICE ~85kCHF)
 - ▶ Mobility grants for international collaborations (~400kCHF in 2009)
- ▶ **Hungarian Scientific Research Fund (OTKA)**
 - ▶ Competitive research funding (2- to 4-year projects)
Annual budget ~30 MCHF (2008)
HEP funding ~100MHUF ~ 0.54MCHF (2009)
 - ▶ Some M&O contributions (eg. TOTEM ~18kCHF) are also paid from these grants
- ▶ **Hungarian Academy of Sciences**
 - ▶ GRID funding ~55kCHF/year
- ▶ **Scientific and Technology Foundation (TÉT)**
 - ▶ Grants for international exchange and collaboration such as Japan-Hungary for Asacusa and GRID (40 kCHF in 2010)
- ▶ **EU FP6, FP7** (eg. EGEE-1,-2,-3)
- ▶ **Research Institutes** (per FTE: 2*4 MHUF~2*22kCHF for salary, operational costs...)

Particle Physics in Hungary



ELTE
RMKI
BME

Uni Debrecen
ATOMKI

HUGHEP - Hungarian High Energy Physics Group



- ▶ Consortium to be founded by RMKI, Budapest and ATOMKI, Debrecen
- ▶ Eötvös University, Budapest and Debrecen University, Debrecen to join
- ▶ Initiated by the Particle Physics Committee of the Hungarian Academy of Sciences
- ▶ To coordinate participation in CERN and other particle physics research projects
- ▶ Under negotiations



Research projects in HEP

- ▶ **Accelerator based**
- ▶ **CERN:**
 - ▶ LHC: CMS, ALICE, TOTEM, [ATLAS]
 - ▶ (LEP: L3, OPAL, [DELPHI])
 - ▶ SPS: NA61/SHINE (NA49)
 - ▶ AD: ASACUSA
- ▶ **RHIC:**
 - ▶ PHENIX, [PHOBOS]
- ▶ **GSI:**
 - ▶ FOPI, CBM@FAIR
- ▶ **Detector R&D**
- ▶ **CERN: RD51**
- ▶ **Non-accelerator based**
- ▶ **Neutrinos:**
 - ▶ [Borexino]
- ▶ **Gravitational waves:**
 - ▶ LIGO, VIRGO
- ▶ **Theory, phenomenology**
 - ▶ EW symmetry breaking
 - ▶ QCD, lattice QCD
 - ▶ Finite-temperature quantum field theory
 - ▶ Heavy ion physics
 - ▶ Astroparticle physics
 - ▶ AdS/CFT, gauge/gravity duality
 - ▶ Non-perturbative field theory
 - ▶ Quantum gravity



Research projects per institute

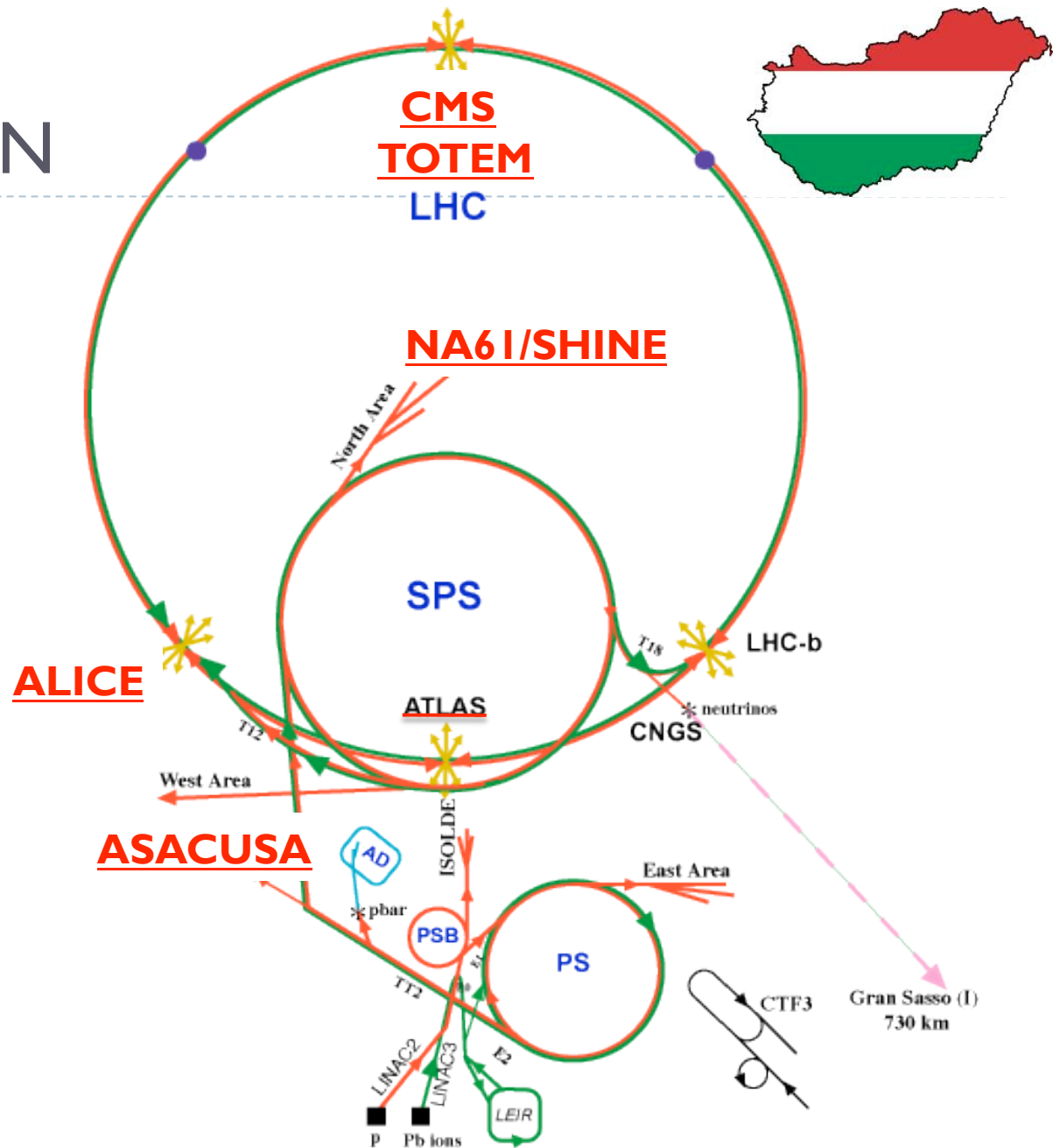
Budapest

- ▶ **RMKI** (Research Institute for Particle and Nuclear Physics of the Hungarian Academy of Sciences)
 - ▶ Involved in all experimental activities
 - ▶ Detector R&D
 - ▶ Theory, phenomenology
- ▶ **ELTE** (Eötvös Loránd University)
 - ▶ (CMS)
 - ▶ PHENIX
 - ▶ (PHOBOS)
 - ▶ RD5I
 - ▶ Theory, phenomenology
- ▶ **BME** (Budapest University of Technology and Economy)
 - ▶ Theory

Debrecen

- ▶ **ATOMKI** (Institute of Nuclear Research)
 - ▶ CMS
 - ▶ Detector R&D
- ▶ **University of Debrecen**
 - ▶ CMS
 - ▶ PHENIX
 - ▶ Detector R&D
 - ▶ QCD, field theory

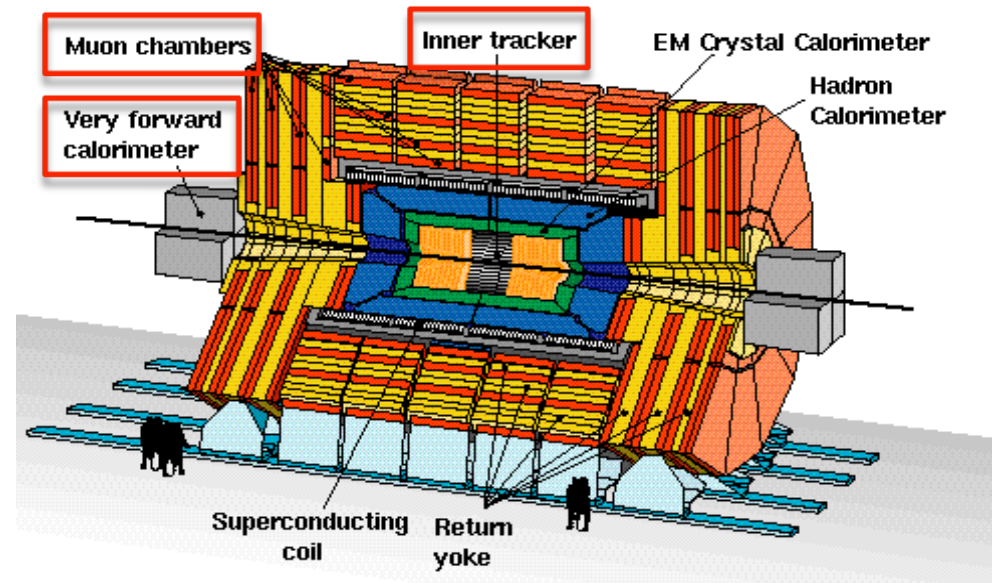
Hungary in CERN



CMS (RMKI, ELTE, ATOMKI, Uni Debrecen)



- ▶ Design, installation and operation of the Muon Barrel Position Monitoring System
- ▶ Construction of the Very Forward Calorimeter
- ▶ Pixel Detector timing and efficiency measurement
- ▶ Fiber optical sensors
- ▶ Responsible for DCS Safety tours
- ▶ Online Data Quality Monitoring
- ▶ CMS Tier-2 GRID site
- ▶ Experimental test of QCD (eg. 1st measurement of the charged hadron spectra at LHC)
- ▶ Heavy Ion physics
- ▶ Search for supersymmetric phenomena, extra dimensions, black holes and anomalous triple gauge couplings



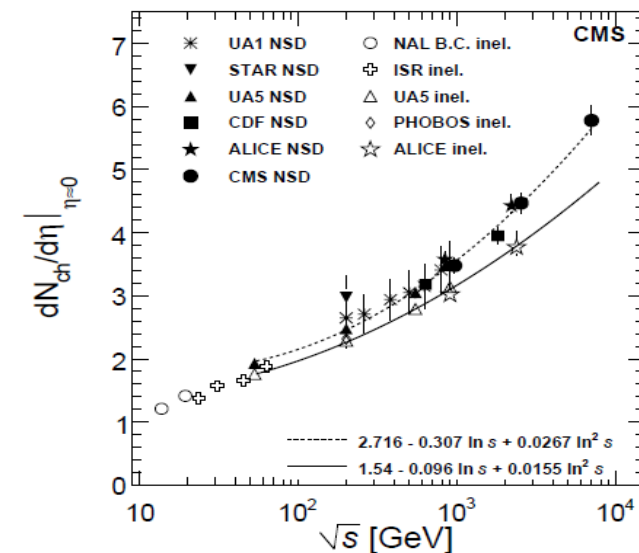
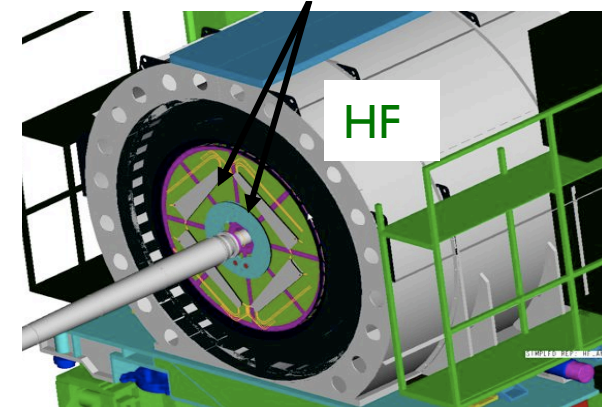
Largest Hungarian experimental team:
~40 participants

CMS: QCD and Heavy Ions (RMKI, ELTE)



- ▶ Leading role in the analysis and publication of first CMS papers (including the first published momentum distributions at LHC):
 - ▶ Establishing the minimum bias scintillator trigger for p-p collisions,
 - ▶ Development of charged particle tracking down to very low momentum,
 - ▶ Measurement of particle yields using pixel cluster counting,
 - ▶ Measurement of particle yields using full tracking,
 - ▶ Preparing the manuscripts for publication.
- ▶ Group members are the conveners of the QCD and Heavy Ions physics analysis groups
- ▶ The group is now active with the analysis of first Pb-Pb data

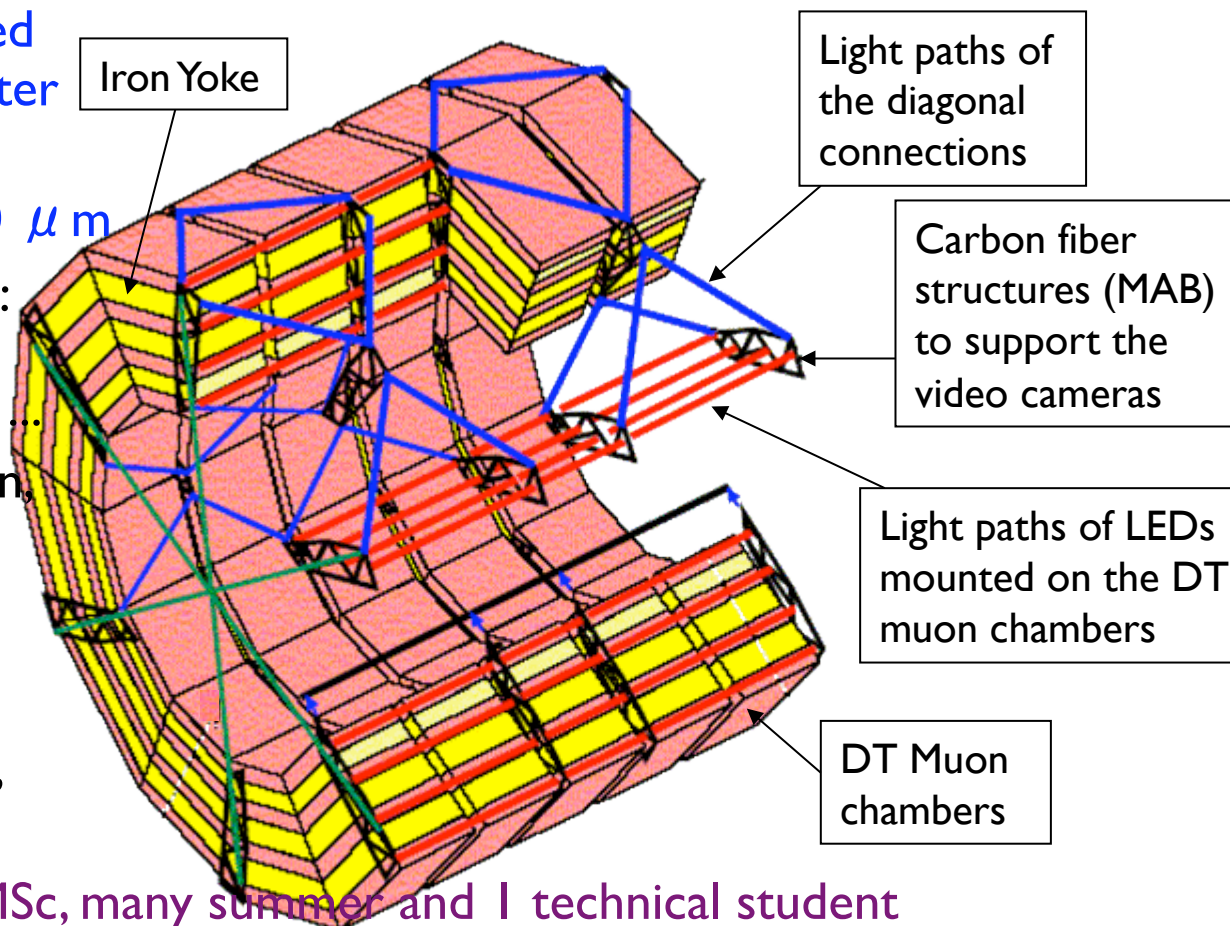
Beam Scintillator Counters



CMS: Muon Barrel Alignment System (ATOMKI, Uni Debrecen, RMKI)



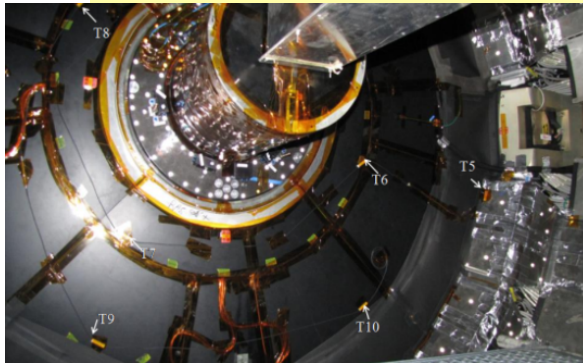
- ▶ 20 physicists, engineers, technicians worked on the project for 10+ years
- ▶ 9000 LEDs mounted on 250 DT chambers, observed by 600 video cameras
- ▶ Measurement performed by a distributed computer network of 36+1 PCs
- ▶ Required precision: 400 μm
- ▶ Hungarian contribution: 100k CHF (8%) + 60k CHF for lab, travel, ...
- ▶ Feasibility studies, design, production of electronic modules, calibration, installation, software development, data analysis, operation, maintenance
- ▶ As a result: 1 PhD, 11 MSc, many summer and 1 technical student



CMS Fiber Optical sensors (ATOMKI)

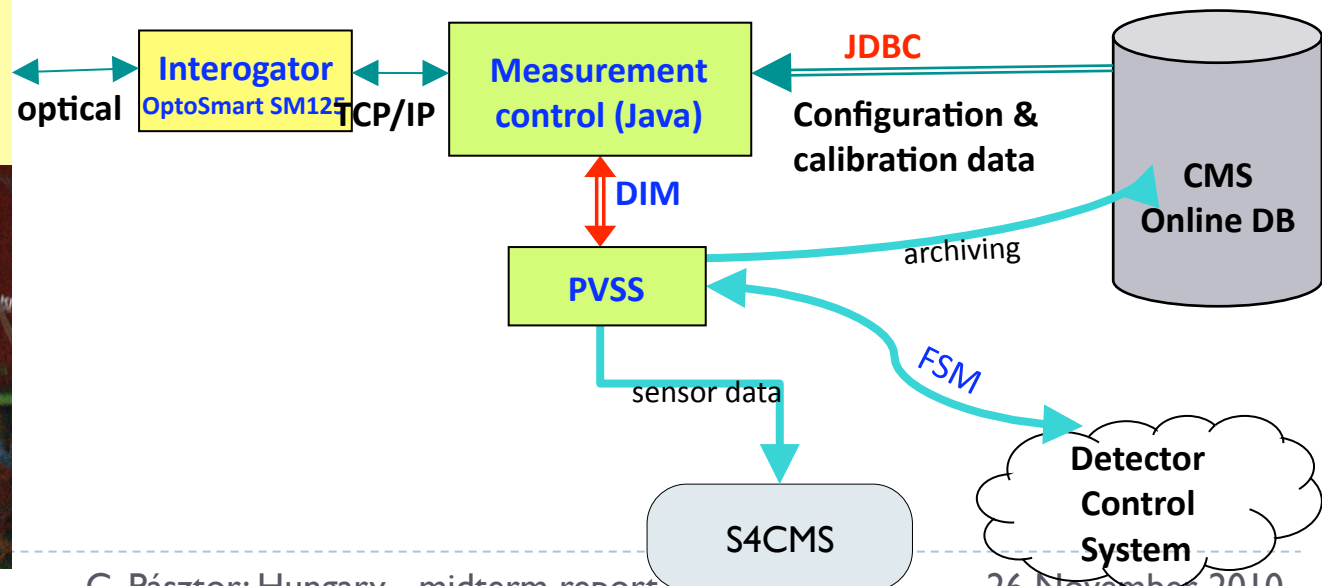
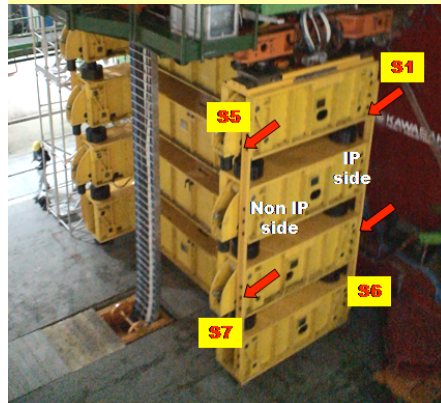


Tracker Bulkhead with temperature sensors



- ▶ Fiber Brag Grating sensors sensitive for strain or temperature change are mounted on the tracker bulkhead, the HF and the Castor platforms
- ▶ ATOMKI (1 postdoc, 1 PhD, 1 MSc student) joined in 2009 the Italian groups to work on data collection, data analysis and integration into DCS
- ▶ Sensors work reliably and now integrated into DCS

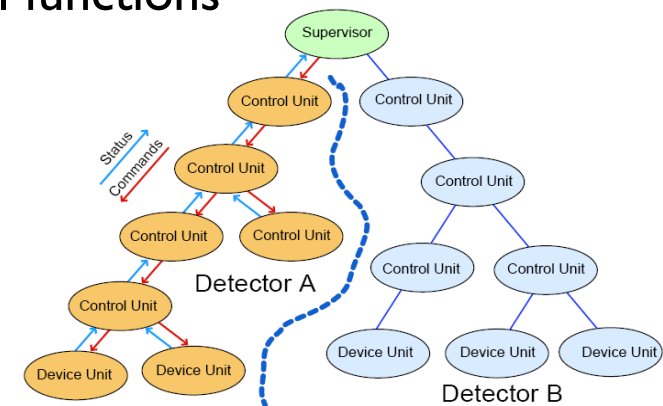
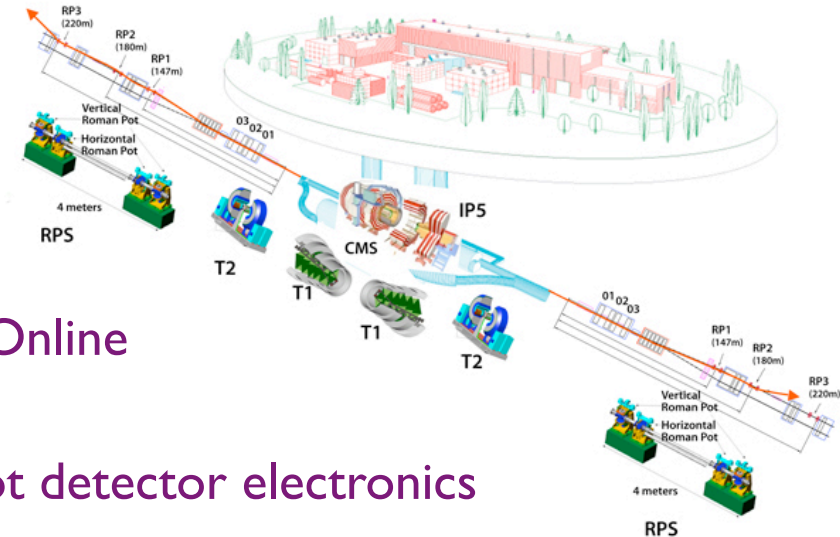
HF platform with temperature and strain sensors



TOTEM (RMKI, ELTE)



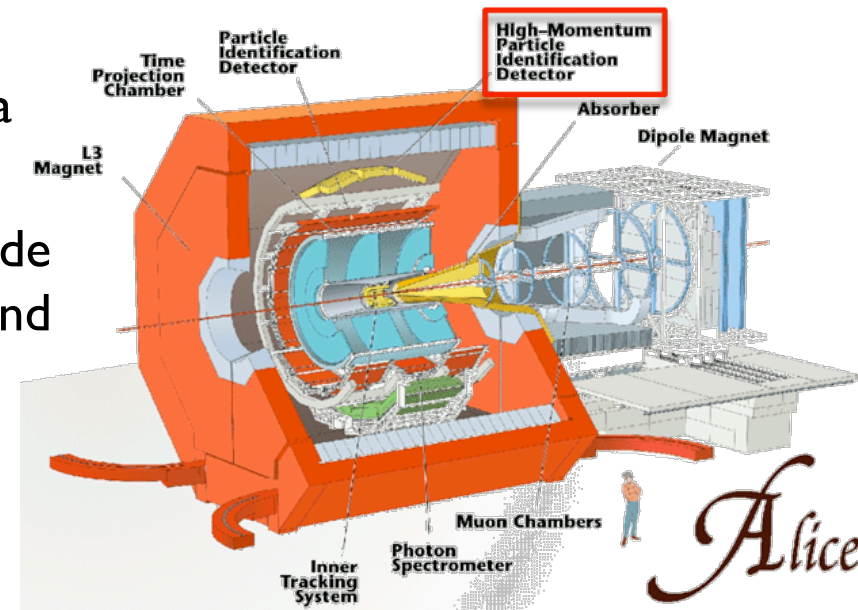
- ▶ Development of the **D**etector **C**ontrol **S**ystem
- ▶ Development of the **D**ata **A**c**Q**uisition system
- ▶ Development and maintenance of the **O**nline and **O**ffline **M**onitoring systems
- ▶ Financial contribution to the Roman Pot detector electronics
- ▶ Software development and edge efficiency studies for Roman Pot detectors
- ▶ Survey of the magnet system to verify the optical functions
- ▶ Development of the analysis framework
- ▶ **M**easurement of diffractive processes
- ▶ **S**tudy of scattering models



ALICE (RMKI, ELTE)



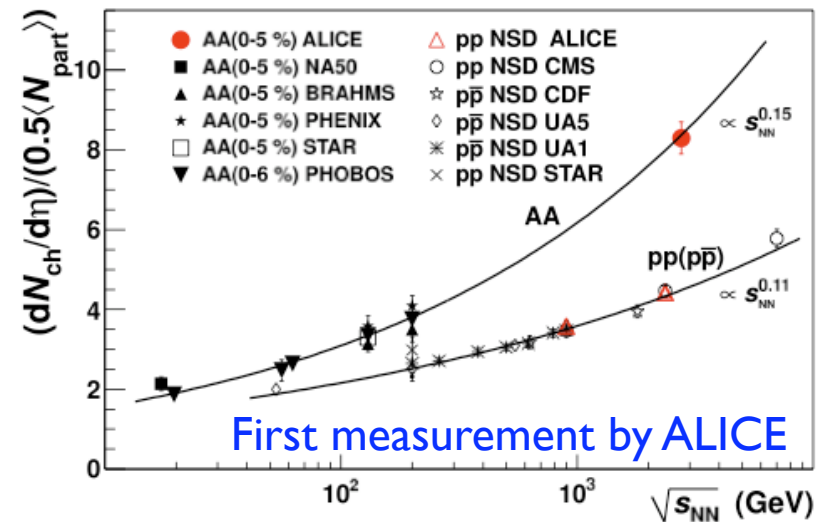
- ▶ High Momentum Particle Identification detector: commissioning, running, QA, data analysis, run coordination
- ▶ Very High Momentum PID detector upgrade R&D: feasibility studies, detector (trigger and mirror) and physics simulations, DAQ specifications, technical coordination
- ▶ Trigger R&D for VHMPID: design and prototype construction
- ▶ Detector Data Link network card and new (PCI Express standard) version of Read-Out Receiver Card developed by RMKI
- ▶ DAQ general support for ~500 DDL cards and R&D for DAQ improvements
- ▶ RMKI ALICE GRID (~1% with 100+ CPU, 30 TB HD)
- ▶ Local cluster to support data analysis and theoretical studies
- ▶ pp and PbPb physics, model building, theoretical studies



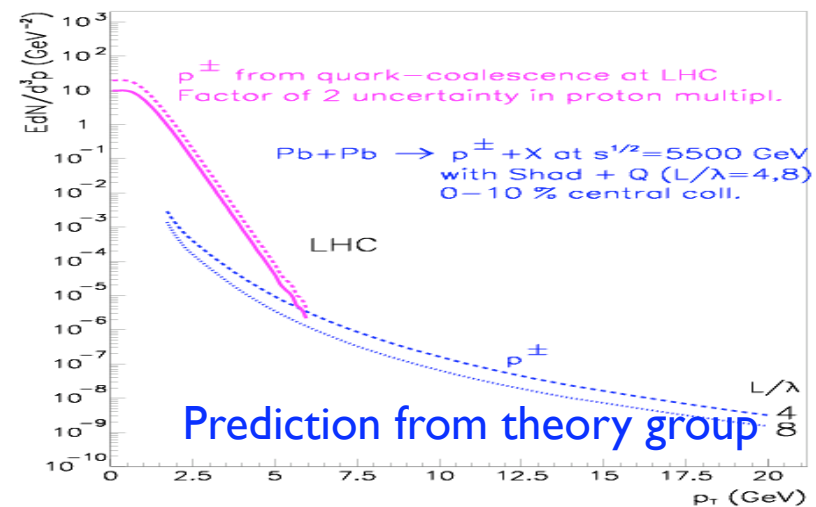
ALICE: physics interests

- ▶ High p_T physics
- ▶ Jet physics
- ▶ Underlying event
- ▶ Identified hadron spectrum and correlations
- ▶ Perturbative QCD
- ▶ Non-perturbative particle production mechanisms
- ▶ Collective behaviours
- ▶ Thermodynamics of strongly interacting plasmas
- ▶ Physics simulation for VHMPID

Large group of 12 researchers,
5 PhD and 6 MSc students

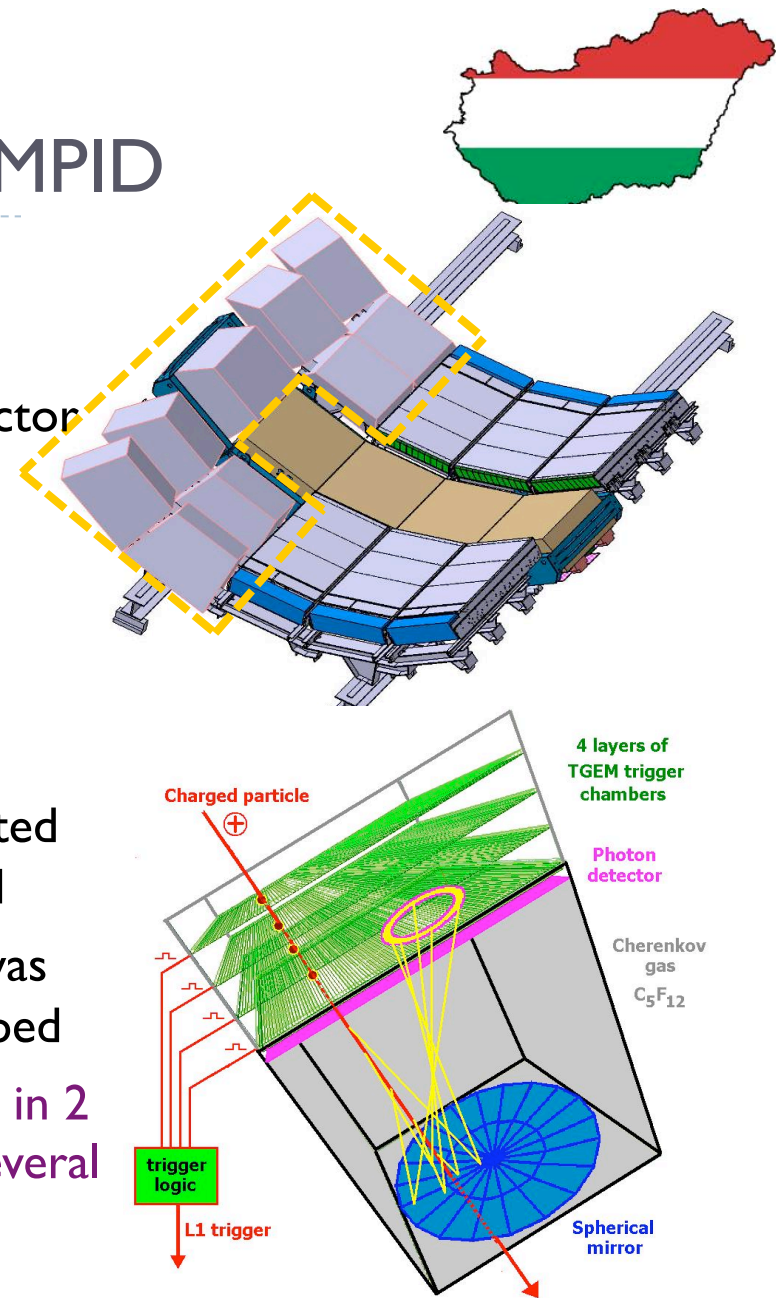


PQCD + Quark Coalescence at LHC for proton



High P_T Trigger Detector: Trigger detector for ALICE VHMPID

- ▶ Cherenkov-detector proposed for Very High Momentum PID in the 5-30 GeV range
- ▶ Hungarian contribution: High P_T Trigger Detector
- ▶ Fast rough tracking trigger to increase the statistics by 40
- ▶ Thick Gas Electron Multiplier and Multi Wire Proportional Chamber options investigated, new Close Cathod Chamber is used
- ▶ Small scale test version built at RMKI and tested in 2009 and 2010 by 7 GeV protons at CERN
- ▶ Based on this experience, the test detector was rebuilt and a new readout electronics developed
- ▶ Decisive contribution from students resulting in 2 BSc theses in 2010 (with 2 PhD, 3 MSc and several BSc students participating at the moment)

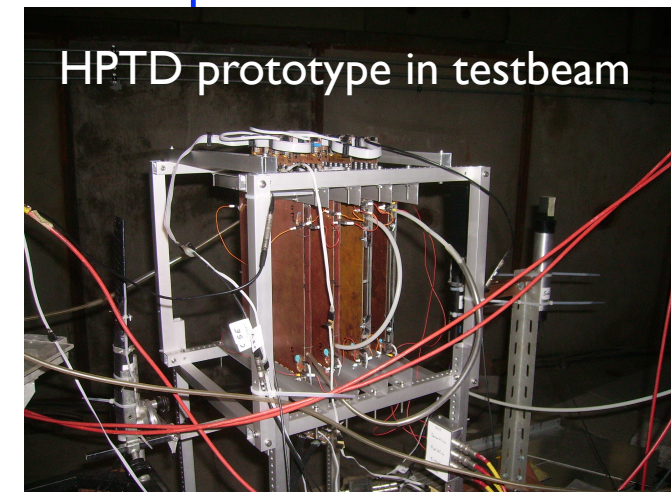


CERN RD51 and REGaRD:

RMKI-ELTE Gaseous Detector R&D project



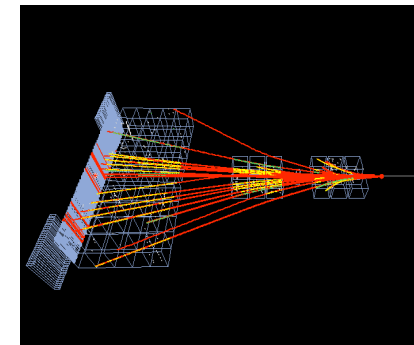
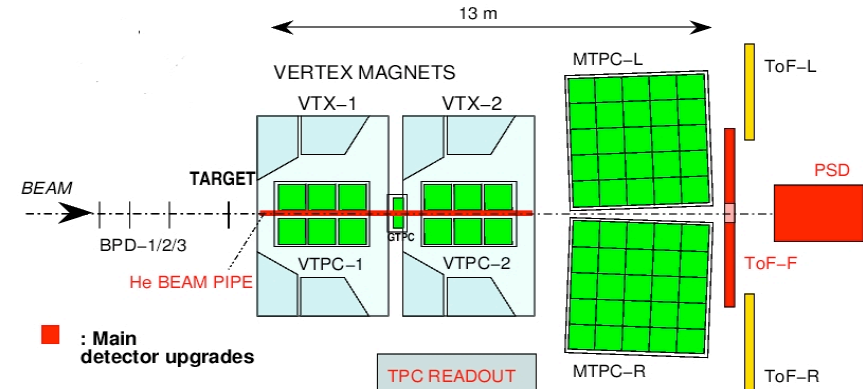
- ▶ Gaseous detector development (tracking, trigger, Particle IDentification) for CERN experiments, medical and environmental applications
- ▶ R&D on micropattern detectors and Gas Electron Multipliers
- ▶ Participation in several projects:
 - ▶ CERN:
 - ▶ Trigger for ALICE VHMPID: PID for high momentum 5-30 GeV charged particles
 - ▶ NA61 Centrality Detector: TPC for PID of 150-450 MeV protons
 - ▶ Medical applications: micropattern detector for PET, radiation detectors
 - ▶ Environmental applications: underground muon tomography, radon detection (also active in underground data collection)
- ▶ Budget: 200 kCHF for 2010-2012
- ▶ Complementary lab spaces at Eötvös University and RMKI
- ▶ Important for our future: 6 / 12 collaborators are students
- ▶ ATOMKI and Uni Debrecen to join



NA6I / SHINE (RMKI)



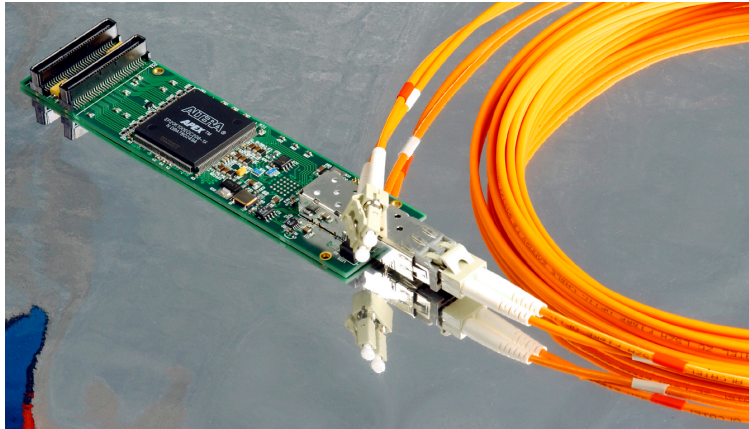
- ▶ Hungarian-Polish initiative to upgrade NA49
- ▶ Leading Hungarian role (co-spokesperson, technical coordinator, collaboration board chair...) with a relatively small group of 6 researchers
- ▶ Physics aim: search for critical point and collect large statistics on high p_T reactions
- ▶ Complete (10-fold) hardware and software upgrade of the NA49 DAQ setup, designed and manufactured in Hungary
- ▶ Data collection started in 2009 with proton and pion beams on carbon and liquid hydrogen targets
- ▶ 40M events during 4 months (=data collected by NA49 in 10 years)
- ▶ First measurements in the 20-160 GeV range for the pp system, useful for T2K neutrino, Auger and KASCADE cosmic ray experiments
- ▶ Group also completing NA49 data analysis
- ▶ R&D for new small size TPC for low momentum PID working in the backward rapidity (to help centrality measurement for pN interactions)



Successful DAQ R&D at RMKI



- ▶ **Detector Data Link (DDL)** made in Hungary is used by the 3 biggest TPC detectors in the world: LHC ALICE, RHIC STAR, SPS NA61/SHINE



- ▶ **Read-Out Receiver Card (RORC)** designed for several experiments



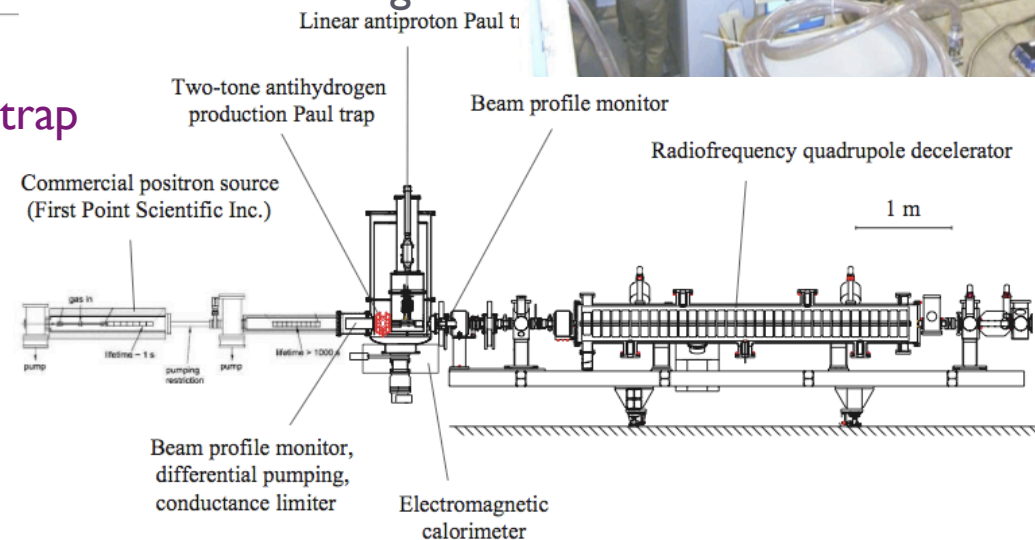
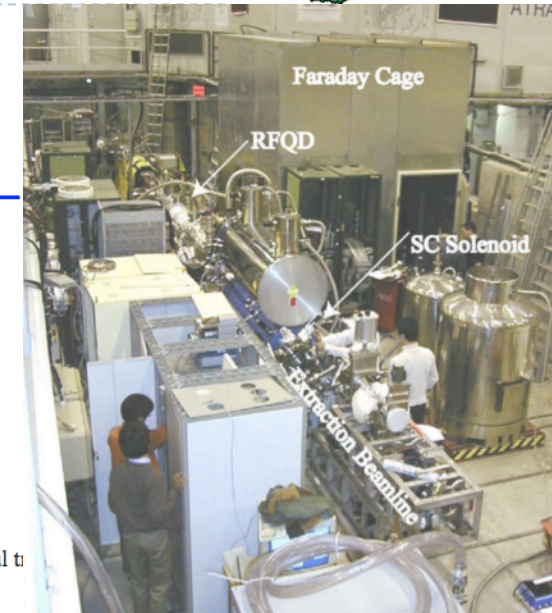
- ▶ **High-speed optical links** produced in Hungary work at data acquisition systems all over the world:

CERN, INFN (Roma, Torino, Bologna, Napoli, Pisa), IPN (Orsay, Nantes), CEA (Paris), NIKHEF (Amsterdam), Max-Planck Institute (München), KFKI-RMKI (Budapest), Stockholm University, IFAE (Univ. of Barcelona), Univ. of Valencia, Univ. of Lausanne, TU München, Bärngische Univ. Wuppertal, Johannes Gutenberg Universität, Manchester University, Univ. of Chicago, Indiana University, Caltech (Los Angeles), Argonne Nat. Lab. (Chicago), Los Alamos Nat. Lab., Fermilab (Batavia), Brookhaven Nat. Lab. (New Jersey), IRAM (an observatory in the Pirennnes), a space telescope in Hawaii, etc.

ASACUSA (RMKI, ATOMKI)



- ▶ Atomic Spectroscopy And Collisions Using Slow Antiprotons (4 participants)
- ▶ Aim: Experimental verification of the CPT invariance (matter – antimatter equivalence)
 - ▶ Measure m_p/m_e and the anti-proton magnetic moment
 - ▶ Measure the hyperfine structure of anti-H
 - ▶ Develop slow, extracted anti-p and anti-H beams (Monoenergetic Ultra Slow Antiproton Source for High-precision Investigations)
- ▶ High precision stands for target and trap
- ▶ Antihydrogen detector
- ▶ Detector system for two-tone Paul trap designed and built with significant RMKI participation to monitor antiproton annihilations after antihydrogen formation



High energy nuclear physics (heavy ion) program (RMKI, ELTE)



- ▶ Strong collaboration between experimenters and theorists
- ▶ Some of the experimental groups are lead by a theorist
- ▶ Students can participate in both experimental and theoretical work during their thesis work

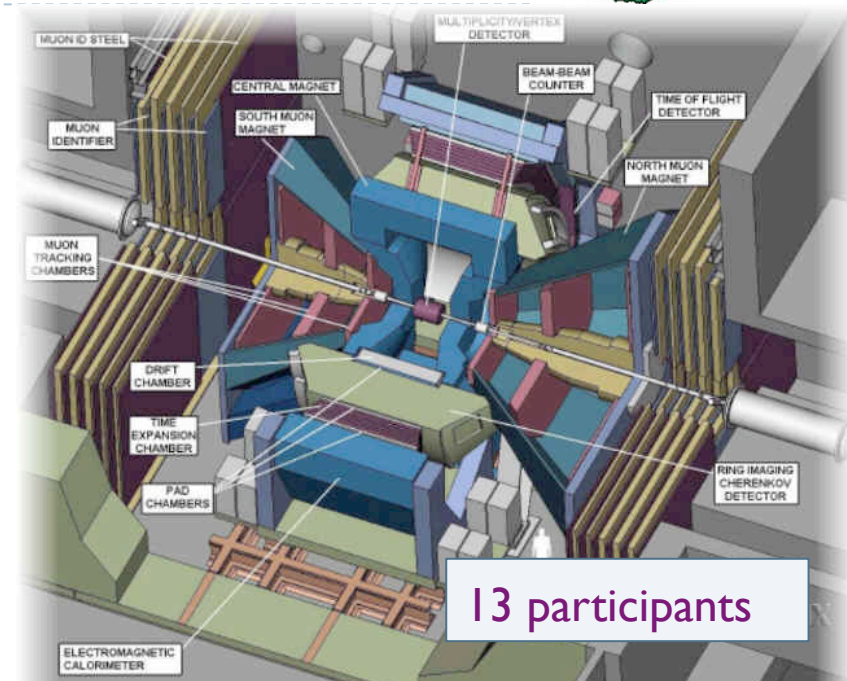
Groups:

- ▶ CERN LHC ALICE (~8 FTE)
- ▶ CERN LHC CMS
- ▶ CERN SPS NA61 [previously NA49] (~5 FTE)
- ▶ CERN RD51 (~3 FTE)
- ▶ BNL RHIC PHENIX (~3 FTE)
- ▶ GSI FAIR CBM, FOPI (~3 FTE)
- ▶ Heavy Ion Theory (~4 FTE)

PHENIX @ BNL RHIC (RMKI, ELTE)



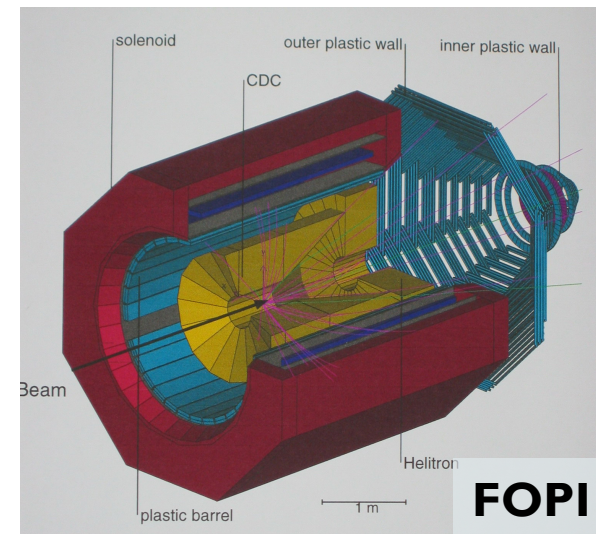
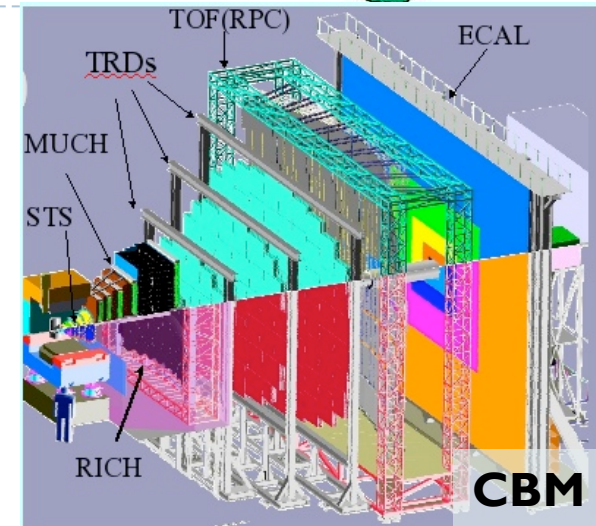
- ▶ Zero Degree Calorimeter: operation, software development, simulation
- ▶ Development of low momentum hadron identification algorithm
- ▶ Simulation and analysis cluster (35 PC + storage) in RMKI
- ▶ Measured Bose-Einstein correlation of pion and kaon pairs revealing a long tail of particle emission due to anomalous diffusion in an expanding fireball
- ▶ Combined PHENIX and STAR analysis of pion correlation found a decreased $\eta'(958)$ mass at the time of production for a very short time indicating the restoration of the $U_A(1)$ symmetry in the hot and dense hadronic matter
- ▶ Measured photoproduction of J/ψ in ultra-peripheral collisions to test distribution functions at low relative parton momentum
- ▶ Study of squeezed correlations, particle spectra and hydrodynamical flow profile



FOPI and CBM @ GSI FAIR (RMKI, ELTE)



- ▶ Participation in the planning of **C**ompressed **B**aryonic **M**atter experiment at FAIR (Facility for Anti-Proton and Ion Research) to study the properties and phase transition of very dense material using high-intensity heavy ion beam and search for critical point:
 - ▶ GEANT4 simulation studies
 - ▶ DAQ
- ▶ Hungarian group is founding member of the FOPI (4π) experiment



VIRGO-LIGO (RMKI, ELTE)



- ▶ Search for gravitational waves
- ▶ RMKI joined VIRGO in 2008
 - ▶ Data analysis
 - ▶ Produce new gravitational wave templates including spin and eccentricity
 - ▶ Implement massively parallelizable analysis algorithms for new or faster computing architectures (GPU, GRIDs)
 - ▶ Participate in the data transfer of the experiments
 - ▶ Participate in the design of the advanced VIRGO detector
- ▶ Eötvös Gravity Research Group (EGRG) of ELTE joined LIGO in 2007



Particle physics theory

(RMKI, ELTE, Uni Debrecen, BME)



- ▶ QCD (effective models, jet cross-sections with NNLO accuracy)
- ▶ Electroweak symmetry breaking (eg. vector boson or fermion condensate models)
- ▶ Lattice theory (eg. QCD hadron spectrum determination, pentaquarks)
- ▶ Heavy Ion theory
- ▶ Astroparticle physics
- ▶ Field theory (renormalization, finite temperature, phase transitions, non-equilibrium, non-perturbative)
- ▶ AdS/CFT, gravity – gauge duality
- ▶ Quantumgravity
- ▶ Oscillons (cosmology, astrophysics)
- ▶ ... and more



Computing: GRID and WLCG

- ▶ Currently four EGI (formerly EGEE) grid sites operate in Hungary

Site	BME	ELTE	NIIF	RMKI
CPU	25	25	10	420
Disk	20 GB	700 GB	3 TB	180 TB

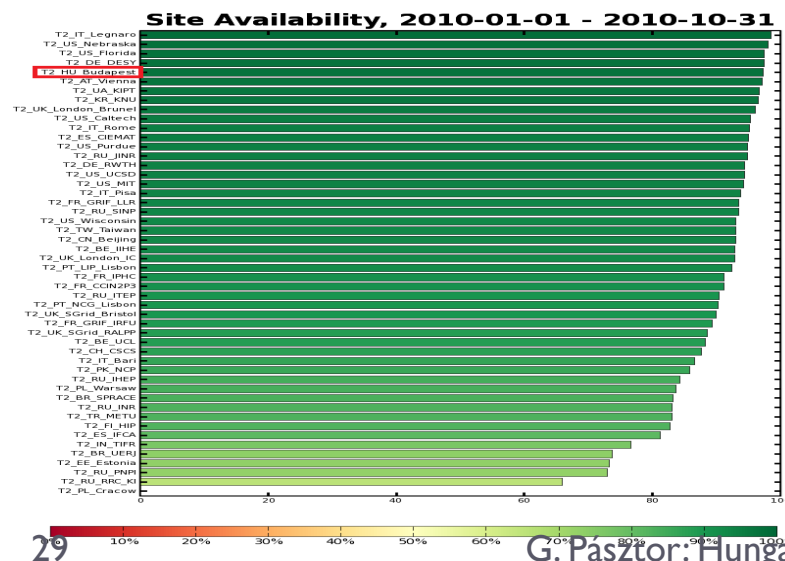
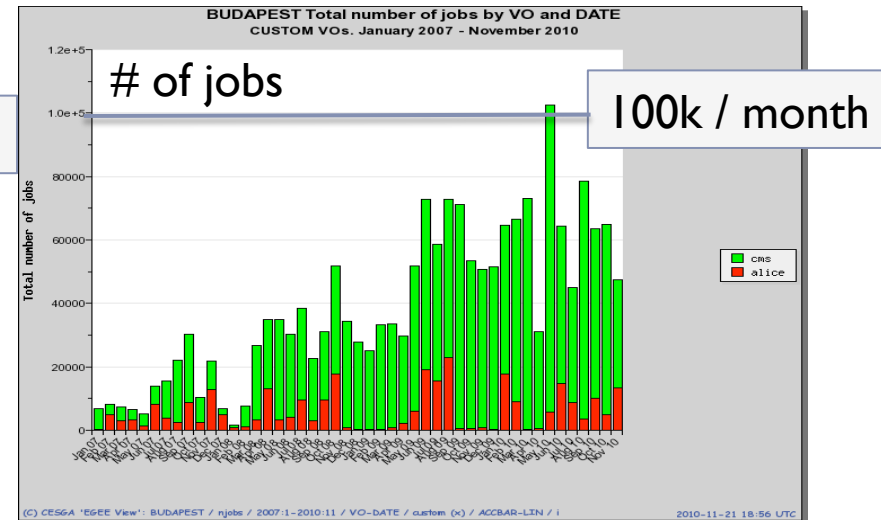
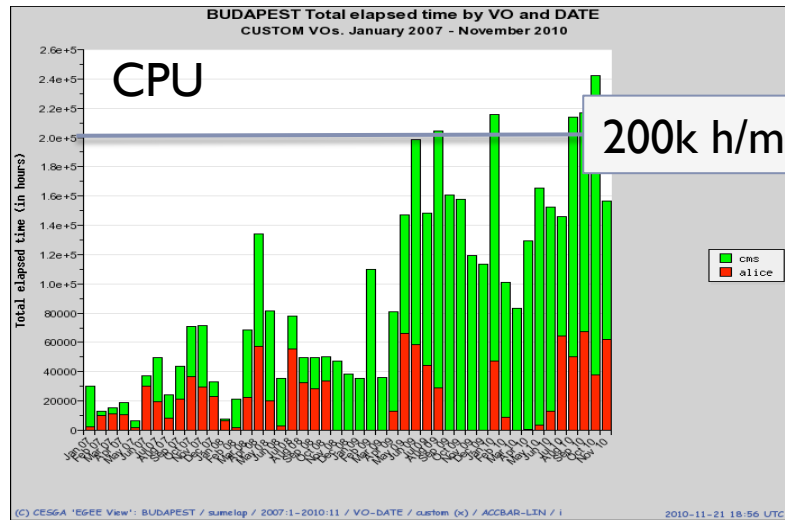
- ▶ A Hungarian Grid Competence Center supports the activities
- ▶ Worldwide LHC Computing Grid Tier-2 site since 2004 in Budapest (RMKI) serving the ALICE & CMS experiments

	2002	2004	2005	2006	2007	2008	2009
CPU (32)	50	100	100	100	100	50	-
CPU (64)	-	-	-	40	280	280	420
Disk (TB)	2	2	5	8	40	70	180
FTE	0,5	1	1	2,5	2,5	1,5	2

Funding (2009):
~10 MHUF/year
(36 k€/year)

- ▶ New CMS Tier-3 site to be built in Debrecen
- ▶ Letter of Intent submitted for CERN Tier-0 site in Hungary

Computing: WLCG performance



CMS site reliability rating: 5th
(8th in 2009, 22nd in 2008)

A very competent team
runs our dynamically growing
Tier-2 site



A selection of schools, conferences

- ▶ [Gribov-80 Memorial Workshop on QCD and beyond](#) , 26 - 28 May 2010, Trieste, Italy
- ▶ [GPU 2010 Mini-Symposium](#) , 4 June 2010, Budapest, Hungary
- ▶ [HCBM 2010 – Hot and Cold Baryonic Matter Workshop](#) , 15 - 20 August 2010, Budapest, Hungary
- ▶ HEP Research Experience for Undergraduates, 1-8 July 2010, Budapest, Hungary
- ▶ CTEQ-Mcnet summer school, 2008, Debrecen
- ▶ Yearly Zimányi Winter School on Heavy Ion Physics (RMKI)
- ▶ Yearly Nuclear and Heavy Ion Physics Summer School (ELTE)
- ▶ Yearly Theoretical Physics School in Gyöngyöstarján
- ▶ Yearly MaFiHE (Hungarian Physics Student Association) Summer School at Lake Balaton

Outreach



- ▶ Yearly Particle Physics Master Classes (one-day video-workshops) in Budapest, Debrecen and Székesfehérvár in cooperation with 70 research institutions from 30 countries
- ▶ Yearly lecture week at CERN for Hungarian physics teachers (pioneered in 2006 by the Hungarian Physical Society and since then adopted by many CERN member states)
- ▶ Researchers' Night
- ▶ Physics Trail at ELTE (university lab visits)
- ▶ From atoms to stars at ELTE (lectures for secondary school students)
- ▶ Ortvay Seminar series (for people with general physics background)
- ▶ Ortvay Competition in Physics (for university students, international)
- ▶ NYIFFF (creative team competition in physics)
- ▶ Hungarian CERN blog
- ▶ Intensive media and www coverage of the restart of LHC
- ▶ Numerous LHC talks for secondary school students and undergraduates



Acknowledgements

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- ▶ Sz. Hernáth (GRID),
- ▶ J. Kecskeméti, Gy. Wolf (GSI experiments),
- ▶ A. Krasznahorkay, J. Tóth (ATLAS)

ATLAS (RMKI)



- ▶ Hungary not an official member
- ▶ Participation via French – Hungarian (CRNS – HAS) exchange agreement
- ▶ Contributed to ATLAS LAr EM calorimeter assembly, testbeam measurements, Monte Carlo simulation and offline reconstruction software
- ▶ Starting search for new physics in top events

