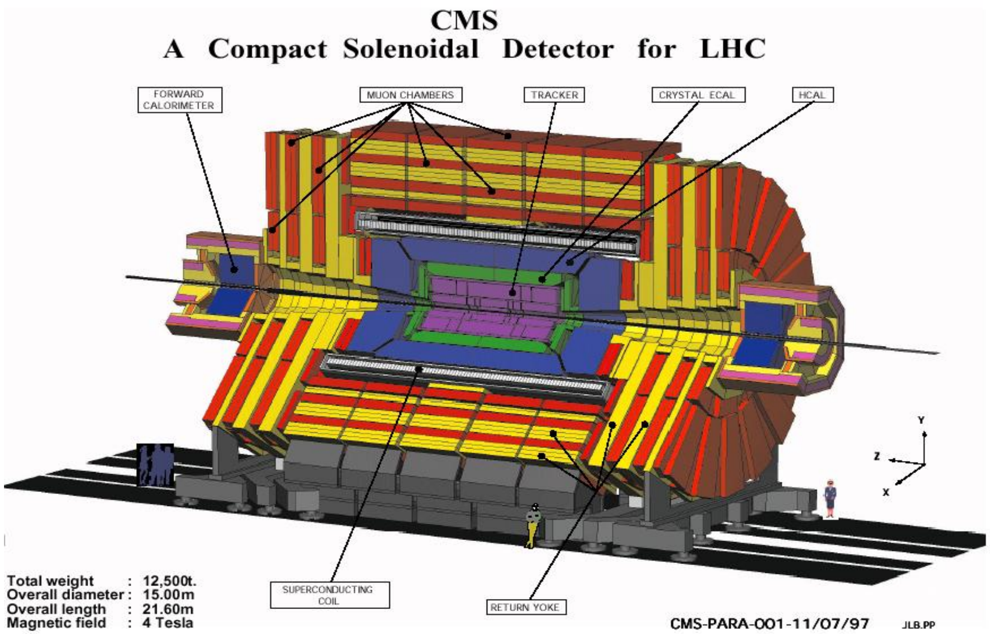
JINR participation in CMS Data Analysis
JINR Topic 02-0-1083-2009/2013



Sergei Shmatov

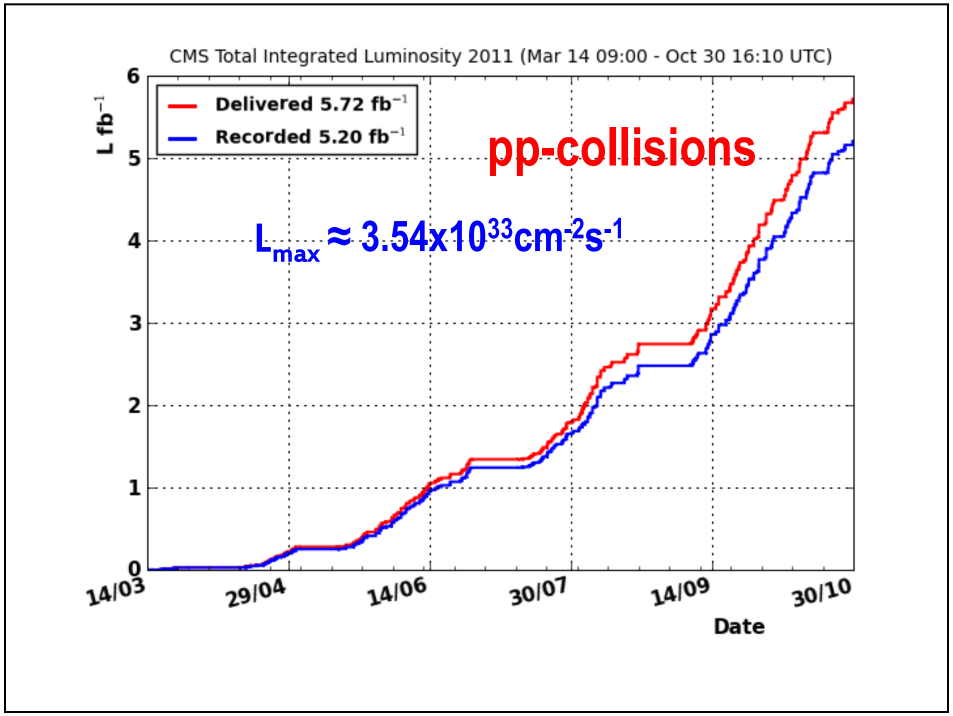
on behalf of JINR CMS Group

111th Session of the JINR Scientific Council, February 16, 2012

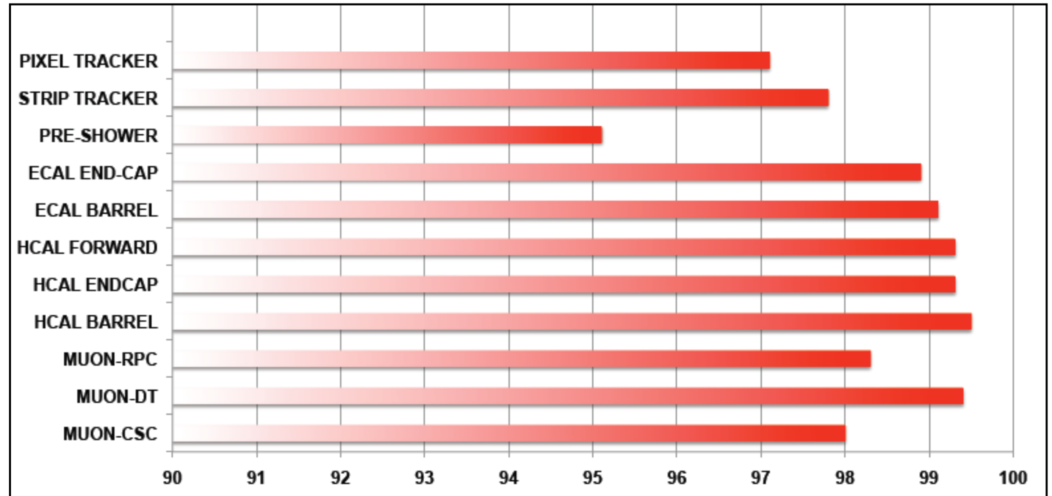
OUTLINE

- **CMS Operations**
  - ✓ data taking and sub-detector operational status
- **JINR in CMS Physics Analyses**
  - ✓ brief review of JINR participation
  - ✓ physics with high-mass dimuons
    - test of standard model
    - searching for new physics
- **Summary**

CMS Data Taking



Operation efficiency of CMS detector systems is high enough



	MUON-CSC	MUON-DT	MUON-RPC	HCAL BARREL	HCAL ENDCAP	HCAL FORWARD	ECAL BARREL	ECAL END-CAP	PRE-SHOWER	STRIP TRACKER	PIXEL TRACKER
Series1	98	99.4	98.3	99.5	99.3	99.3	99.1	98.9	95.1	97.8	97.1

good data taking efficiency

ε > 91% for pp **ε > 94 % for PbPb**

pp-collisions Run @ 7 TeV of 2011 (14 March – 30 October) :

5.22 fb^{-1} of data collected by CMS

PbPb-collisions Run @ 5.5 TeV/nucleon (12 November – 07 December) :

158 μb^{-1} of data collected by CMS.

The CMS Physics Analyses

The goals are

- rediscovery of standard model
- test of standard model in new energy scale
- looking for Higgs bosons
- looking for physics beyond the Standard Model
  - SUSY, Exotics
- heavy ion studies

124 papers were accepted or submitted to J. High Energy Phys, Phys. Rev. Lett., Phys. Lett. B, Eur. Phys. J.

http://cdsweb.cern.ch/collection/CMS Papers

~ 30 papers are in final reading inside the CMS Collaboration

99 authors from RDMS of 2175 /17 authors from JINR (< 1 % of all CMS authors) + 11 from DMS

JINR physicists are writers of seven CMS Physics Analyses (~ 5% of all CMS papers) and two CMS Internal Notes

JINR in CMS Physics Analyses

- ✓ JINR group concentrated on few selected physics topics, where JINR physicists already contributed significantly in preparation of CMS physics program
- ✓ Well integrated into the CMS physics program
  - Search for Higgs bosons (2l2ν channel, 4l channel)
  - Study of dimuon production in the large invariant mass region inaccessible at other accelerators
    - for SM verification and search of new physics beyond Standard Model (extended gauge models and extra dimensions etc)
  - Study of jet physics
    - to extend PDF's at range of small-x and large-Q^2 and measurement of α_s
    - 2 jet production in diffraction processes (single and double pomeron exchange)
  - Study of pair of gauge bosons (ZZ, WW)
    - Bose-Einstein correlations of gauge bosons of the same sign
    - anomalous coupling constants in production of WWγ, WWZ, WZγ, W$\gamma\gamma$
- ✓ Complex of RDMS Grid-computing based on the special RDMS Tier-1 centre at CERN and Tier-2 in Dubna provides efficient participation of JINR team in data taking and physics analysis

The last overview was presented on PAC, January 23, 2012

15 JINR Physicists take part actively in data processing and analysis, among them 5 PhD Students

JINR in CMS Physics Analysis Papers

JINR physicists are writers of seven CMS Physics Analyses (~5% of all CMS papers) and two CMS Internal Notes:

CMS Physics Analyses Notes:

- *A.Lanyov, I.Belotelov, S.Shmatov, et al. "Measurement of the differential and double differential Drell-Yan cross section in proton-proton collisions at $\sqrt{s}$ = 7 TeV in dimuon channel",* CMS AN-2012/063
- *D. Acosta, …, I.Belotelov, A.Lanyov, M. Savina, S. Senkin, S. Shmatov et al*. "Search for High-Mass Resonances Decaying to Muon Pairs with Collisions Gathered at $\sqrt{s}$ = 7 TeV", CMS AN-2011/472.
- *D. Acosta, …, I.Belotelov, A.Lanyov, M. Savina, S. Senkin, S. Shmatov et al*. "Search for High-Mass Resonances Decaying to Muon Pairs with Collisions Gathered at $\sqrt{s}$ = 7 TeV with 1.1 fb-1", CMS AN-2011/278, CMS PAS EXO-11-019 arXiv:1103.0981
- *A.Ferapontov, G.Landsberg, P.Tsang, V.Konoplianikov, M.Savina, S.Shmatov*, "Searches for Microscopic Black Holes Production in pp Collisions at sqrt(s) = 7 TeV with the CMS Detector with 1.1 fb-1", CMS AN-2011/256, PAS EXO-11-071
- *D. Acosta, …, I.Belotelov, A.Lanyov, M. Savina, S. Senkin, S. Shmatov* et al. "Search for High-Mass Resonances Decaying to Muon Pairs with Collisions Gathered at $\sqrt{s}$ = 7 TeV ", CMS AN-2011/222
- *A.Lanyov, I.Belotelov, S.Shmatov et al*. "Drell-Yan Differential Cross Section Measurement at 7 TeV in the Muon Channel", CMS AN-2011/013, CMS-EWK-10-007. Published as CMS Col. Results in arXiv:1108.0566, JHEP 10 (2011) 007
- *D. Acosta, …, I.Belotelov, A.Lanyov, M. Savina, S. Senkin, S. Shmatov et al*., " Search for High-Mass Resonances Decaying to Muon Pairs with 40 pb^{-1} of collisions gathered at $\sqrt{s}$ = 7~ TeV", CMS AN-2010/317, arXiv:1103.0981, JHEP05 (2011) 093

CMS Internal Notes:

- *I. Altsybeev, V. Konoplianikov, S. Shmatov, A. Tumasyan, A. Zarubin*, "Jet Energy Scale Calibration Using W -> qqbar Process", CMS IN-2011/010
- *V. Konoplianikov , S. Shulga, A. Zarubin*, " HF Calorimeter Calibration Using Events with Direct Photons and Jets", CMS IN-2011/001

Conference Talks by JINR Physicists

More than 15 talks on behalf of CMS Collaboration at the International Conferences, in particular:

The Nuclear Physics Department of RAS Conference "The Physics of Fundamental Interactions“, 21-25 Nov. 2011, Moscow:

- Ivan Belotelov, “Studies of Drell-Yan process in pp collisions at 7 TeV with CMS Experiment”
- Pavel Bunin, “Measurement of the transverse energy flow in a large eta range and forward jets at LHC at sqrt(s) = 0.9 and 7 TeV at the CMS Experiment” *(PhD Student)*
- Ilya Gorbunov, “Forward-Backward Asymmetry of DY pairs and measurement of weak mixing angle in pp collisions at 7 TeV with CMS Experiment” *(PhD Student)*
- Maria Savina, “Searching Microscopic Black Holes in pp collisions at 7 TeV at the CMS Experiment”
- Serge Shmatov “Searches for Physics Beyond the Standard Model (Exotica) in pp collisions at 7 TeV at the CMS Experiment”

15th Lomonosov Conference on Elementary Particle Physics, 18-24 Aug. 2011, Moscow:

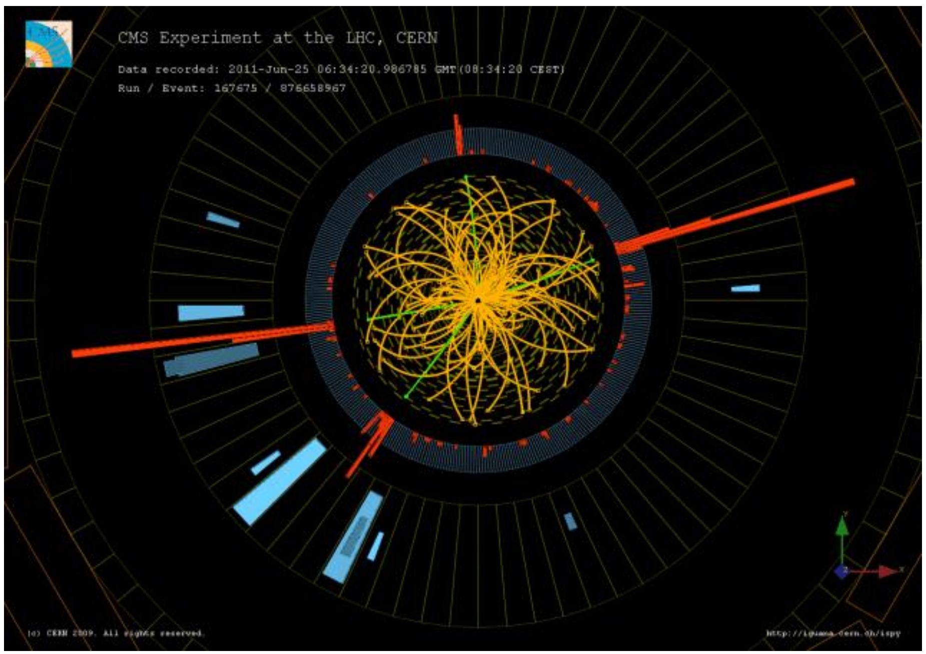
- Maria Savina, “Search for Microscopic Black Hole signatures in the CMS Experiment”

Also JINR physics results are summarized

- Annual RDMS CMS Collaboration Conferences
- Joint RDMS Seminar “Physics at LHC ” http://rdms.jinr.ru/
- CMS Collaboration Workshops and Working Group Meetings (more than 30 talks)

Di-muon Physics with CMS: results of 2010-2011

This program was initiated by Dubna in 2002



CMS Physics Analyses Notes:

- *"Measurement of the differential and double differential Drell-Yan cross section in proton-proton collisions at √s = 7 TeV in dimuon channel",* CMS AN-2012/063
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- "Search for High-Mass Resonances Decaying to Muon Pairs with Collisions Gathered at √s = 7 TeV with 1.1 fb-1", CMS AN-2011/278, CMS PAS EXO-11-019 , arXiv:1103.0981
- "Search for High-Mass Resonances Decaying to Muon Pairs with Collisions Gathered at √s = 7 TeV ", CMS AN-2011/222
- "Drell-Yan Differential Cross Section Measurement at 7 TeV in the Muon Channel", CMS AN-2011/013, CMS-EWK-10-007, arXiv:1108.0566, JHEP 10 (2011) 007
- " Search for High-Mass Resonances Decaying to Muon Pairs with 40 pb^{-1} of collisions gathered at √s = 7~ TeV", CMS AN-2010/317, arXiv:1103.0981, JHEP05 (2011) 093

Why Di-muons?

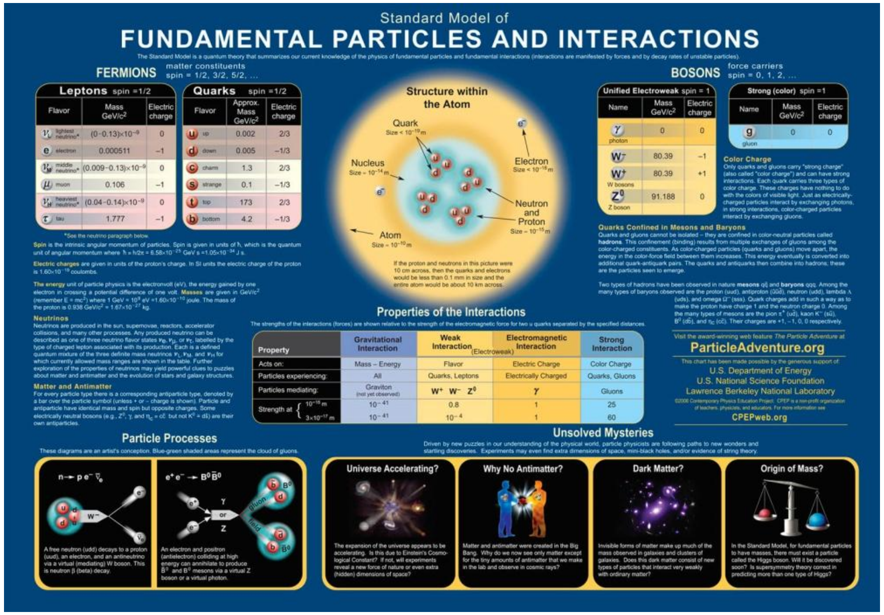
- Many theoretical reasons: verification of Standard Model with Drell-Yan processes, hunting for new physics beyond SM (extra gauge models, extra dimensions etc)
- Cross-sections of hadron signatures are higher, but leptonic decays provide clear signatures with lower and controllable backgrounds!
- Why muons? Because it is Compact MUON Solenoid where Dubna group plays important role since conceptual design through PhTDR up to physics analysis
  - strong B-field and long lever arm (from IP and tracker to Muon system) for precise momentum estimation
  - high precision muon detectors with redundant muon trigger

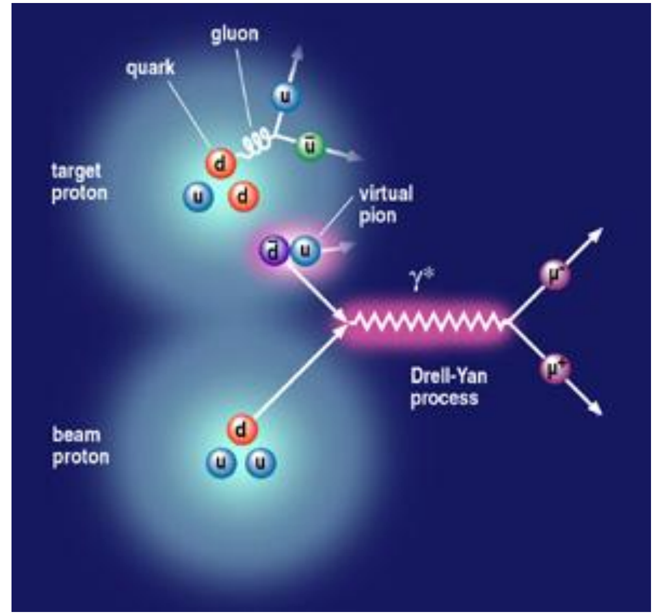
$\Rightarrow$ priority in JINR physics program – search for new physics in di-muon channels at the invariant mass region uncovered so far by other accelerators

RDMS Participation (JINR + Belarus): from theoretical studies up to final physics analysis, including

- high efficiency of registration, triggering and reconstruction for muons
- validations software with Monte-Carlo data, muon cosmic data, SPS and LHC beams
- studies of systematic effects (misalignment, material non-uniformities, B-filed, miscalibration etc)
- physics analysis

Tests of Standard Model

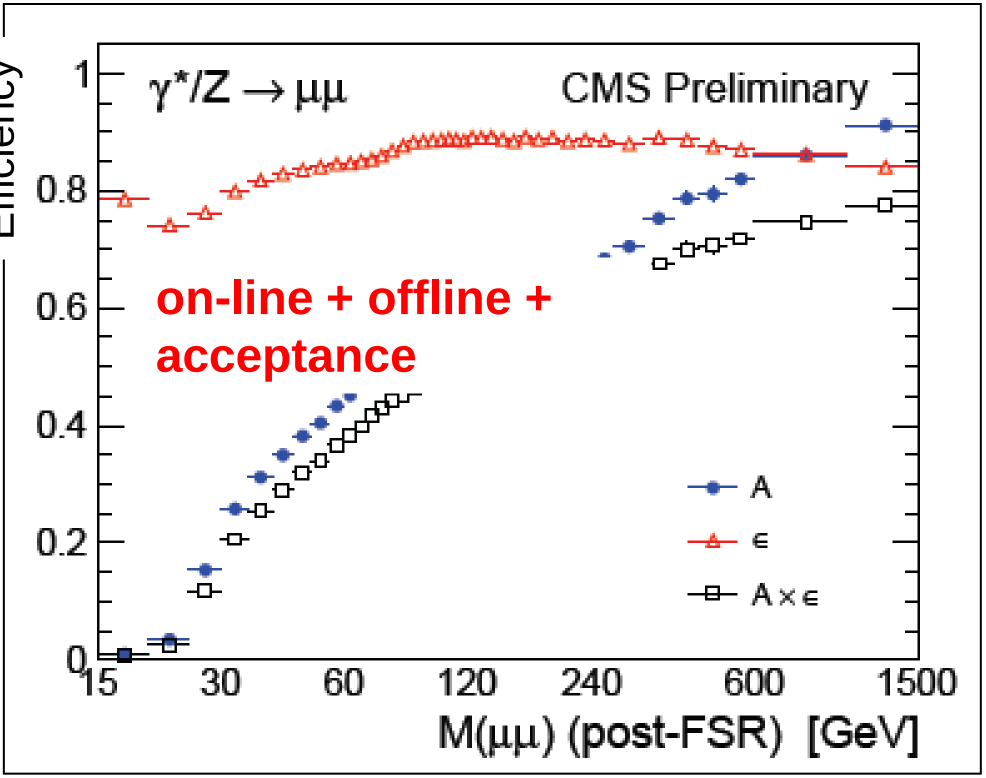




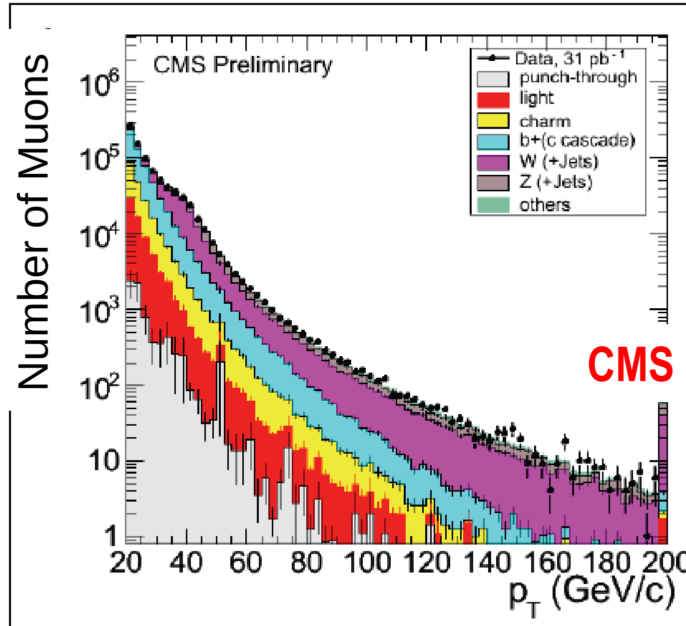
- ❑ Measurements of di-muon spectrum (ω, ϕ, J/ψ etc)
- ❑ Study of Drell-Yan process to verify Standard Model:
  - ✓ cross-sections vs invariant mass
  - ✓ angular distributions (helicity structure of processes)
  - ✓ forward-backward asymmetry
  - ✓ weak-mixing angle

Trigger and Reconstruction Performance

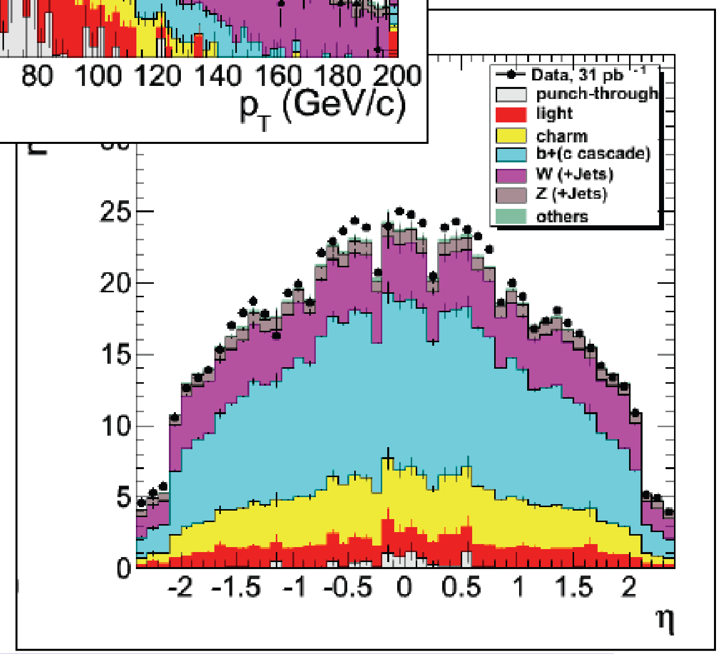
Good agreement with MC prediction



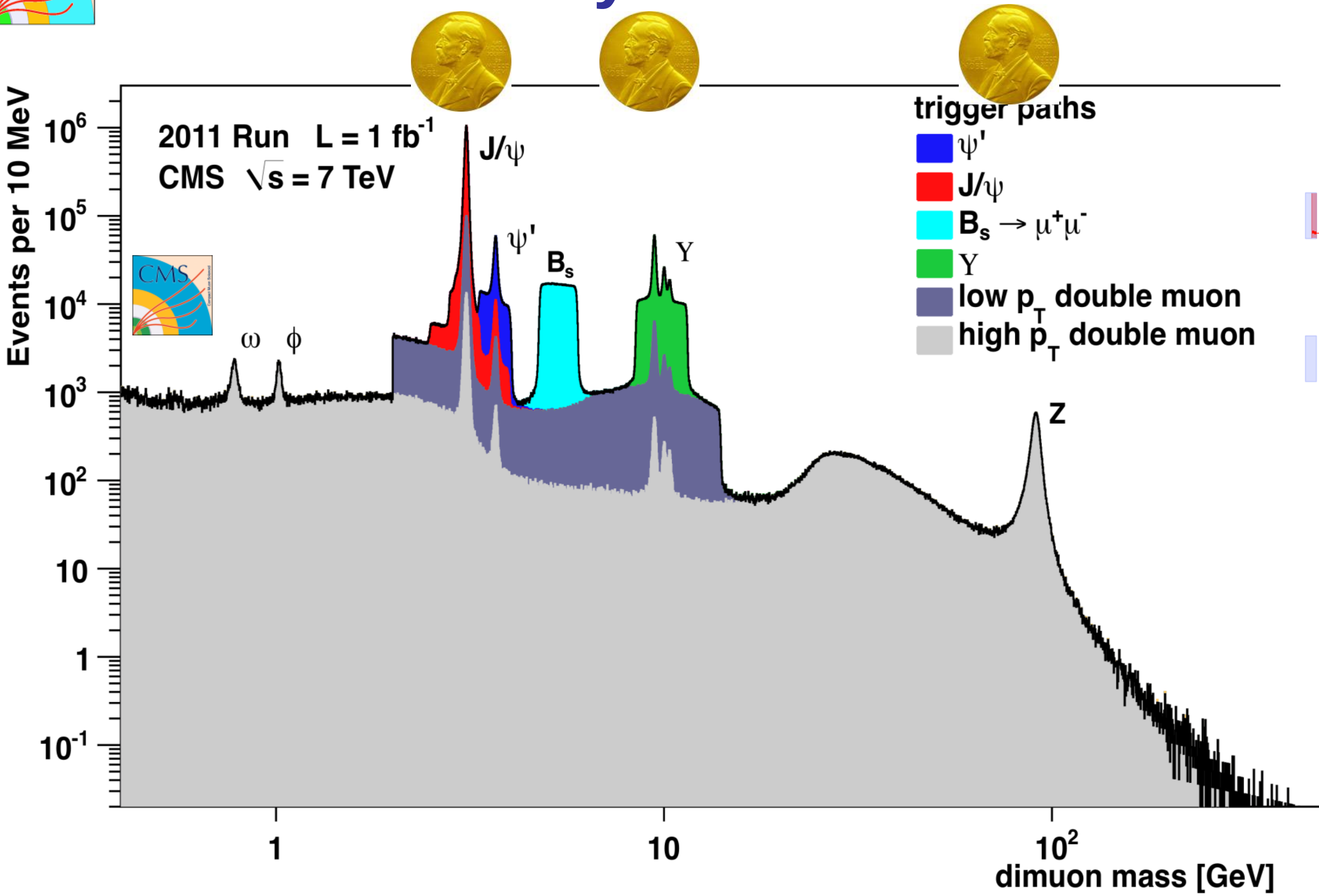
CMS EWK-10-007
arXiv:1108.0566
JHEP10 (2011) 007

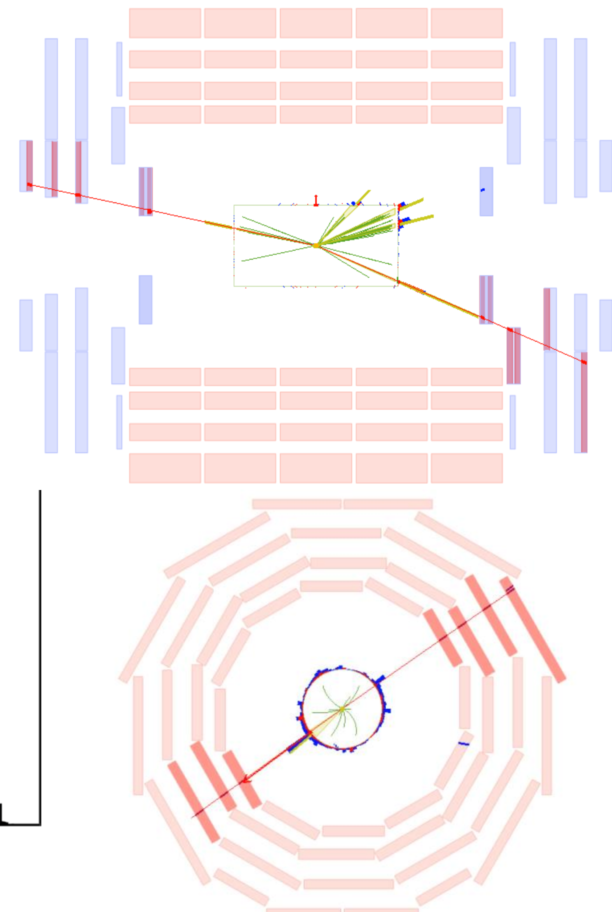


CMS MUO-10-004



Rediscovery of Standard Models in μ+μ-





SM model resonances (from ω-meson up to Z-boson) were observed:

- ✓ "commissioning "of trigger/selection/reconstruction chain – it works good
- ✓ yields are reproduced by SM

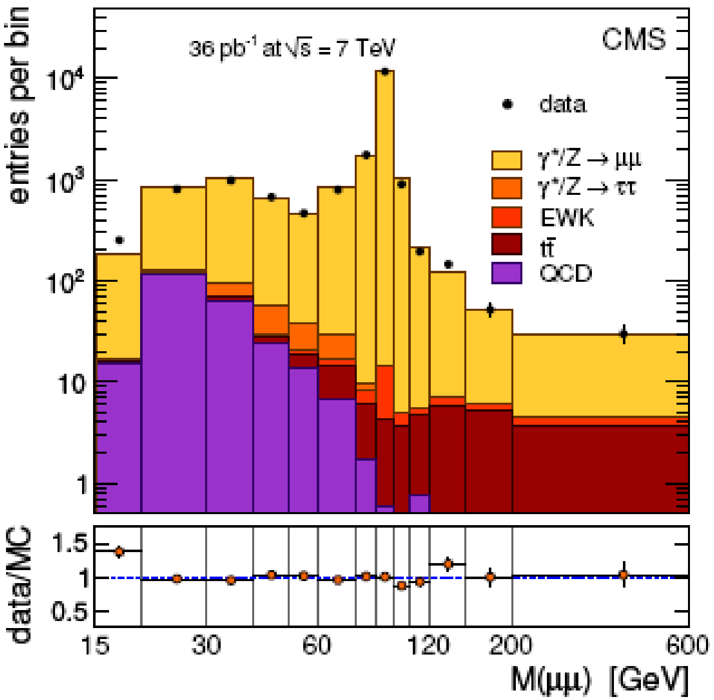
exploration of ~TeV region is started !!!

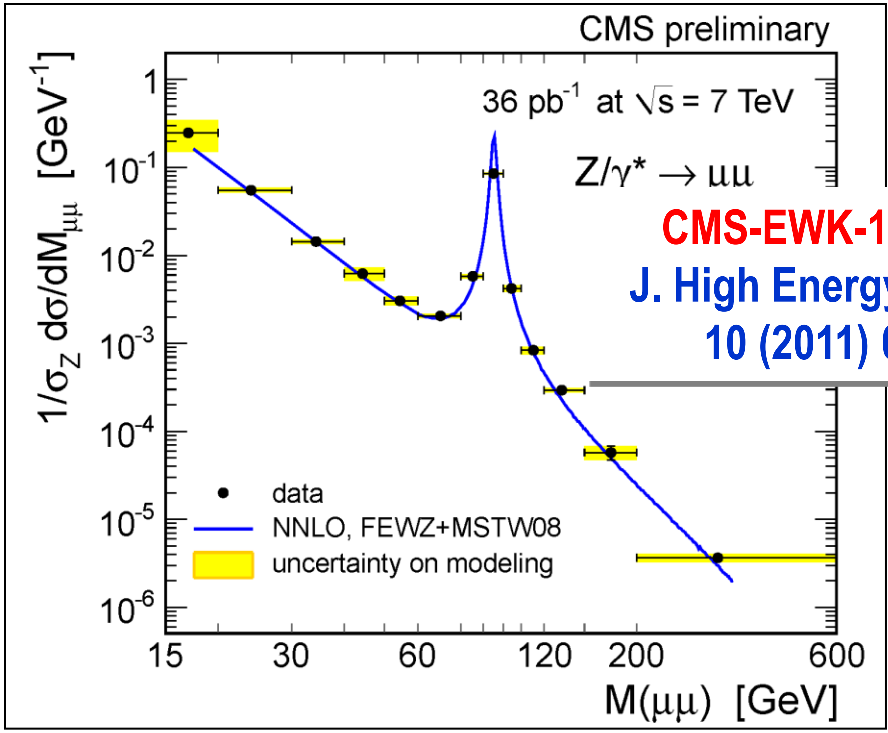
Drell-Yan Processes

Background: **$0 < M_{\ell^+\ell^-} < 600$ GeV**

EWK – from MC

QCD – from MC + estimation from data





CMS-EWK-10-007

J. High Energy Phys. 10 (2011) 007

Uncertainties:

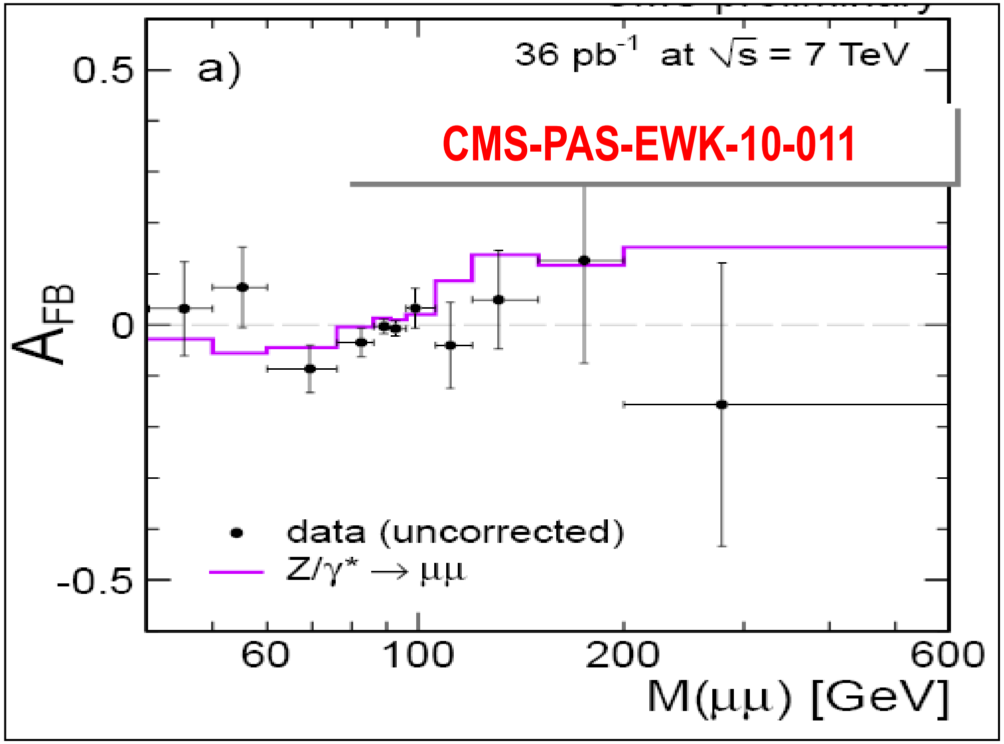
efficiency (1.1-2.1 %), background (K-factor and PDF) (3.6-10%), unfolding (up 1.7 %), FSR (up to 2%), other (up to 3%), acceptance (up to 2.2 %)

Good agreement CMS Data and SM predictions (NLO MC generator POWHEG + MSTW08 PDFs)

Results for ~5 fb^{-1} is ready, collaboration approval is in progress

Forward-Backward Asymmetry

Forward-backward asymmetry is defined as $A_{FB}=(N_F-N_B)/(N_F+N_B)$, where N_F is the number of events in which some particular final-state particle is moving "forward" with respect to some chosen direction (in general quark direction is "forward")



A_{FB} value is sensitive to contribution both vector and axial-vector couplings
⇒ Test of SM / new physics

"Dilution" asymmetry measurements:
- bin-to-bin migration due to finite detector resolution
- Final-State-Radiation (FRS)
- acceptance cuts
- unknown quark/antiquark direction for the LHC

Results with corrections for ~5 fb^{-1} is ready, collaboration approval is in progress

Will be available for public discussion for two weeks!

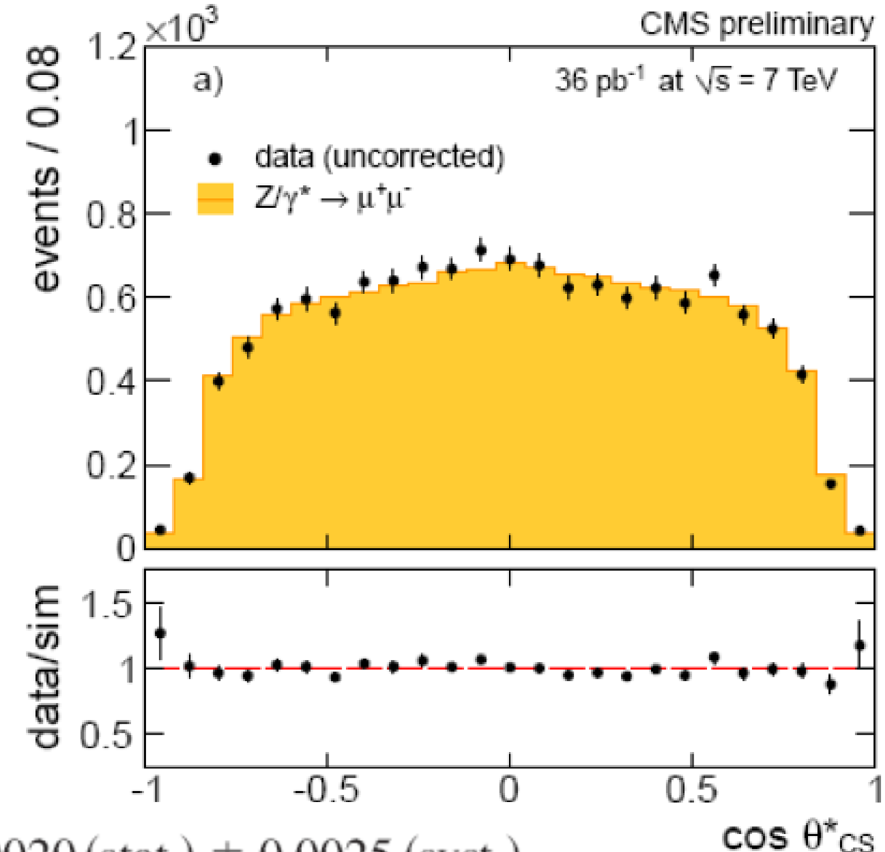
Measurement of Weak-mixing Angle

Drell-Yan yield = F [lepton angular ($\cos\theta_{CS}$). dilepton rapidity (Y,) dilepton mass (s)]

$$\frac{d\sigma_{pp\to l^+l^- X}(Y,s,\cos\theta^\star_{CS})}{dY\ ds\ d\cos\theta^\star_{CS}} \propto \sum_{q=u,d,s,c,b} [\hat{\sigma}^{even}_{q\bar{q}}(s,\cos^2\theta^\star_{CS},\sin^2\theta_{eff}) + D_{q\bar{q}}(s,Y)\times\hat{\sigma}^{odd}_{q\bar{q}}(s,\cos\theta^\star_{CS},\sin^2\theta_{eff})]\times F_{q\bar{q}}(s,Y)$$

dilution factor (reflects the fact that the quark direction is generally unknown and is taken as the boost direction of the dilepton system)

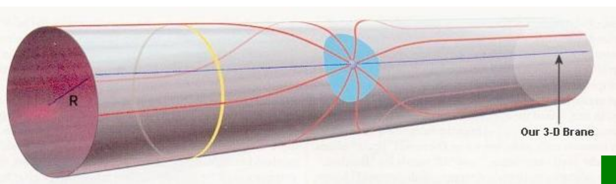
parton factor (takes into account flavour-dependence)

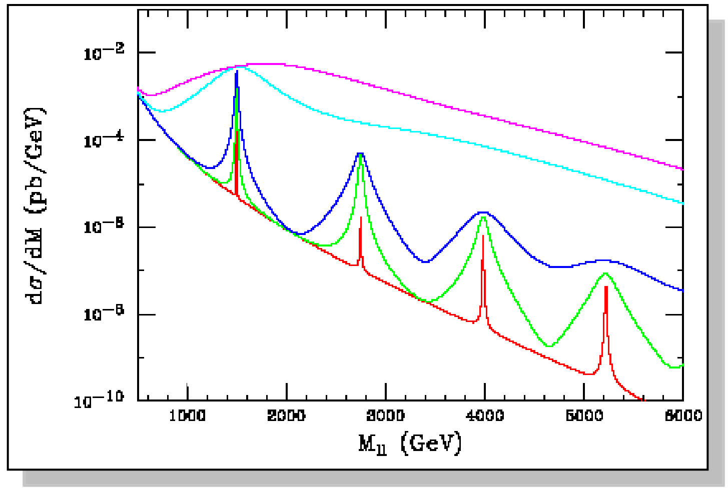


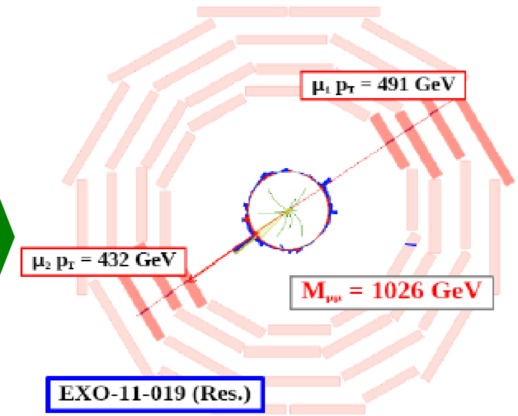
$$\sin^2\theta_{eff} = 0.2287 \pm 0.0020\,(\text{stat.}) \pm 0.0025\,(\text{syst.}).$$

CMS-PAS-EWK-10-011
CMS-PAS-EWK-11-003
Phys. Rev. D 84, 112002 (2011)

Looking for New Physics beyond SM



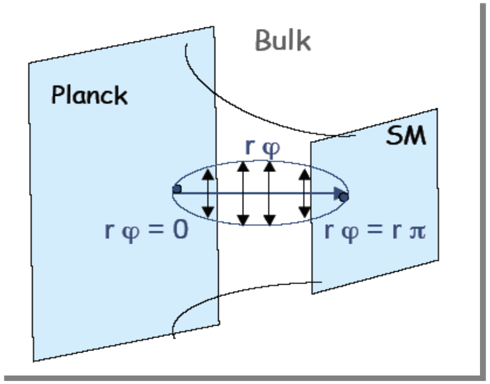




- resonance states:
  - ✓spin-1 states: heavy (m~ TeV) gauge bosons Z' from extended gauge models and KK excitations of gauge bosons in TeV-1 models (Z_{KK})
  - ✓spin-2 states: heavy (m~TeV) RS-graviton in Randall-Sundrum TeV-scale gravity models
- non-resonant state:
  - ✓ TeV-scale gravity model – light ADD-graviton
  - ✓ compositeness models

New Resonance Mass Limits

L. Randall and R. Sundrum (RS1 scenario), PRL83 3370 (1999)

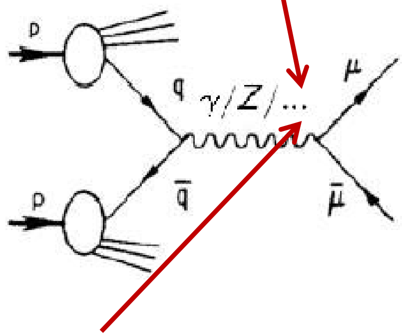


5D curve space with AdS_5 slice: two 3(brane)+1(extra)+time!

Heavy KK-excitations of gravitons (spin-2 state)

Extended gauge models based on GUT E6 or SO(10) theories or Left-Right Symmetric Model (LRM)

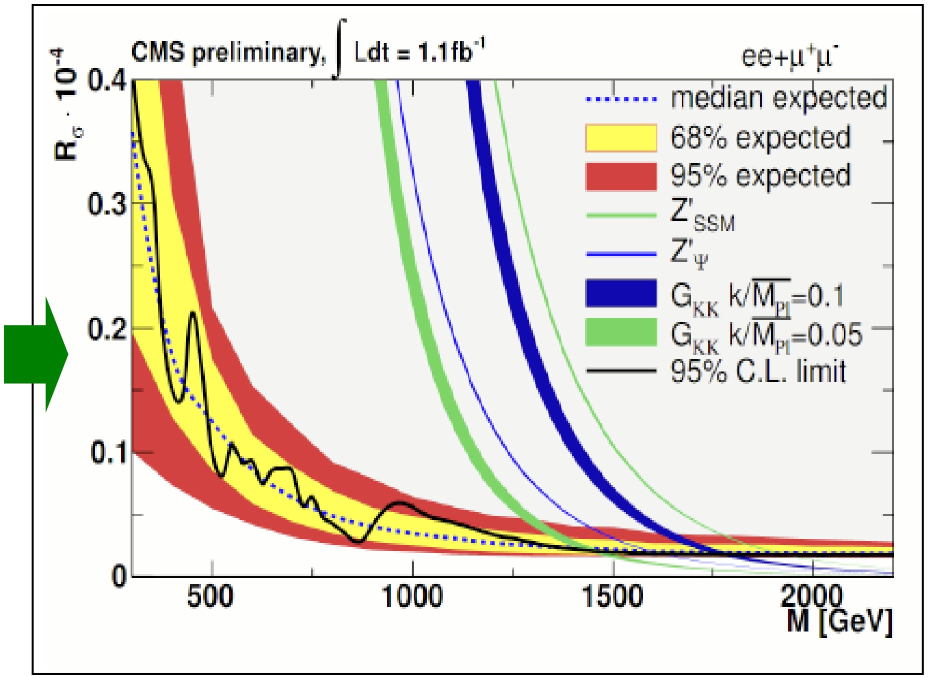
Extra gauge bosons Z′ (spin-1 state)



$$pp \to G_{KK}, Z_{KK}, Z' \to e^+e^-, \mu^+\mu^-, \gamma\gamma, jet + jet$$

$$R_\sigma \equiv \frac{\sigma(pp \to Z' + X \to \ell\ell + X)}{\sigma(pp \to Z + X \to \ell\ell + X)}$$

CMS PAS EXO-11-019



Z′ with standard-model-like couplings can be excluded below 1940 GeV, the superstring-inspired Z′ below 1620 GeV, and RS Kaluza–Klein gravitons below 1450 (1780) GeV for couplings of 0.05 (0.10)

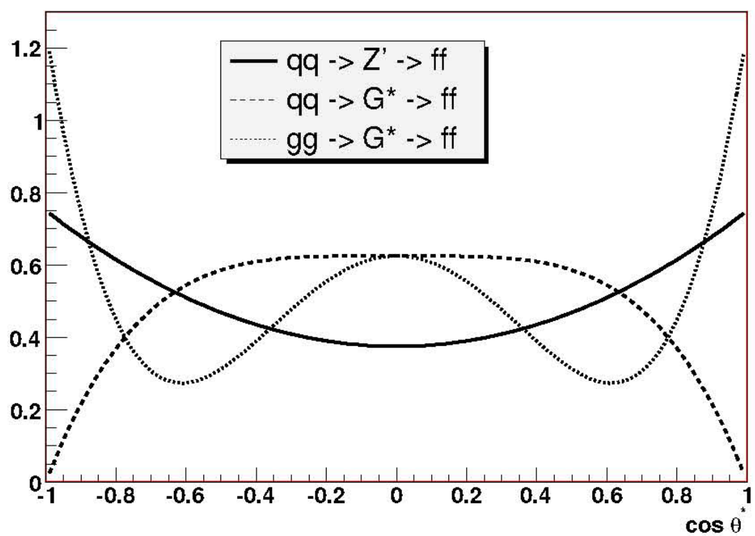
… and again on AFB (looking forward)

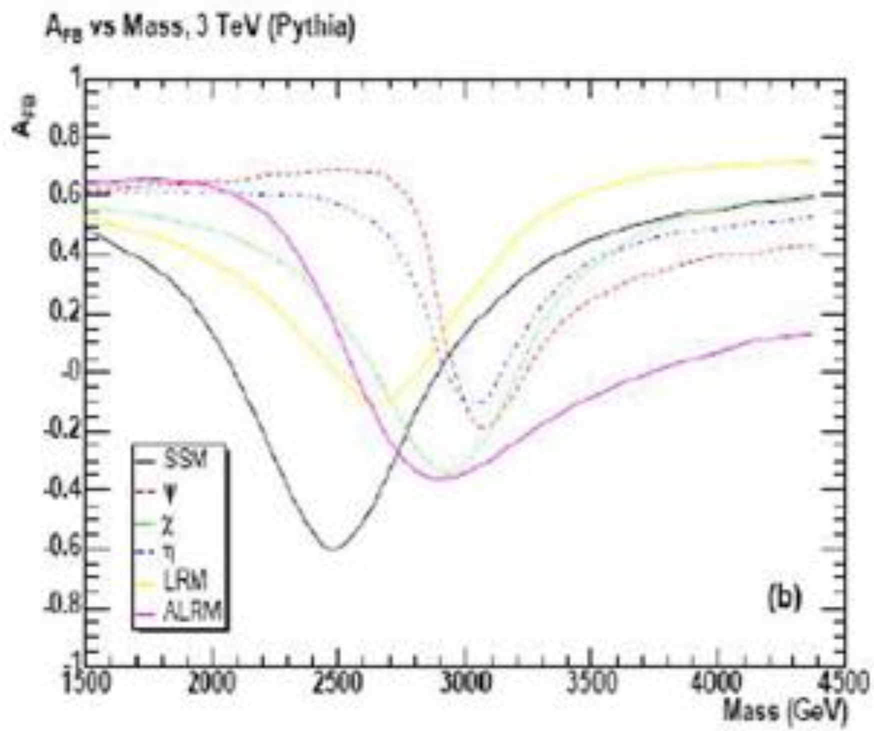
spin-1/spin-2 discrimination

gV/gA measurements ≡ model discrimination (even with the same spin)

Angular distributions

- $qq \to G \to ff$: $1 - 3\cos^2\theta + 4\cos^4\theta$
- $gg \to G \to ff$: $1 - \cos^4\theta$
- $qq \to G \to VV$: $1 - \cos^4\theta$
- $gg \to G \to VV$: $1 + 6\cos^2\theta + \cos^4\theta$
- DY background: $1 + \cos^2\theta$

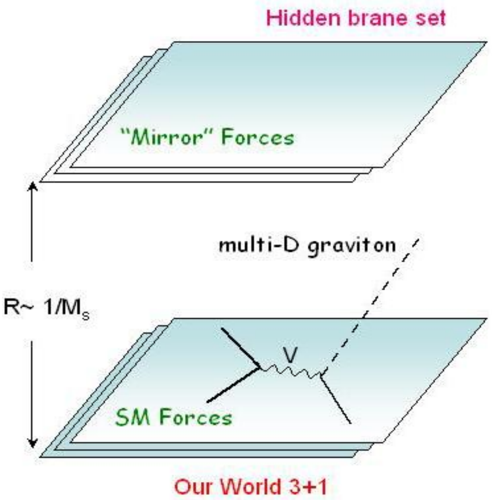




A_{FB} behavior differs for different new resonance states of extra gauge bosons (Z′)

Searching for virtual ADD-graviton in μ+μ-

N.Arkani-Hamed, S.Dimopoulos, G.Dvali (ADD scenario), Phys.Lett. B429(1998), Nuc.Phys.B544(1999)

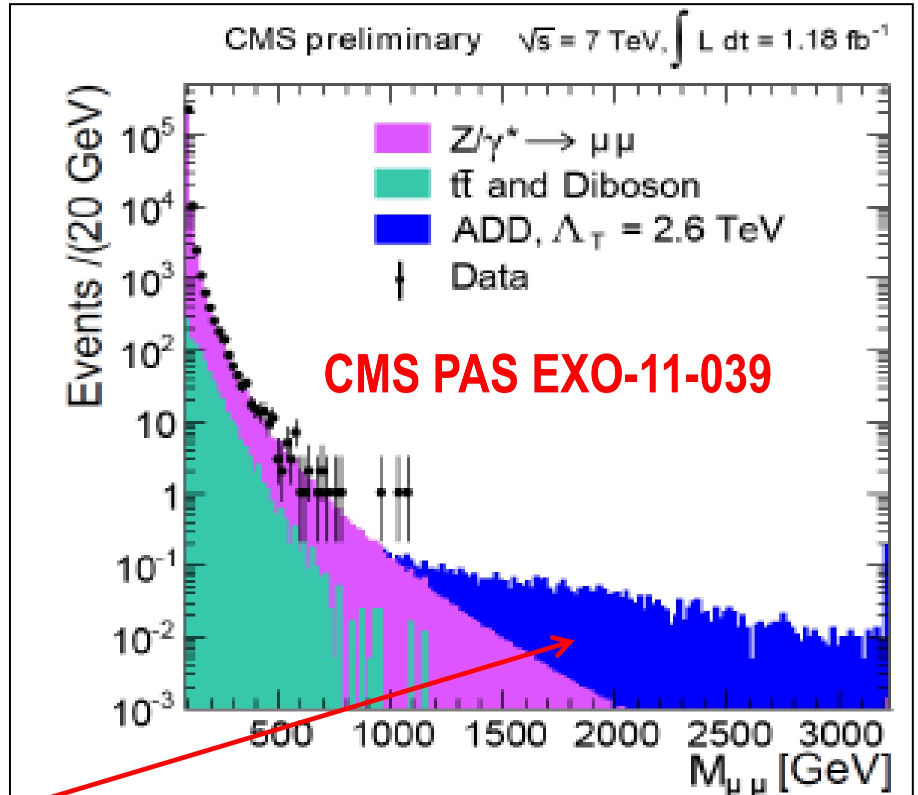


n (up to 7) flat –Euclidian uxtra spatial dimensions

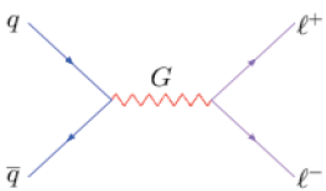
fundamental scale is not planckian: M_D ~ TeV

SM forces live on 3D brane

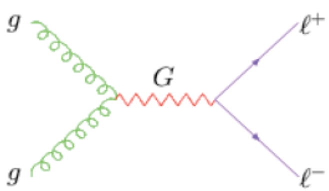
Only gravitons are multi-dimensional



Graviton contributions to SM (Drell-Yan) processes:



$q\bar{q} \rightarrow l^+l^-$



$gg \rightarrow l^+l^-$

M_D limits:

n=2	n=3	n=4	n=5	n=6	n=7
2.6	3.1	2.6	2.3	2.1	2.0

SUMMARY

- ❑ CMS data taking and detector operations are high efficient
- ❑ The CMS analyses based on 2010-2011 data are almost completed
  ~ 120 papers are published or submitted to publish, many analyses are going to be public

JINR participation in CMS is very successful - JINR physicists are involved in whole CMS chain from data taking (shifts) and to final data analysis

- ✓ we contributed in seven CMS physics analyses
- ✓ young physicists are involved actively

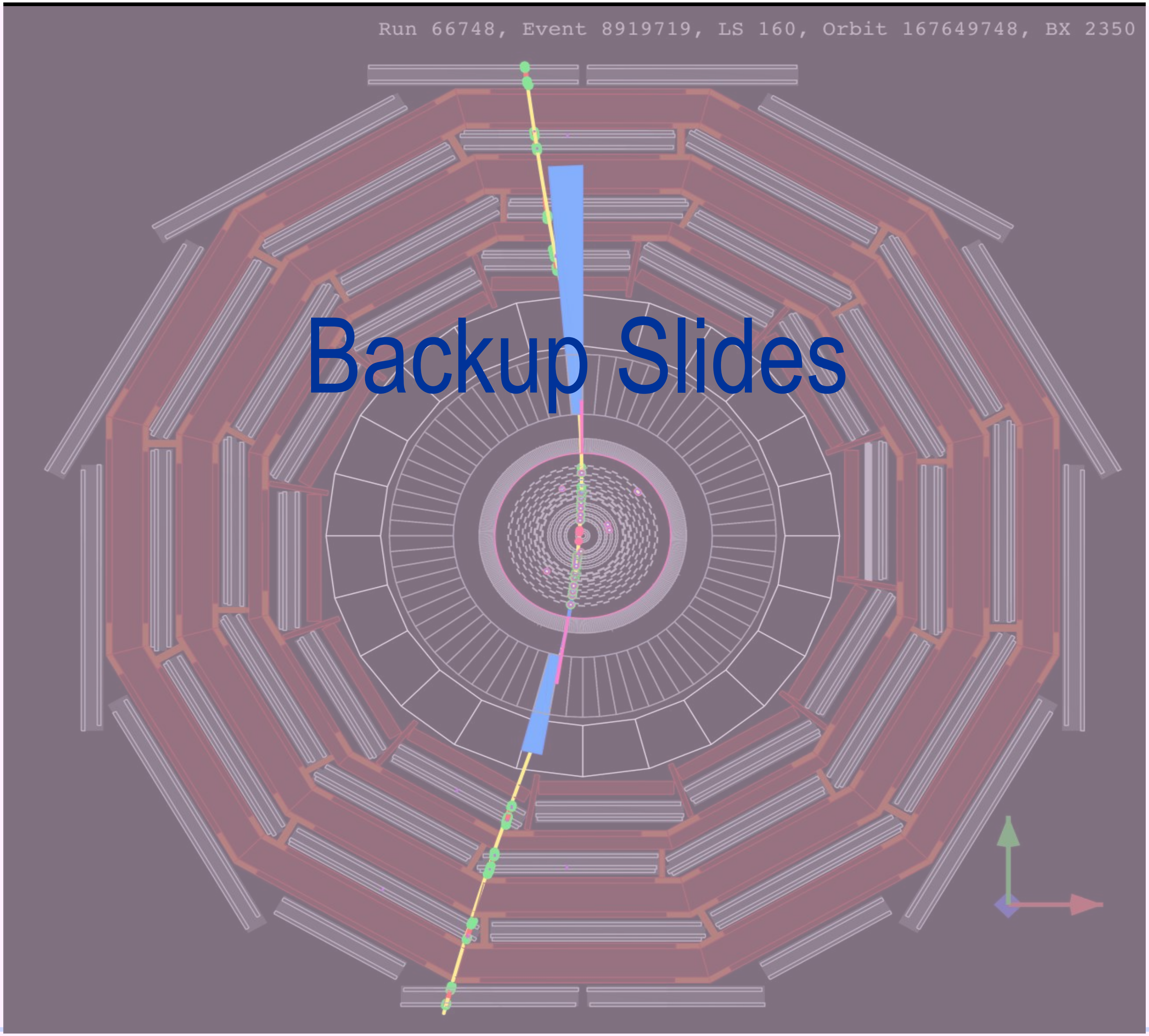
The first-priority JINR physics task - **10 years long** dimuon physics campaign initiated by Dubna in 2002 – is beginning to yield results:

- ✓ Drell-Yan dimuon production yield is measured up to 600 GeV @ 7 TeV
- ✓ angular behavior and forward-backward asymmetry are studied
- ✓ weak-mixing angle is measured
- ✓ new limits on new physics beyond SM are derived
- ✓ di-muon results are summarized in six CMS analysis papers and many conference talks

In 2012 we expect plenty of results on 8 TeV beams with ~15 fb^{-1} !!

Thank you for your attention!

Backup Slides

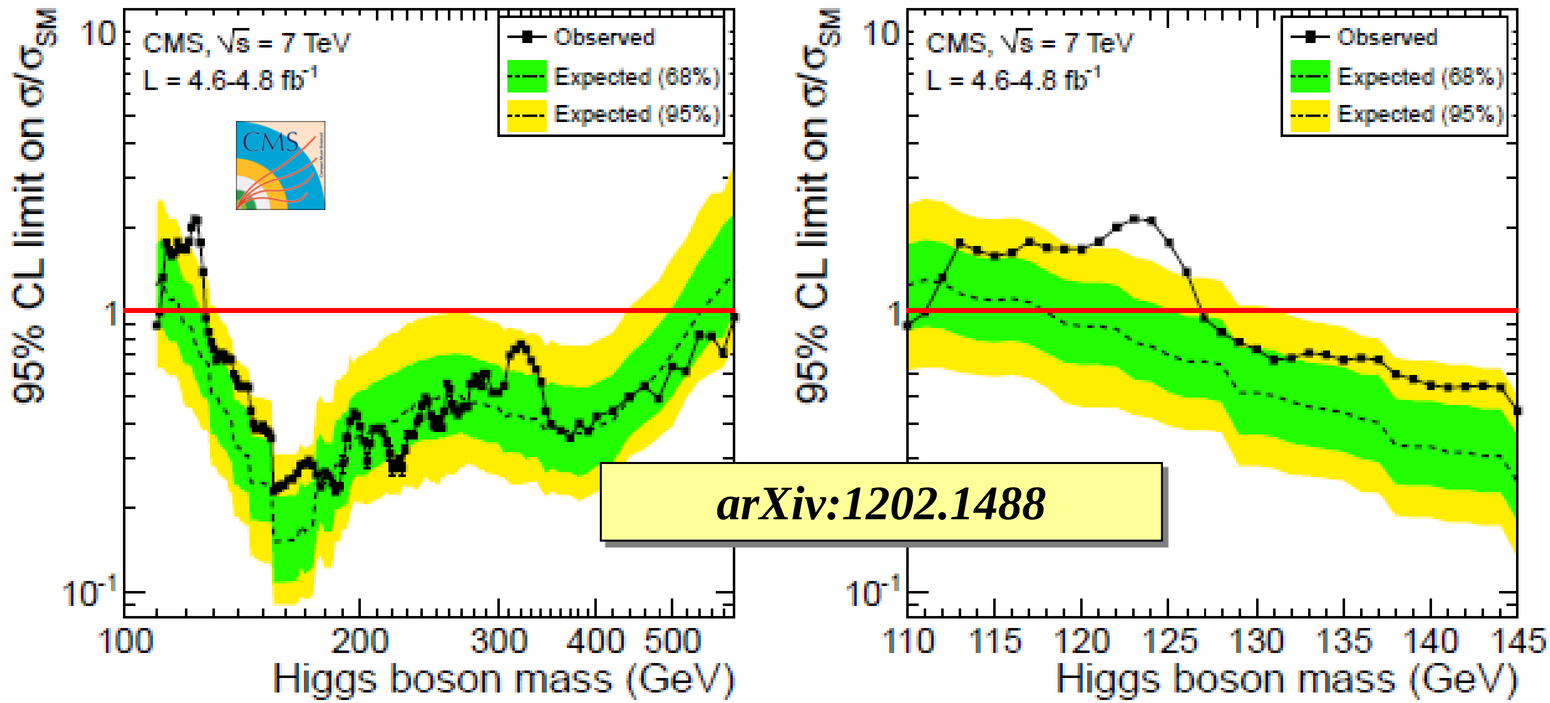


The Higgs Searching

The CMS search for the Higgs boson is being carried out with 4.6-4.7 fb^{-1} using a range of decay products:

$H \rightarrow \gamma\gamma$, $\tau\tau$, bbbar, $WW \rightarrow 2l2\nu$, $ZZ \rightarrow 4l$, $ZZ \rightarrow 2l2\nu$, $ZZ \rightarrow 2l2q$

The CMS analysis excludes the existence of a Standard Model Higgs boson in Higgs mass range: 127-600 GeV at 95% C.L. (129-525 GeV at 99% C.L.)



arXiv:1202.1488

DMS (Dubna and Ukraine) participates in analyses in 2l2ν (L.Levchuk et al) and 4l reconstruction (Dubna)

Theoretical Motivations

Standard model weak points (except for Higgs is not found so far):

- Hierarchy Problem
  - ✓ fine tuning of higgs masses is needed to “neutralize” contribution from high order corrections
  - ✓ huge gap between Electroweak (10^3 GeV) and Grand Unification (10^{16} GeV) scales), **Gravity/EW ~ $10^{19}/10^2$ GeV?**
- Yukawa hierachy (explanation of mass patterns for quarks and leptons)
- Unification of interactions, number of generations (why 3?) they can not be fixed in the framework of SM
- Gravity is not described by SM
- Set of cosmological problems (inflation, dark matter, CP-violation in the early Universe etc)

Possible ways to solve:

Extended Gauge Theories

GUT $\mathbf{E_6}$ or **SO(10)** theories or Left-Right Symmetric Model (**LRM**)

unification, tuning, CP-violation…

Large Spatial Extra Dimensions

Real World is multi-dimensional space (two parameters– fundamental scale M_D and space curvature k) with embedded 3D-Universe

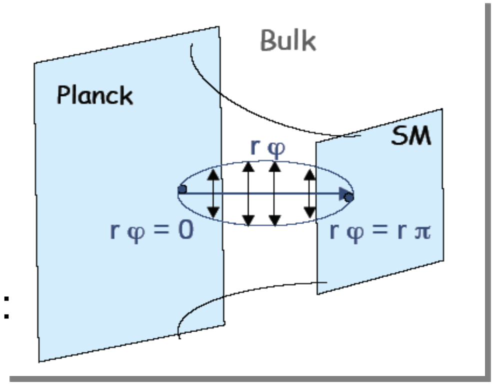
SM is reproduced, hierarchy, includes Gravity, harmonious cosmological picture…

Physics Scenarios

One Extra Dimension

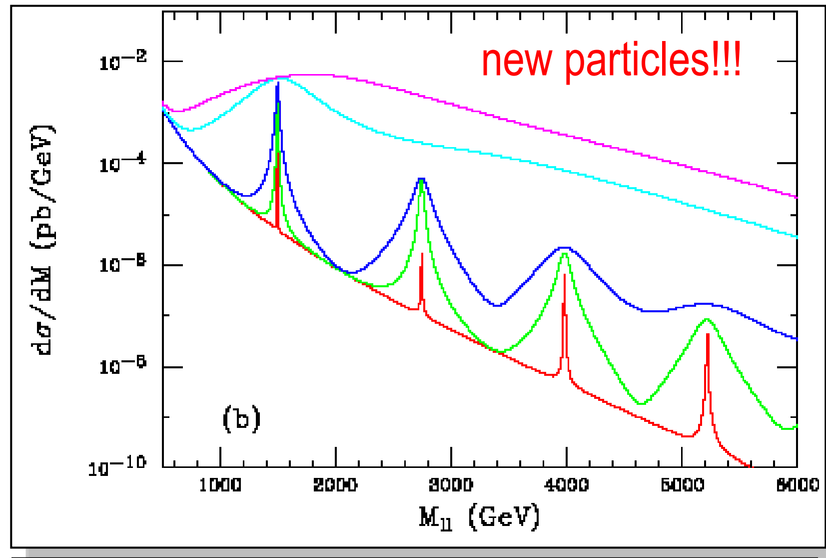
L.Randall and R.Sundrum
PRL83 3370 (1999)
(RS1 scenario),

5D curve space with AdS_5 slice:
two 3(brane)+1(extra)+time!



Heavy KK-excitations of gravitons (spin-2 state)

$$G_{KK}, Z_{KK}, Z' \rightarrow e^+e^-, \mu^+\mu^-, \gamma\gamma, jet + jet$$



I.Antoniadis,
PLB246 377 (1990)
TeV^{-1}

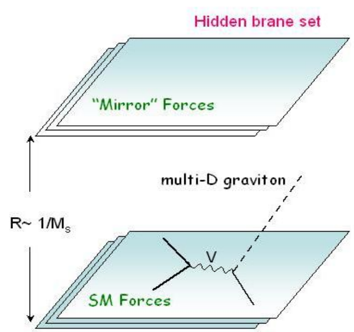
flat 5D space in the simplest case d =1

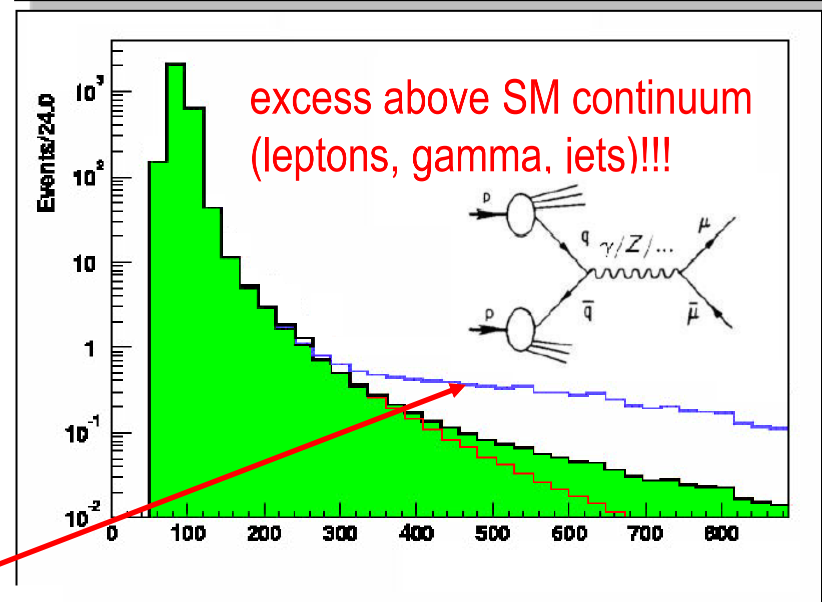
fundamental scale M_D ~ TeV

KK-excitations of SM gauge bosons (spin-1 state like **extra Z′** from extended gauge models**)**

(n up to 7) Extra Dimensions

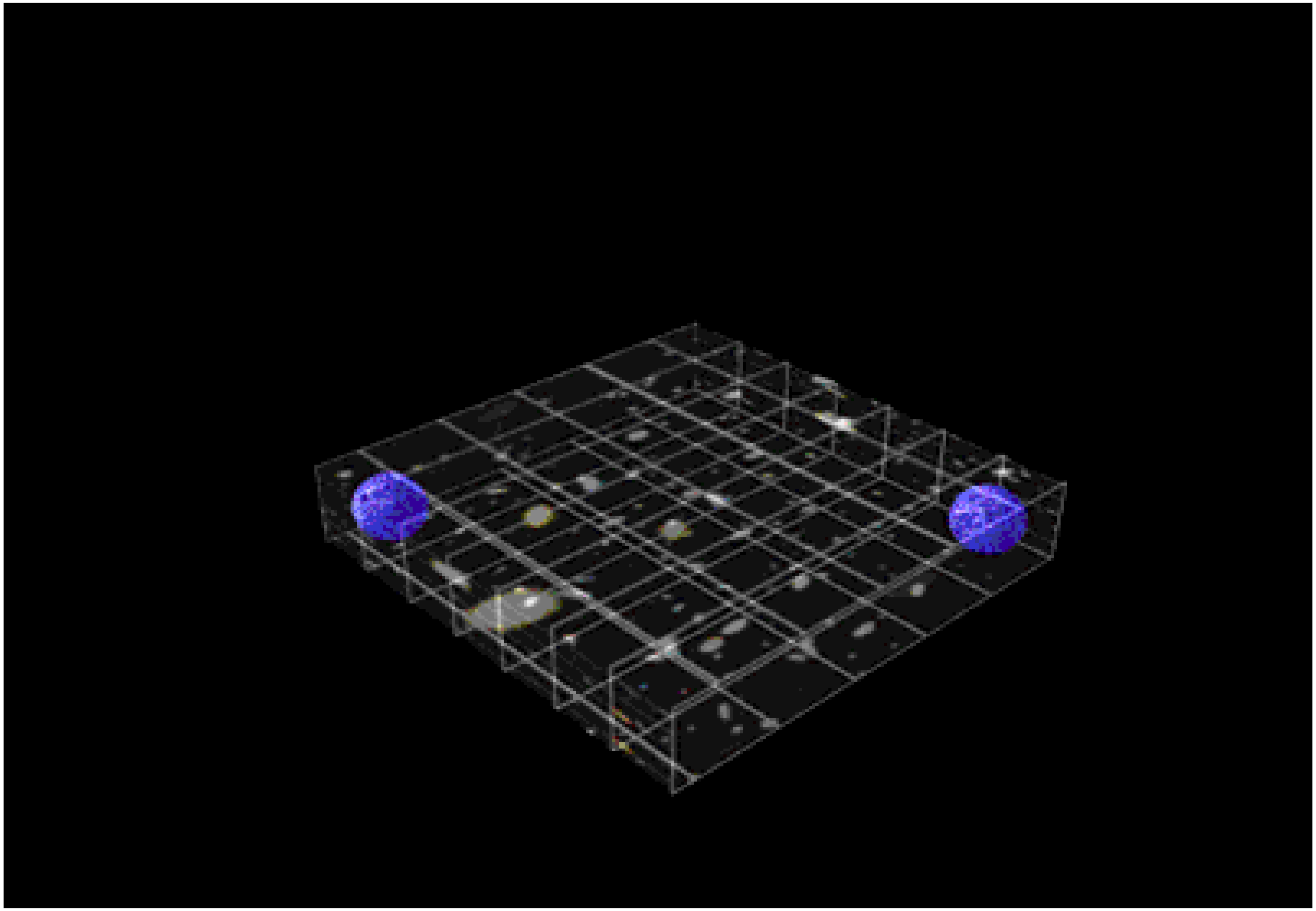
N.Arkani-Hamed, S.Dimopoulos,
G.Dvali, Phys.Lett. B429(1998),
Nuc.Phys.B544(1999)
(ADD scenario)





multiple ADD-graviton contributions to Drell-Yan process

Two-particle Interaction on the 3D-brane



Extra dimensions can be large enough!!!!
~ μm for a flat space

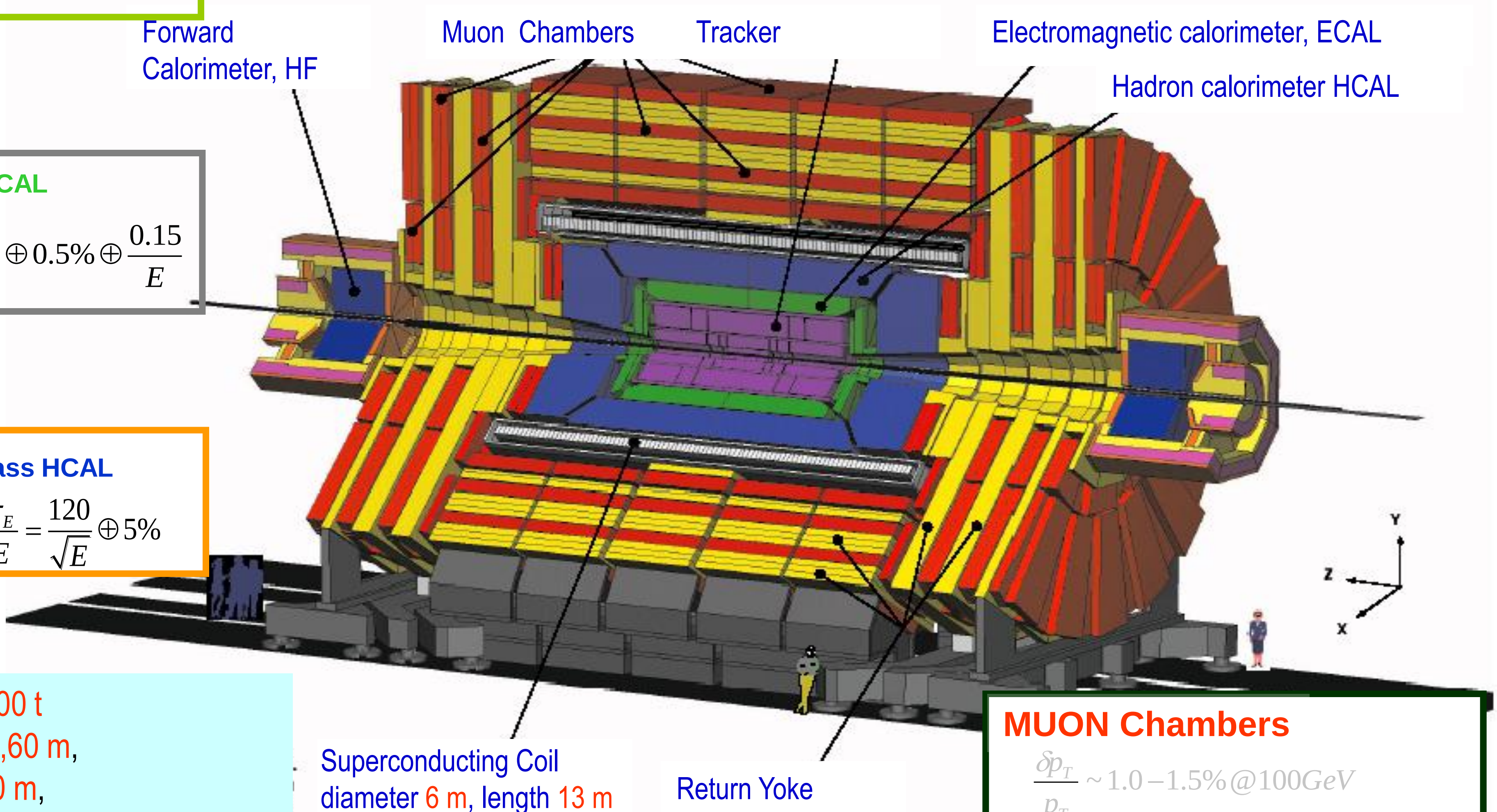
$$R \sim M^{-1}\left(\frac{M_{Pl}}{M}\right)^{2/d} \sim 10^{32/d} \times 10^{-17} \ \text{sm}$$

Compact Muon Solenoid- CMS

Silicon Tracker

$$\frac{\delta p_T}{p_T} \sim 15 \times p_T(TeV)\%$$

Detector subsystems are designed to measure: the energy and momentum of photons, electrons, muons, jets, missing E_T up to a few TeV



$PbWO_4$ ECAL

$$\frac{\sigma_E}{E} = \frac{2.7\%}{\sqrt{E}} \oplus 0.5\% \oplus \frac{0.15}{E}$$

sampling brass HCAL

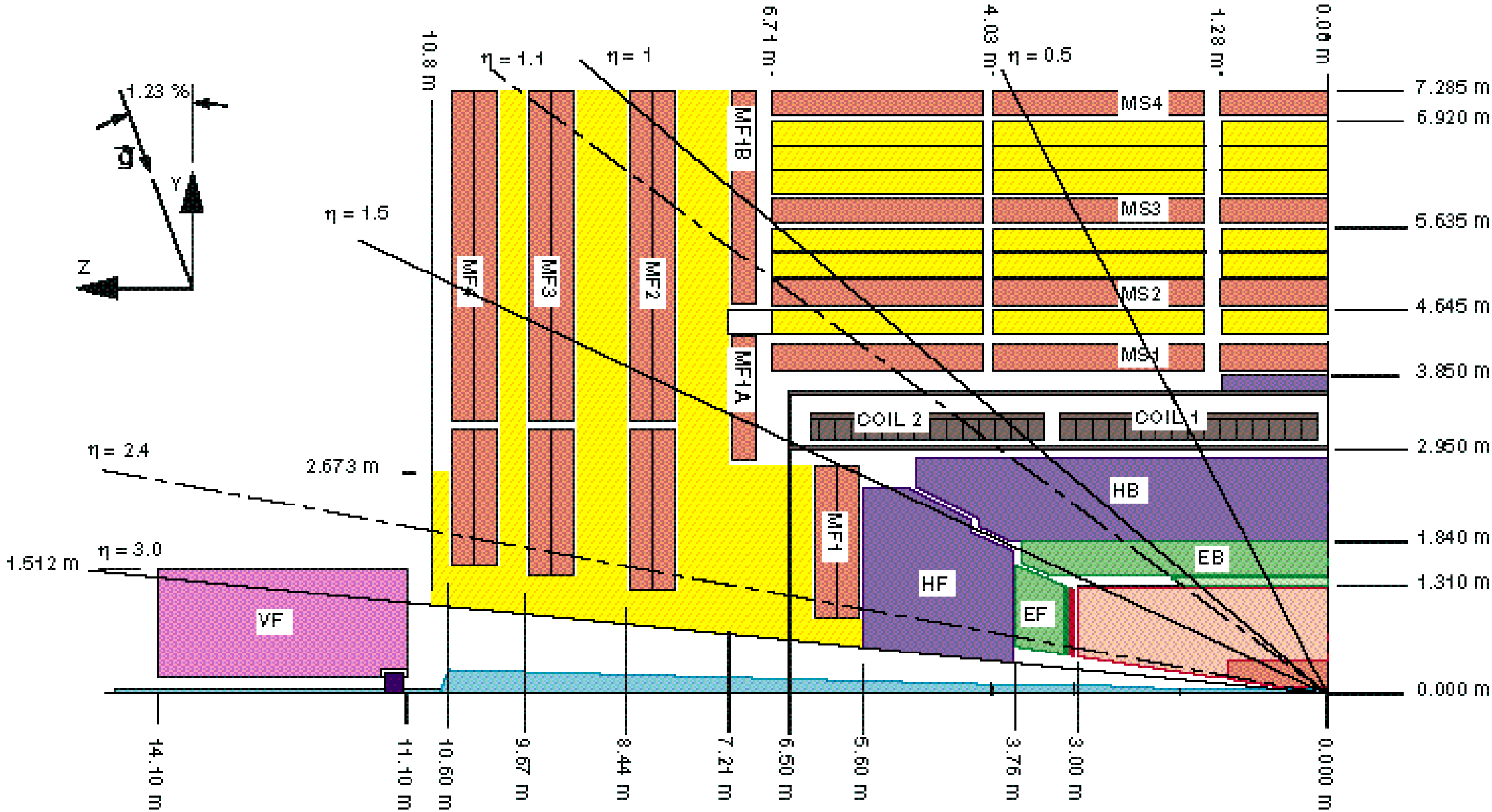
$$\frac{\sigma_E}{E} = \frac{120}{\sqrt{E}} \oplus 5\%$$

weight - 14500 t
diameter - 14,60 m,
length - 21,60 m,
B-field - 4 T

MUON Chambers

$$\frac{\delta p_T}{p_T} \sim 1.0 - 1.5\% @ 100 GeV$$

CMS Longitudinal View



Longitudinal View **CMS - PARA- 008 22/11/94** P.P.

ADD: flat large extra dimensions

N.Arkani-Hamed, S.Dimopoulos, G.Dvali '98

Multidimensional gravity action with multidimensional constant $G_{(D)}$

$$S = -\frac{1}{16\pi G_{(D)}}\int d^D X \sqrt{g^{(D)}} R^{(D)}$$

$$G_{(D)} = \frac{1}{M^{D-2}} \equiv \frac{1}{M^{d+2}}$$

effective

4D-action

$$S_{eff} = -\frac{V_d}{16\pi G_{(D)}}\int d^4 X \sqrt{g^{(4)}} R^{(4)}$$

$$G_{N(4)} = \frac{1}{M_{Pl}^2}$$

Planck mass becomes effective derived from the "true" multidimensional mass scale:

$$M_{Pl}^2 = V_{(d)} M^{d+2}$$ where $$V_{(d)} \propto R^d$$ $$d = D-4$$

A size of extra dimensions depends on a number of ED and a multidimensional scale

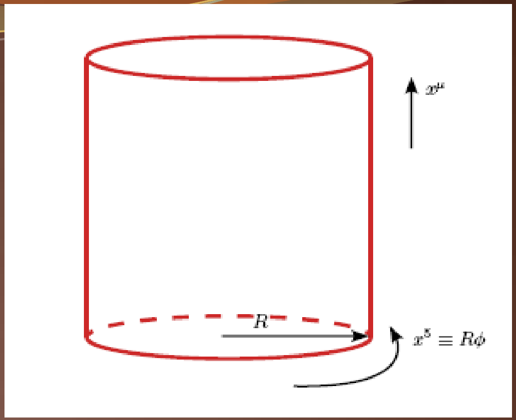
$$R \sim M^{-1}\left(\frac{M_{Pl}}{M}\right)^{2/d} \sim 10^{32/d} \times 10^{-17}\ \text{sm}$$ (for M about a few TэB)

$$G_{N(4)} = \frac{1}{V_{(d)}} G_{N(4+d)}$$

The hierarchy problem solution!

Стандартный калуца-кляйновский подход

(4+1)D-теория свободного скалярного поля. Одно компактное дополнительное пространственное измерение с условием периодичности по доп. коорд.:



$$\eta_{\mu\nu} = +1, -1, -1, ..-1; \quad (\partial_\mu \partial^\mu - \partial_y^2)\phi = 0, \quad \mu = 0,1,2,3$$

КК-декомпозиция:

$$\phi(x, y) = e^{ip_\mu p^\mu} e^{in\frac{y}{R}}, \qquad \mathrm{n} = 0, \pm 1, \pm 2, ...$$

$$\mathrm{p}_\mu p^\mu = \frac{n^2}{R^2} = m^2 \longleftarrow$$ массы КК-мод

угловой момент

Существует однородная нулевая мода с m=0, распространяющаяся вдоль браны (модуль). 4D-лоренц-инвариантность не нарушена, трансляционная инв-ть нарушена в направлении, перпендикулярном бране

m_{KK} не ниже ТэВ (из эксперимента)

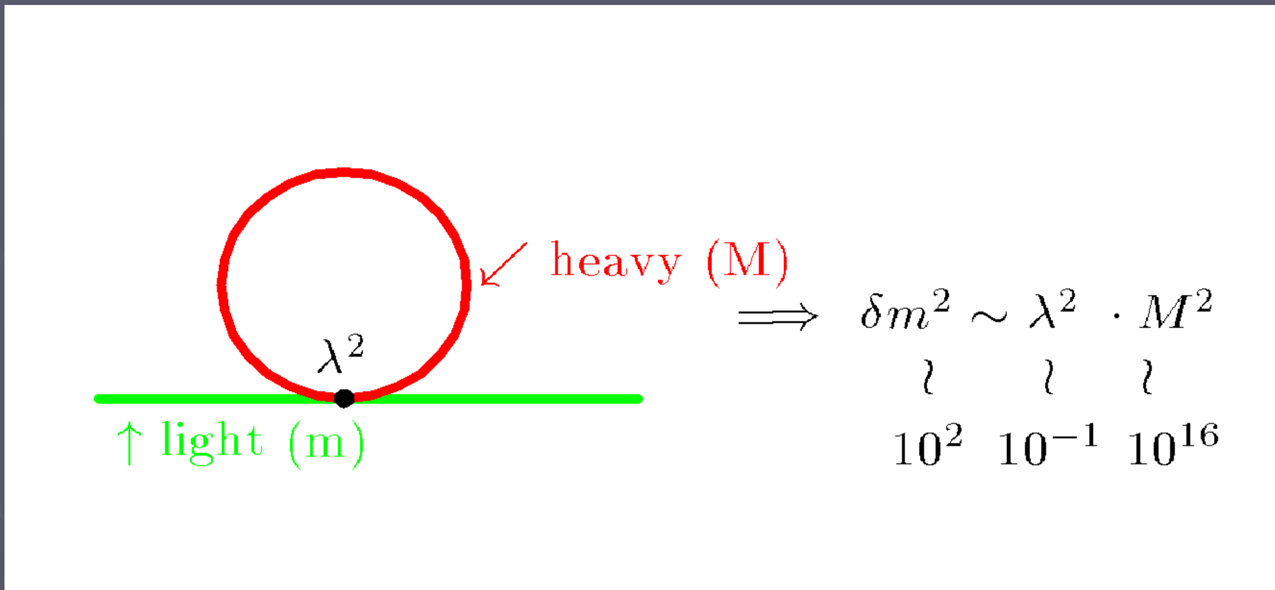
Несколько ED: по-прежнему одна нулевая мода, но много КК-мод с фиксир. массой

$$\phi(x, y) = e^{ip_\mu p^\mu} e^{in_1\frac{y_1}{R_1}} \mathrm{e}^{\mathrm{i}n_2\frac{y_2}{R_2}} ...\mathrm{e}^{\mathrm{i}n_N\frac{y_N}{R_N}}, \qquad \mathrm{y}_{1,...}y_N \to R_1,...R_N$$

$$m_{\{n\}}^2 = \sum \frac{n_i^2}{R_i^2}$$

Higgs selfenergy – quadratic divergency and fine tuning

First formulated by S.Weinberg ’76



Radiative corrections to the “naked” higgs mass

↓

very large contributions

↓

must be compensated by a bare mass value m_0:

From the gauge sector →

$$m_H^2 = m_0^2 + (c_2 g^2 + c_4 g^4 + ..)\Lambda^2$$

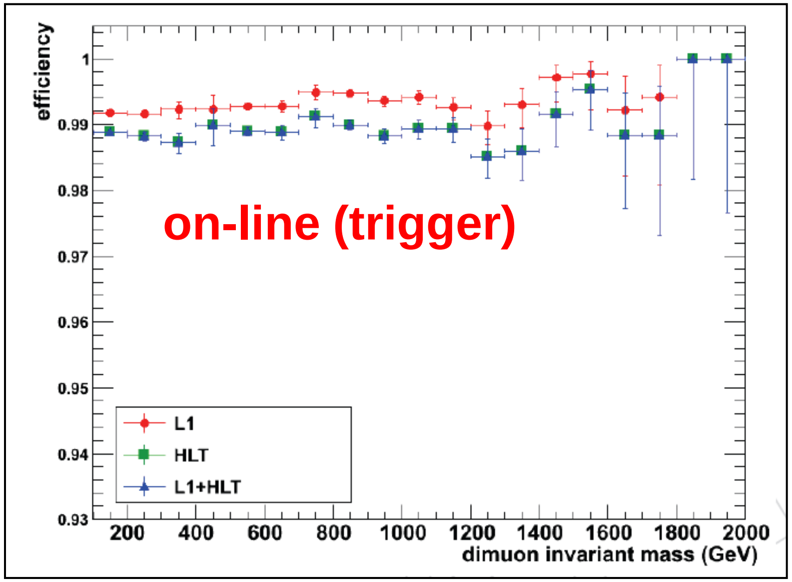
How large the UV scale Λ can be? → Two standard UV cut-offs →

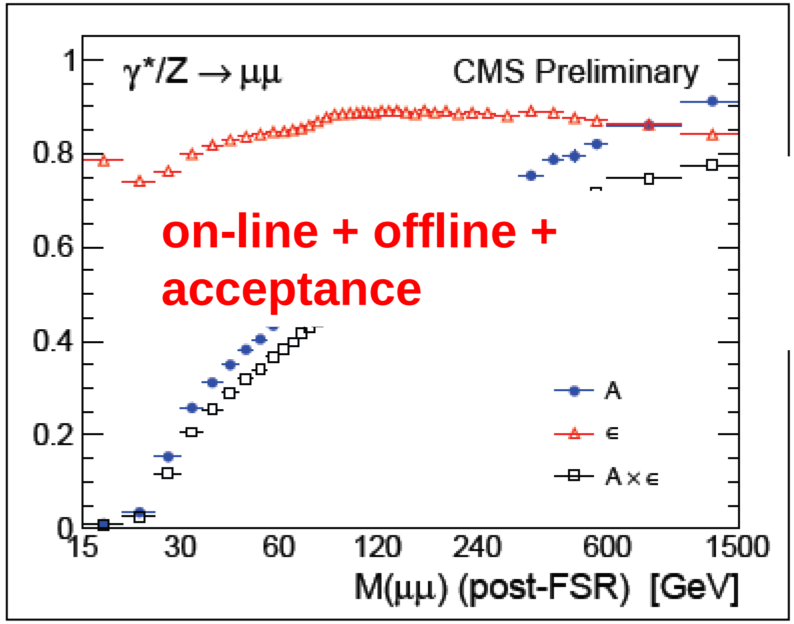
$$M_{GUT} \approx 10^{16} GeV \qquad M_{Pl} \approx 10^{19} GeV$$

$$\left(\frac{\eta}{\Lambda}\right)^2 \approx 10^{-28} - 10^{-34}$$

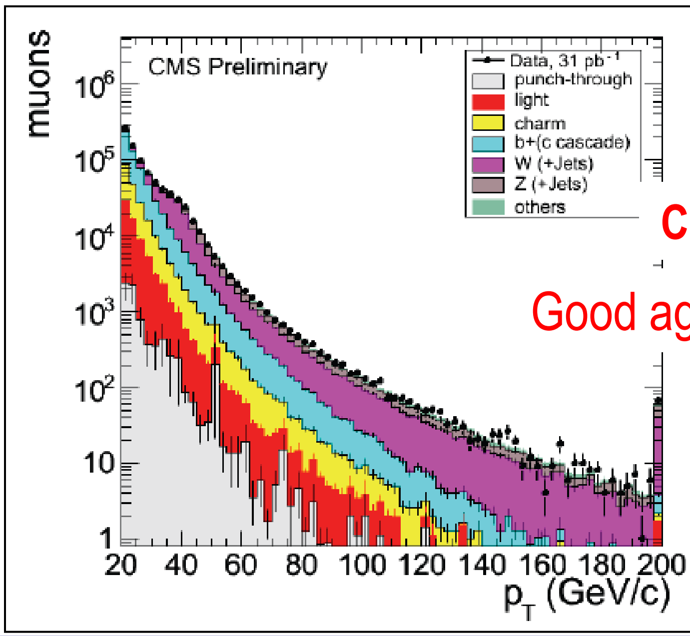
Absolutely unclear what can provides fine-tuning at such a small level !

Trigger and Reconstruction Performance



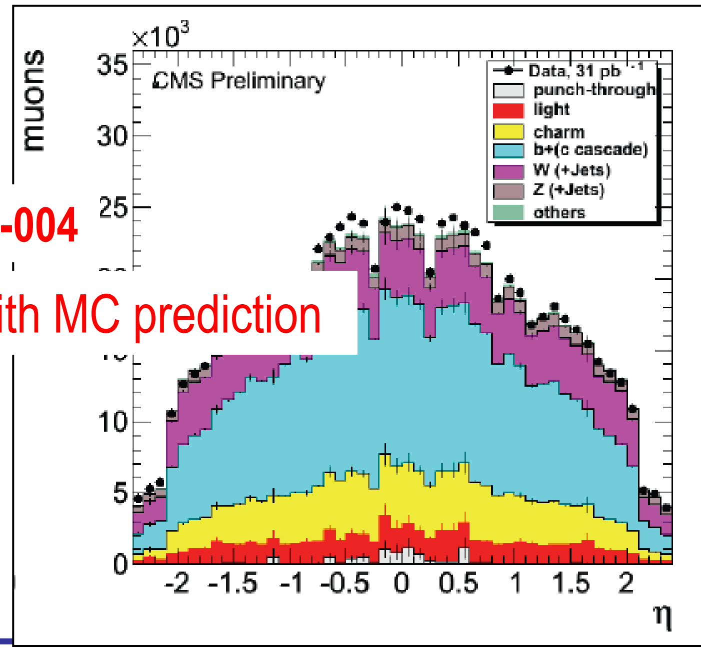


CMS EWK-10-007
arXiv:1108.0566
JHEP10 (2011) 007



CMS MUO-10-004

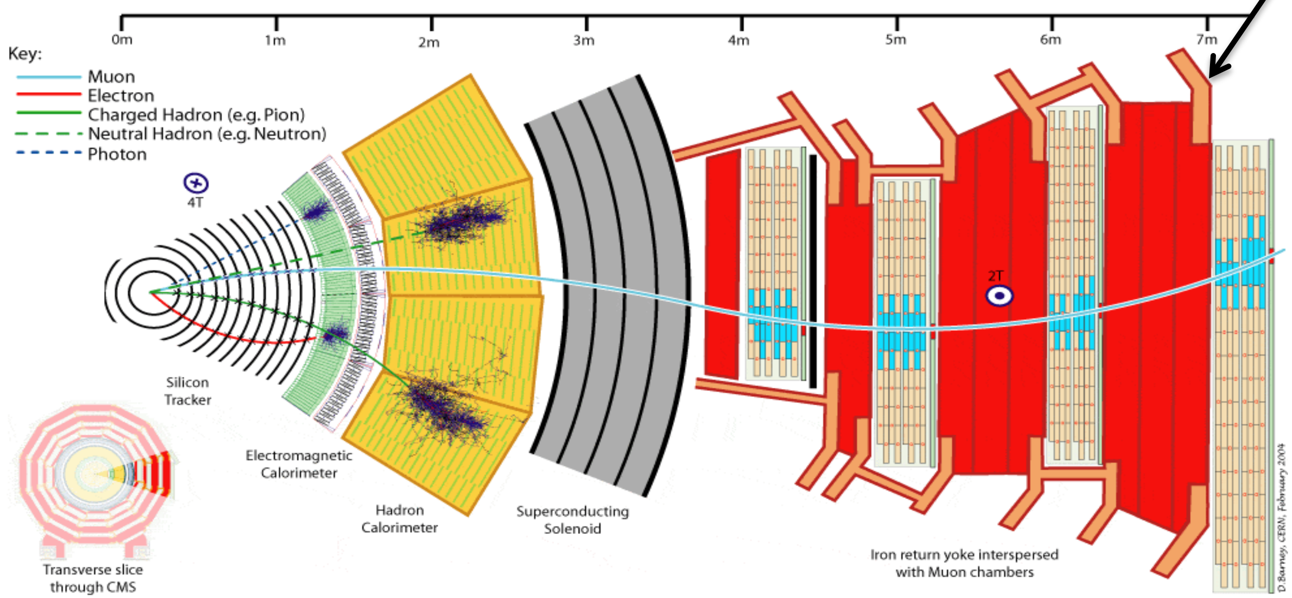
Good agreement with MC prediction

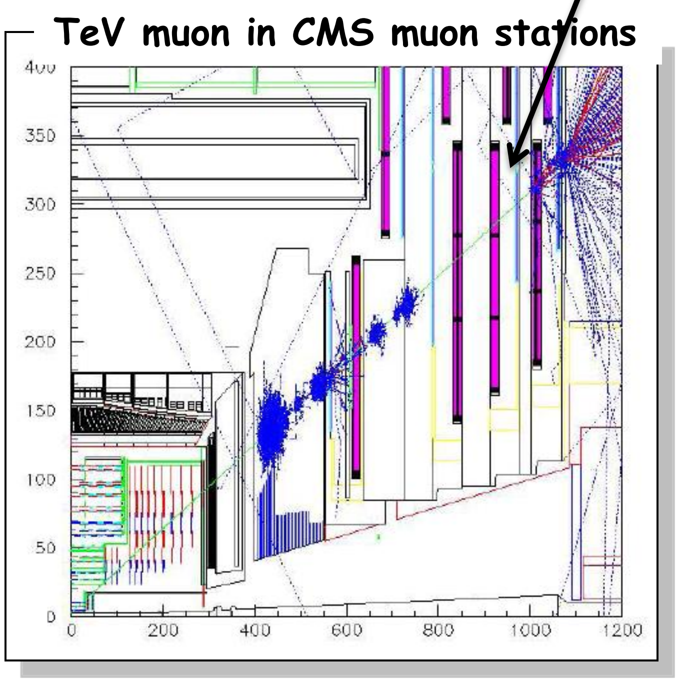


Features of high energy muons

Features of a muon of high energy (a few hundred GeV - TeV)

- ❑ low curvature of muon trajectory $\Rightarrow$ limited pT estimation precision
- ❑ bremsstrahlung and EM showering $\Rightarrow$ contaminated events, problems with isolation
- ❑ precision is sensitive extremally to detector misalignment





new algorithms (or improvements), new trigger paths for high energy particles (no calorimeter isolation), better understanding systematic effects, tested with MC data and experimental data (cosmic muons and SPS beam)

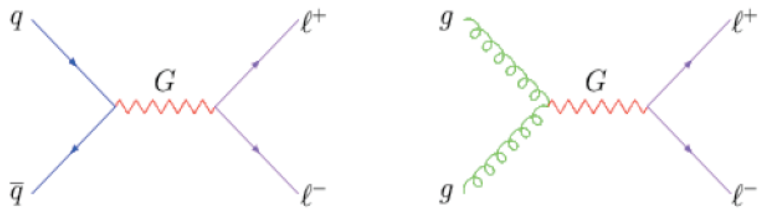
Table 1: Number of dilepton events with invariant mass in the control region $120 < m_{\ell\ell} < 200$ GeV and the search region $m_{\ell\ell} > 200$ GeV. The total background is the sum of the SM processes listed. The yields from simulation are relatively normalized using the expected cross sections, and overall the simulation is normalized to the data using the number of events in the mass window $60 - 120$ GeV. Uncertainties include both statistical and systematic components added in quadrature.

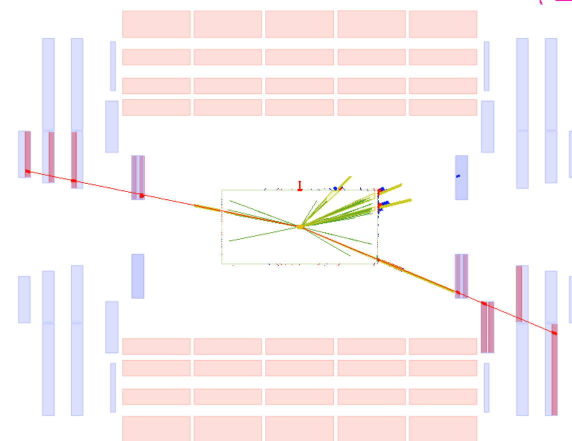
Source	Number of events			
	Dimuon sample		Dielectron sample	
	(120 – 200) GeV	>200 GeV	(120 – 200) GeV	>200 GeV
CMS data	5216	1095	3410	809
Total background	5537 ± 250	1100 ± 48	3375 ± 161	787 ± 67
Z/γ^*	5131 ± 246	922 ± 44	2992 ± 149	622 ± 62
$t\bar{t}$ + other prompt leptons	404 ± 46	178 ± 20	275 ± 20	118 ± 8
Multi-jet events	3 ± 3	0	107 ± 43	46 ± 18

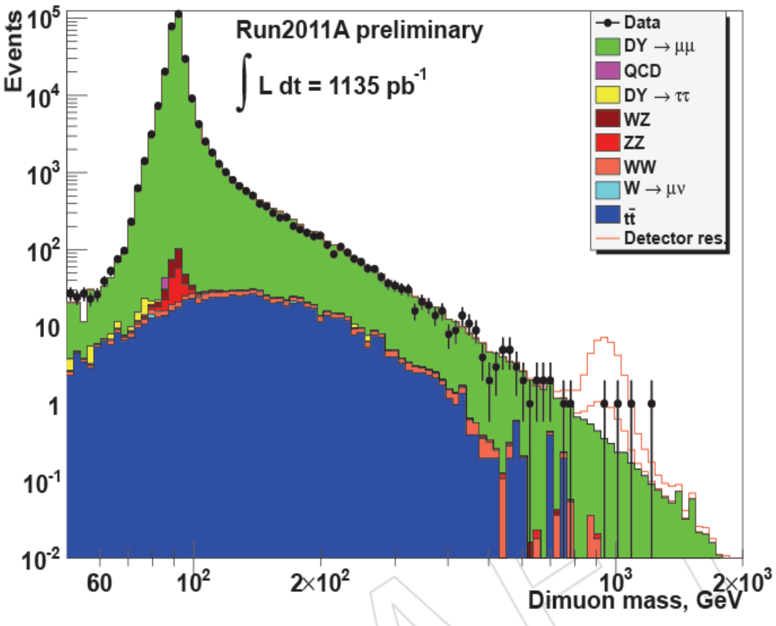
Efficiencies and Background

New Physics ($Z'/Z_{KK}/G_{KK}$) contributions to SM processes:

$q\bar{q} \rightarrow l^+l^-$ $\qquad$ $gg \rightarrow l^+l^-$







CMS PAS EXO-11-019

✓ $\varepsilon_{trigger}$ = 95% (barrel) and 89.9% (endcap) with Data/MC scale factors of 0.978 ± 0.003 and 0.966 ± 0.004, respectively

✓ $\varepsilon_{identification}$ = 96.4% (barrel) and 96.0% (endcap) with Data/MC scale factor of 0.999 ± 0.003 and 0.983 ± 0.005, respectively

✓ $\varepsilon_{reconstruction}$ = 99 %

✓ dimuon mass resolution is estimated to be 4% at 500 GeV and 7% at 1 TeV.

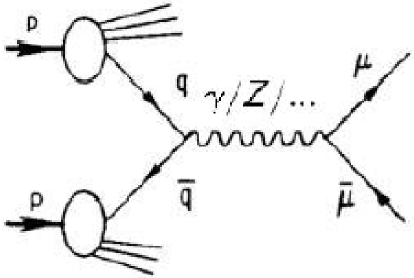
✓ Z/γ^* + EWK (Pythia + FEWZZ V1.X for NNLO + CTEQ6.1 PDFs), QCD (MadGraph)+data estimation

Uncert. of backg.: K-factor (< 10 %) and PDF (~ 12 %)

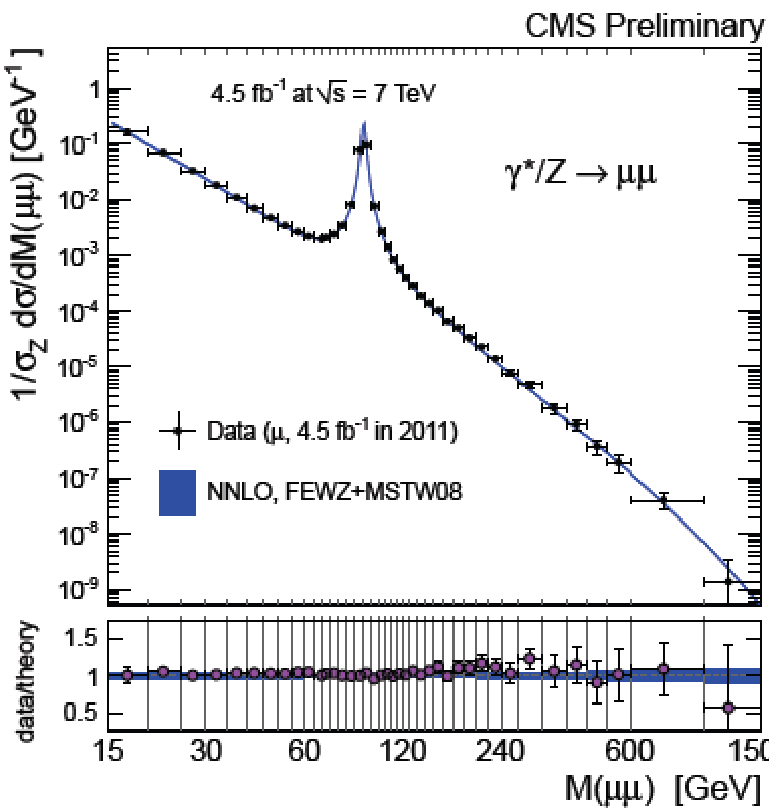
CMS Data: 5216 (120-200 GeV),
1095 (>200 GeV)

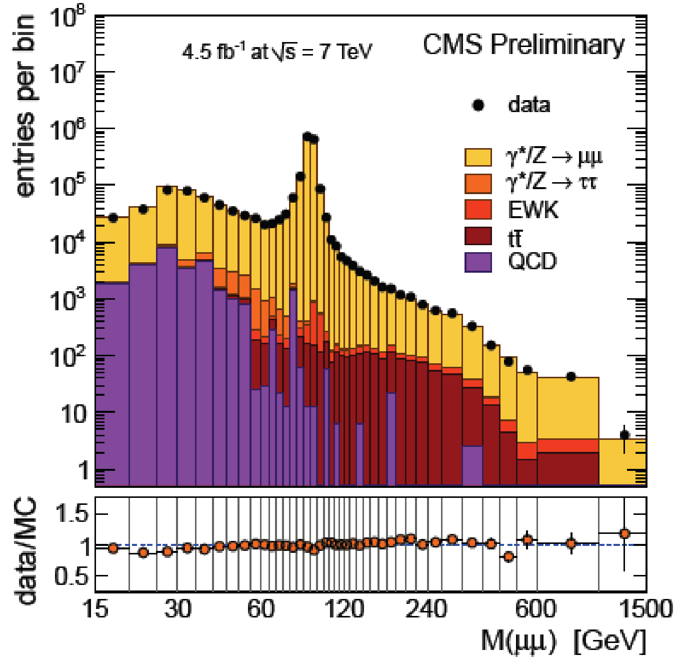
Total bckg.: 5131 ± 250 (120-200 GeV)
922 ± 44 (>200 GeV)

Drell-Yan Processes



CMS-EWK-10-007
J. High Energy Phys. 10 (2011) 007
EWK-11-007 (4.5 fb^{-1})





Background:
EWK – from MC
QCD – from MC + estimation from data

$0 < M_{\ell^+\ell^-} < 1500$ GeV

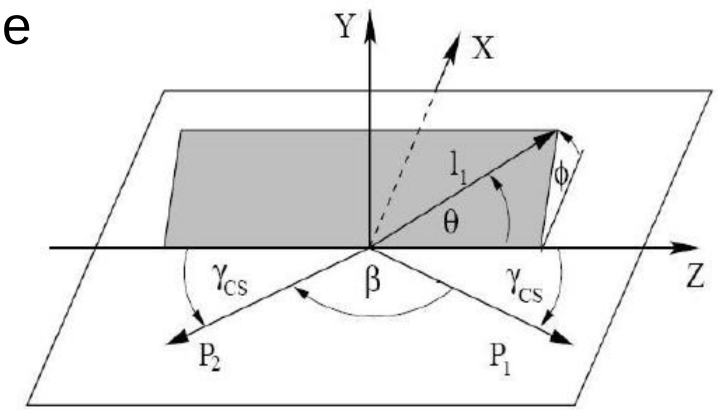
Uncertainties:
efficiency (1.1-2.1 %), background (3.6-10%)
unfolding (up 1.7 %), FSR (up to 2%),
other (up to 3%), acceptance (up to 2.2 %)

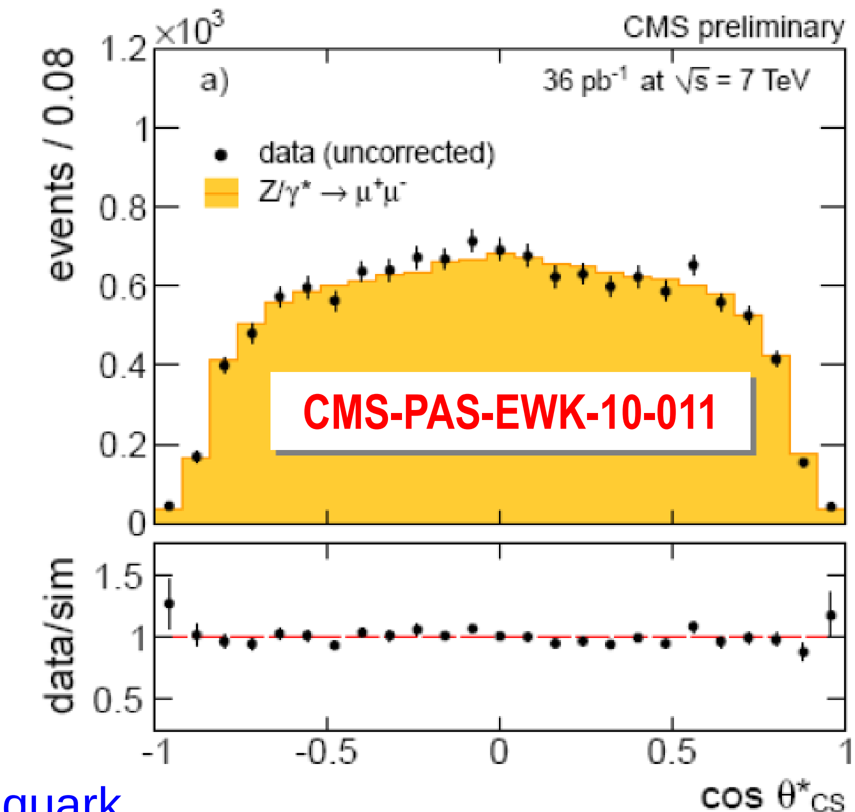
Good agreement CMS Data and SM predictions (NLO MC generator POWHEG + MSTW08 PDFs)

Drell-Yan Angular Distributions

$$\frac{d\sigma}{d\cos\theta} = A(1+\cos^2\theta) + B\cos\theta$$

θ - angle between the lepton momenta and a z axis that bisects the angle between the quark momentum and the anti-quark momentum in the Collins-Soper frame





for pp collider the quark direction is unknown

⇩

boost direction of dimuon approximates quark direction

⇩

mistag probability (fraction of events with wrong quark direction) – dilution effect is more significant for small values of dileption rapidity

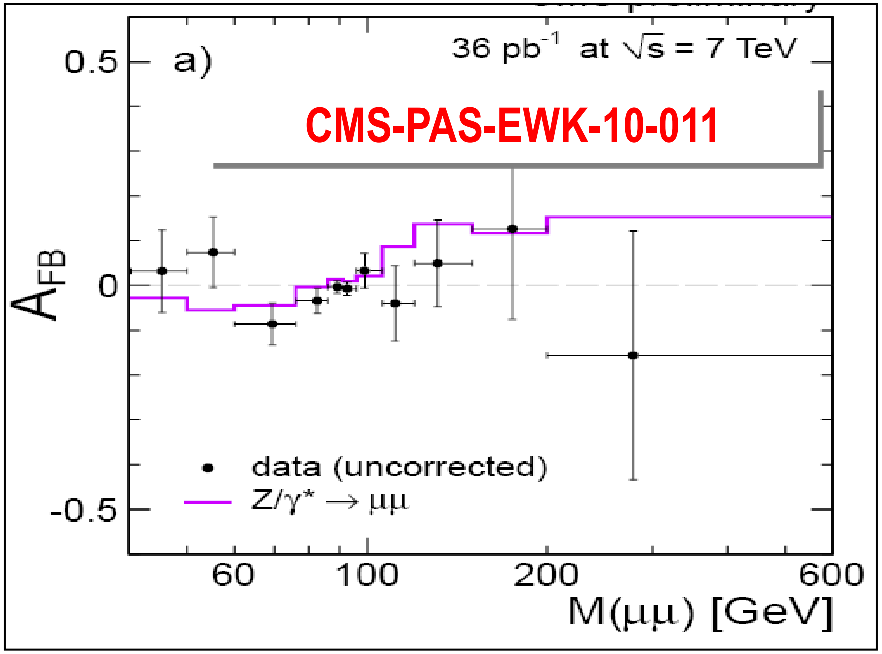
Forward-Backward Asymmetry

$$\frac{d\sigma}{d(\cos\theta^*)} = \frac{1}{2\left(1+\frac{b}{3}\right)}\left(1 + b\cos^2\theta^*\right) + A_{FB}\cos\theta^*$$

$$A_{\mathrm{FB}} = \frac{\sigma_{\mathrm{F}} - \sigma_{\mathrm{B}}}{\sigma_{\mathrm{F}} + \sigma_{\mathrm{B}}} = \frac{3B}{8A}$$

$$\sigma_{\mathrm{F}} = \int_0^1 \frac{d\sigma}{d(\cos\theta)} d(\cos\theta)$$

$$\sigma_{\mathrm{B}} = \int_{-1}^0 \frac{d\sigma}{d(\cos\theta)} d(\cos\theta)$$



AFB value is sensitive to contribution both vector and axial-vector couplings

⇒ Test of SM / new physics

“Dilution” asymmetry measurements:

- bin-to-bin migration due to finite detector resolution
- Final-State-Radiation (FRS)
- acceptance cuts
- unknown quark/antiquark direction for the LHC

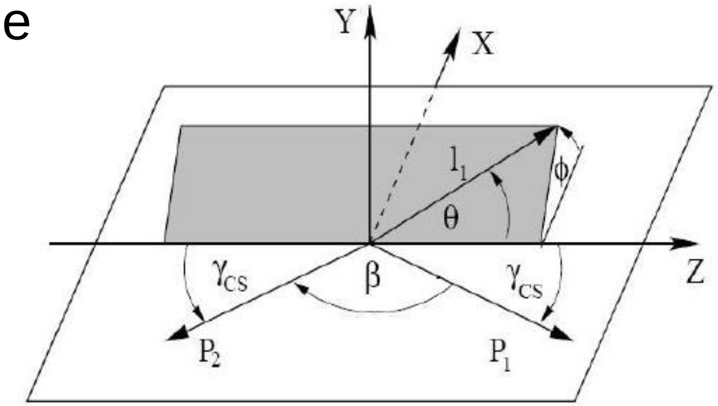
Results with corrections for ~5 fb-1 is ready, but is not approved by the Collaboration

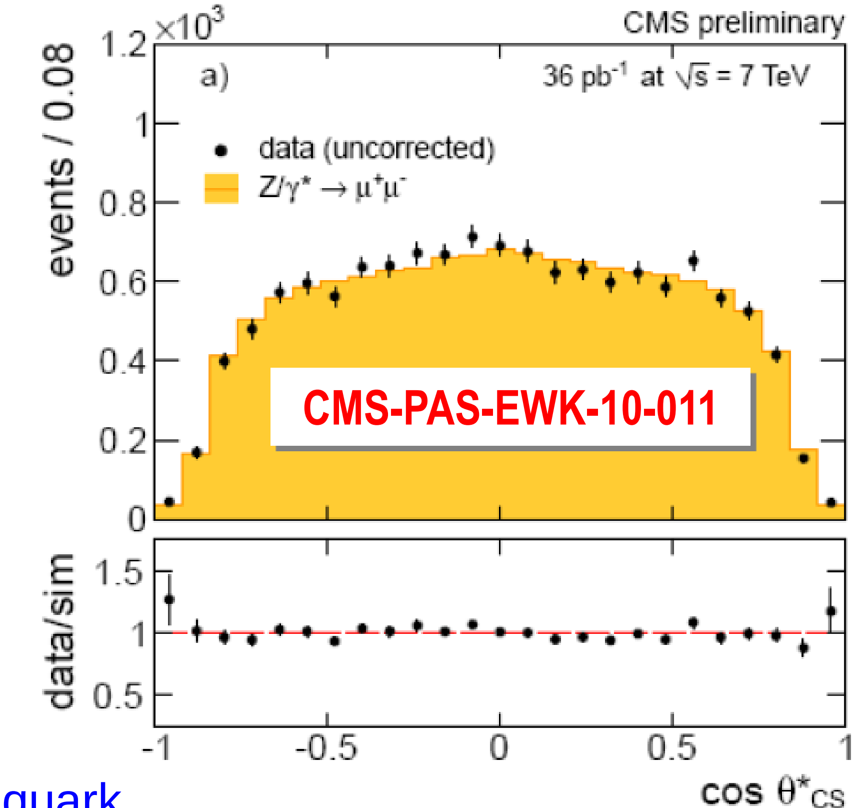
Will be available for public discussion for two weeks!

Drell-Yan Angular Distributions

$$\frac{d\sigma}{d\cos\theta} = A(1+\cos^2\theta) + B\cos\theta$$

θ - angle between the lepton momenta and a z axis that bisects the angle between the quark momentum and the anti-quark momentum in the Collins-Soper frame





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