

Consuntivo delle attività di Gruppo I a Pavia nel 2012/2013

Giacomo Polesello (INFN Pavia)

Introduzione

- La CERN si occupa di esperimenti di fisica delle particelle con acceleratori
- La ricerca, dopo 40 anni di successi dello Standard Model (SM) è focalizzata al completamento del medesimo (Higgs, misure di precisione) e al suo superamento attraverso la ricerca di nuova fisica
- Ricerca sviluppata su due frontiere:
 - Frontiera dell'energia: acceleratori ad alta energia per mettere alla prova il modello a distanze sempre più piccole
 - Frontiera della precisione: studio ad alta precisione di decadimenti di particelle SM per osservare discrepanze con le previsioni del SM generate da correzioni radiative coinvolgenti particelle non presenti nel modello

Attività a Pavia

- A Pavia gruppi attivi su entrambe le frontiere
 - Frontiera dell'energia
 - CDF
 - ATLAS
 - CMS
 - Frontiera della precisione
 - MEG
 - p-SuperB

CDF



1996: rolling in CDF detector



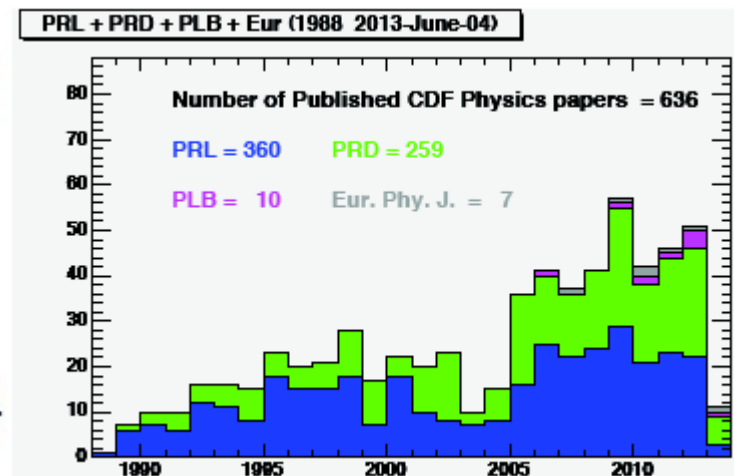
10 fb⁻¹ of p-pbar
data recorded
until 30th Sept
2011



2013: CDF detector out of the
collision hall for good

Unique data

- Unique **initial state** vs LHC (e.g. Asymmetry measurements, flavour physics)
- **Multiple energy** collisions (300 GeV, 900 GeV, 1960 GeV)
- Well understood experiments: legacy **precision measurements** (e.g. M_W , M_t)
- Continued **physics output**
 - Expect long tail
 - ~ 15 papers published-accepted in 2013 to-date



CDF data preservation

At Fermilab, data preservation project involving CDF and D0 experiments and the Computing Sector.

Goal:

- Maintain full analysis capability
- Seek common solutions between experiments where possible
- Until 2020 (SL6 support) *at minimum*

Work ongoing on different areas

- **Data preservation:** migration to new media and new data access system
- **Software preservation:** CDF legacy software release in preparation
- **Job submission:** opportunistic usage of Fermilab resources using virtual machines
- **Documentation:** new web-page, documents archived in Inspire

CDF, partecipazione pavese

1 FTE, Gianluca Introzzi

Dal 2012 responsabile (con G. Bellettini) dei summer student italiani a Fermilab (NON solo a CDF, ma di tutti quelli presenti al laboratorio).

In particolare, nel 2012 ha seguito uno di loro nell'analisi "Search for light Higgs and new physics in associate production with Top quark pairs"

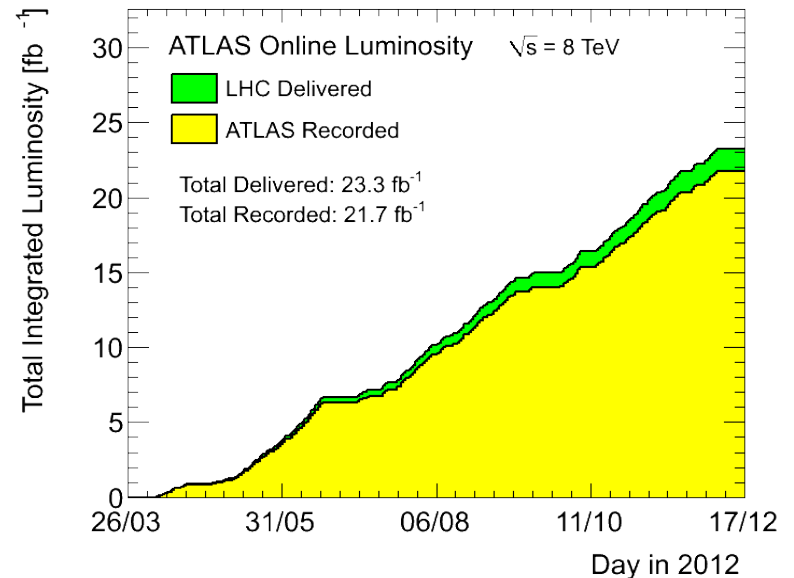
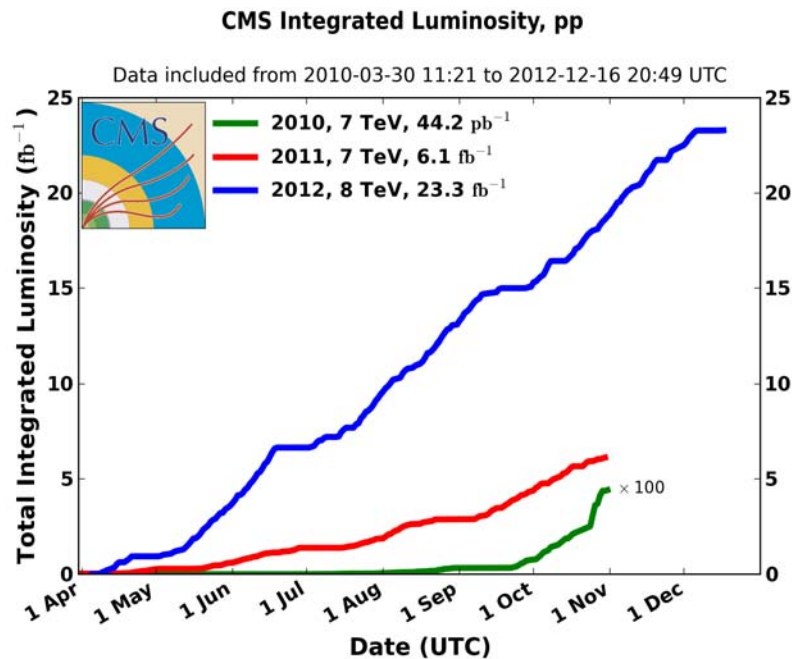
Nell'estate 2013 svolgerà lo stesso incarico, seguendo stavolta un' analisi su "Multiple p-pbar interactions at CDF".

LHC

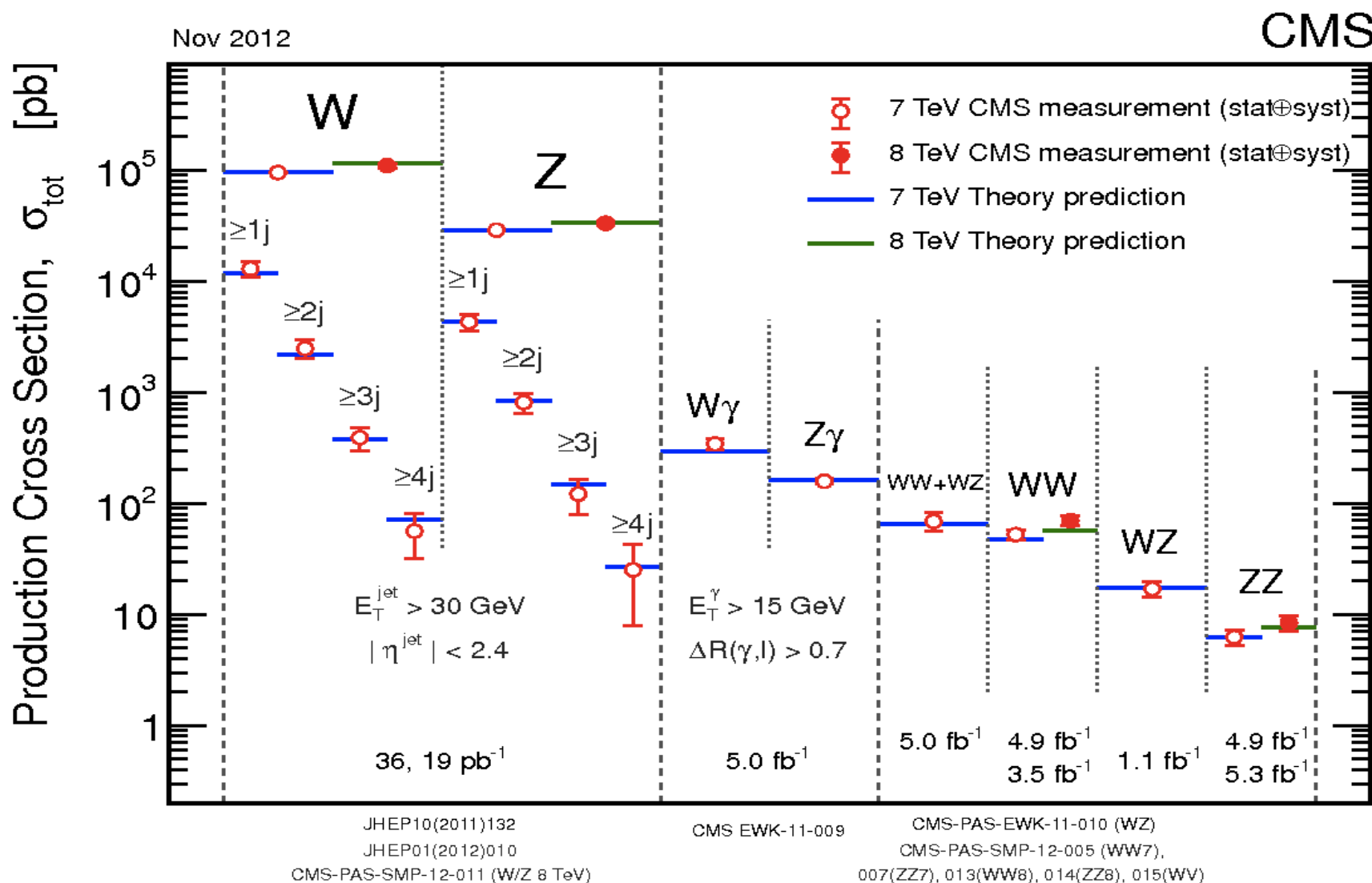
2012 – un anno d'oro per il progetto LHC

Luminosità integrata dell'LHC di più 20 fb⁻¹

Entrambi i rivelatori hanno funzionato con altissima efficienza



Abbiamo misurato con precisione numerosi processi SM

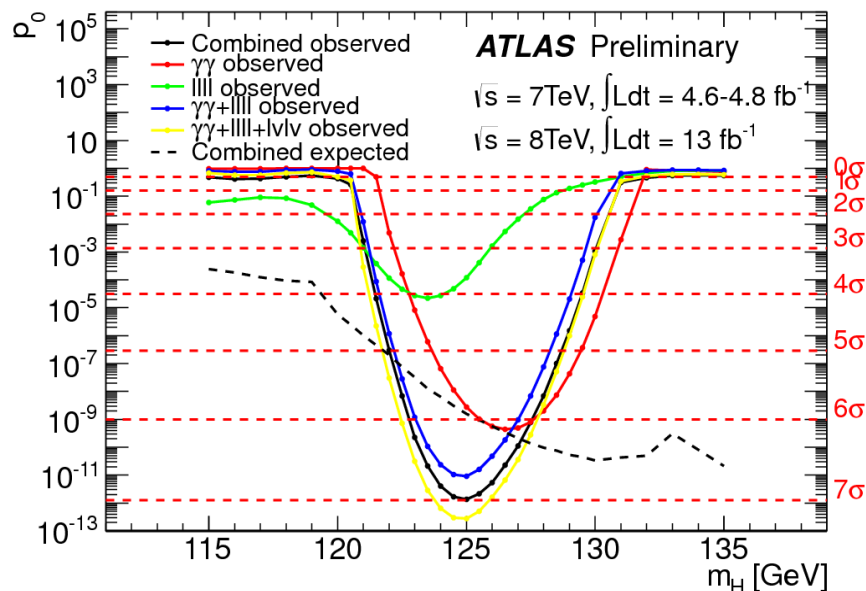
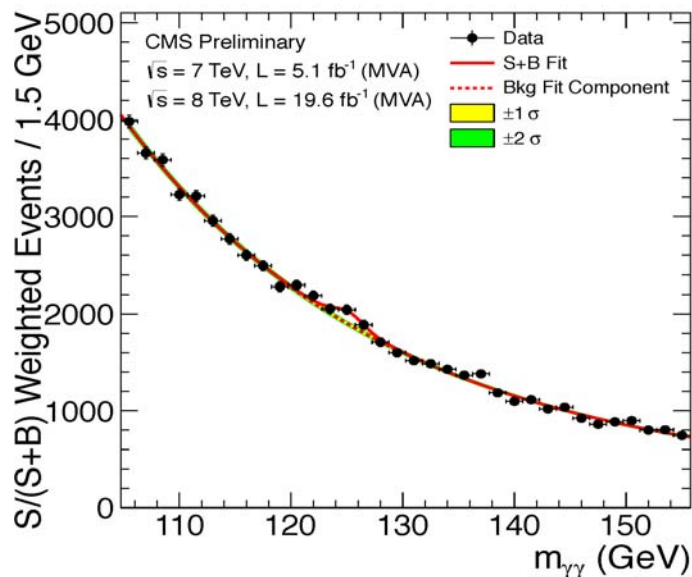
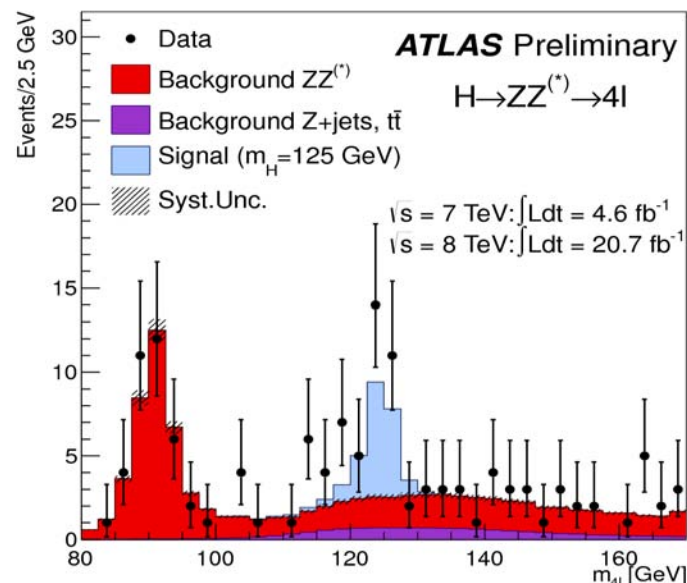


La scoperta dell'Higgs e' andata su tutti I giornali

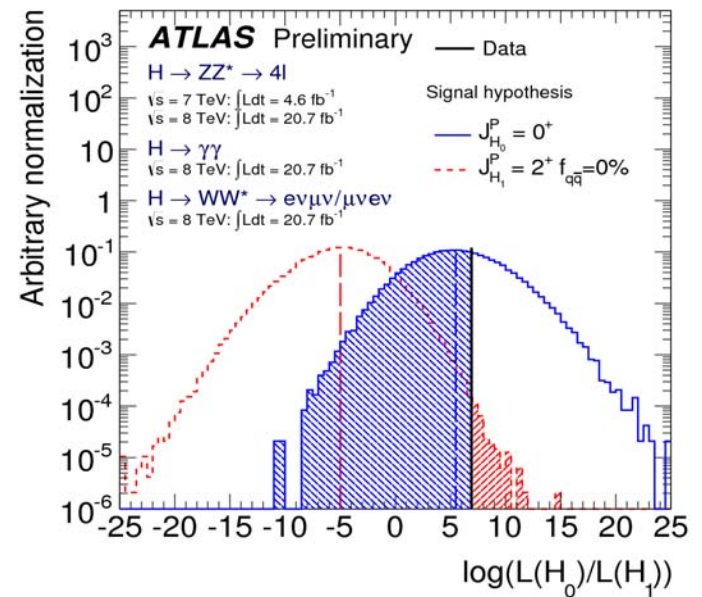
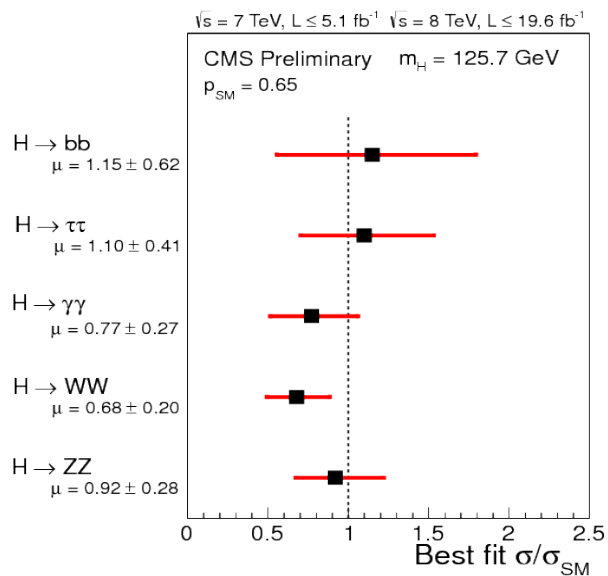
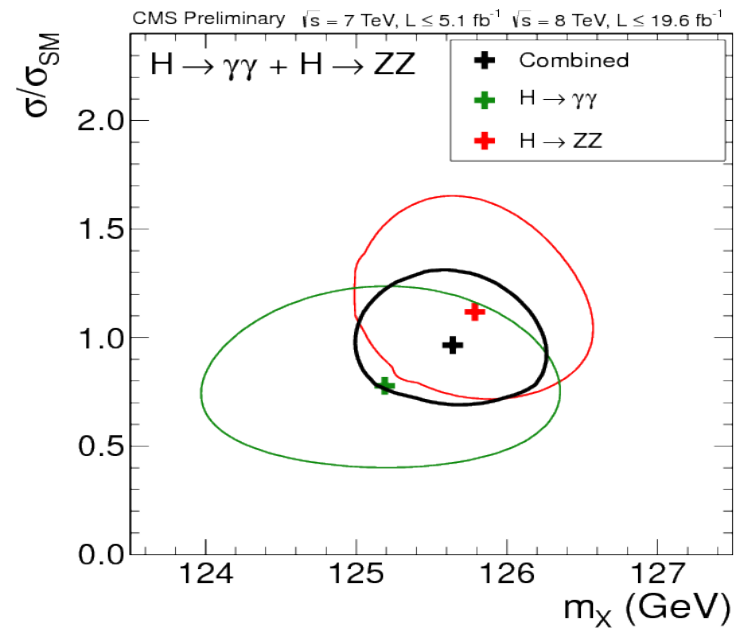


Chiario segnale in diversi canali
di decadimento

Significanza combinata in ATLAS
al di sopra di 7 sigma



...ne stiamo misurando le proprietà



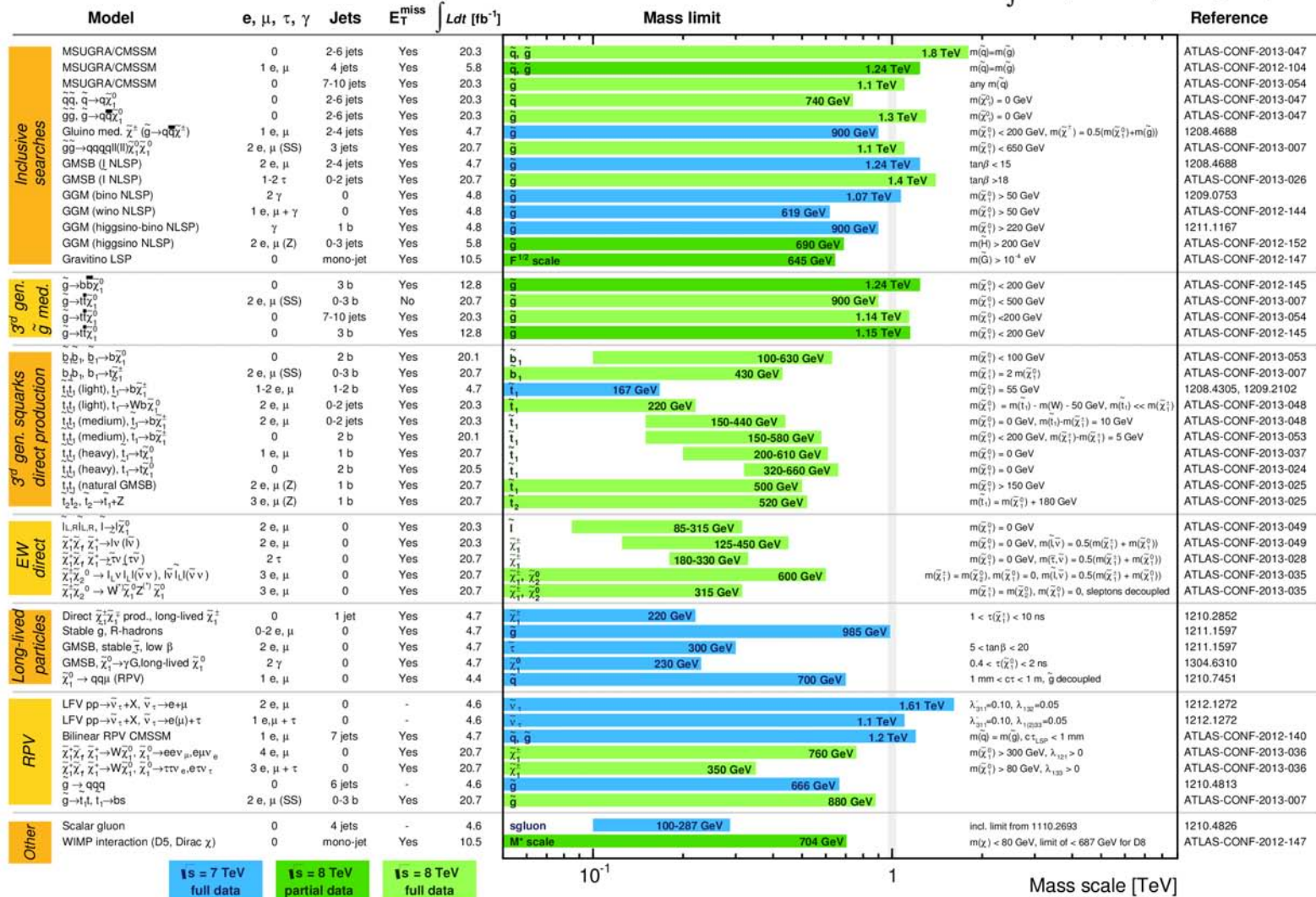
E abbiamo escluso la presenza di nuova fisica su un'ampia parte dello spazio dei Parametri sotto 1 TeV

ATLAS SUSY Searches* - 95% CL Lower Limits

Status: LHCP 2013

ATLAS Preliminary

$$\int L dt = (4.4 - 20.7) \text{ fb}^{-1} \quad \sqrt{s} = 7, 8 \text{ TeV}$$



*Only a selection of the available mass limits on new states or phenomena is shown. All limits quoted are observed minus 1σ theoretical signal cross section uncertainty.

Consuntivi 2012

Gruppo ATLAS Pavia

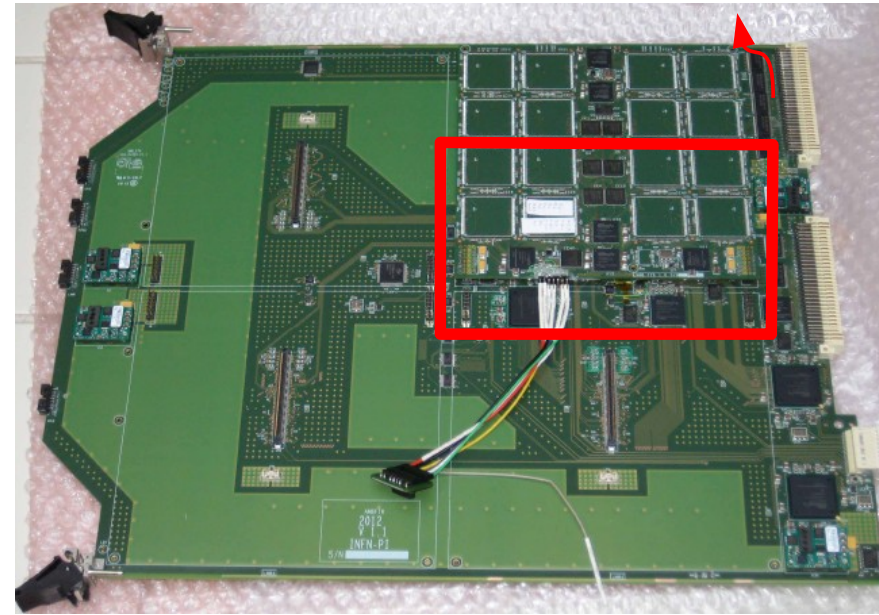
Pavia, 13 giugno 2013

Manutenzione e servizi per i rivelatori di muoni

- Portato a termine il lavoro di sostituzione delle ventole nei generatori primari dei muoni (14 unità con 2 ventole ciascuno). Le nuove hanno il sensore di velocità e sono monitorate attraverso l'interfaccia realizzata in sezione (nel 2011).
- E' continuata la manutenzione ordinaria dei moduli alimentatori di MDT e RPC nel laboratorio di test appositamente attrezzato.
- La riprogettazione dei carichi di bassa tensione per il laboratorio di test è terminata, i nuovi carichi saranno installati e resi operativi nel 2013.

FTK: LAMB

- Completato il layout della mezzanina con le memorie associative (LAMB)
- Prototipo prodotto dopo svariate modifiche necessarie a causa della complessità realizzativa dello stampato a multistrati
- Prototipo testato in autunno presso la sezione di Pisa, per carenza di manpower a Pavia
- Versione successiva del prototipo, con interfacce basate esclusivamente su bus seriali ad alta velocità (fino a 5 Gbit/s), passata sotto la responsabilità di Pisa, sempre per la carenza di manpower a Pavia



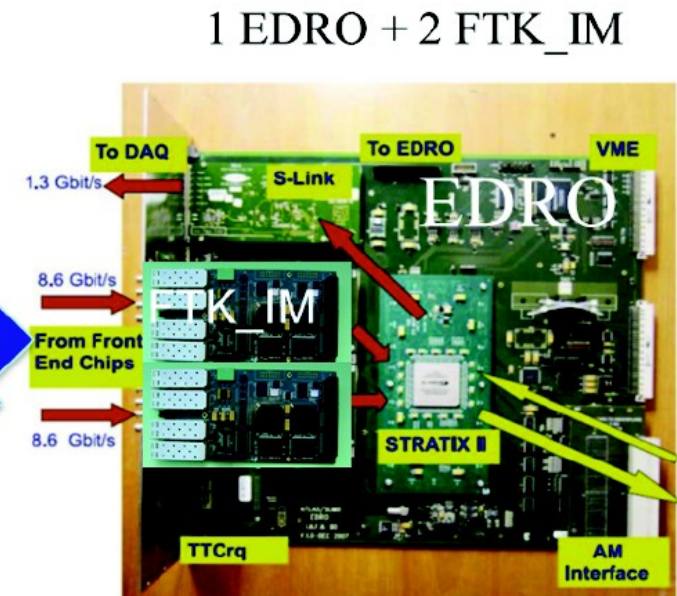
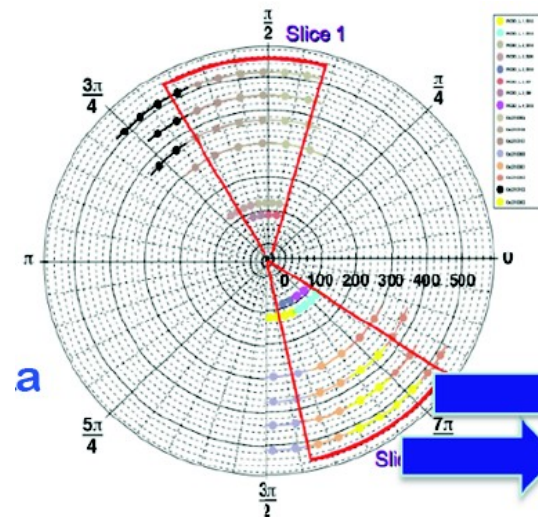
FTK: HW di integrazione in ATLAS

- Definita la meccanica dei crate VME 9U da 5kW che dovranno ospitare le schede di memorie associative. Prototipo discusso con Wiener, acquistato e installato al Cern per test (vedi figura a fianco)
- Definito layout di massima degli 8 rack che ospiteranno l'hardware a partire dal 2015. Sei di questi dovranno essere installati ex-novo, mentre due saranno recuperati da altre attività



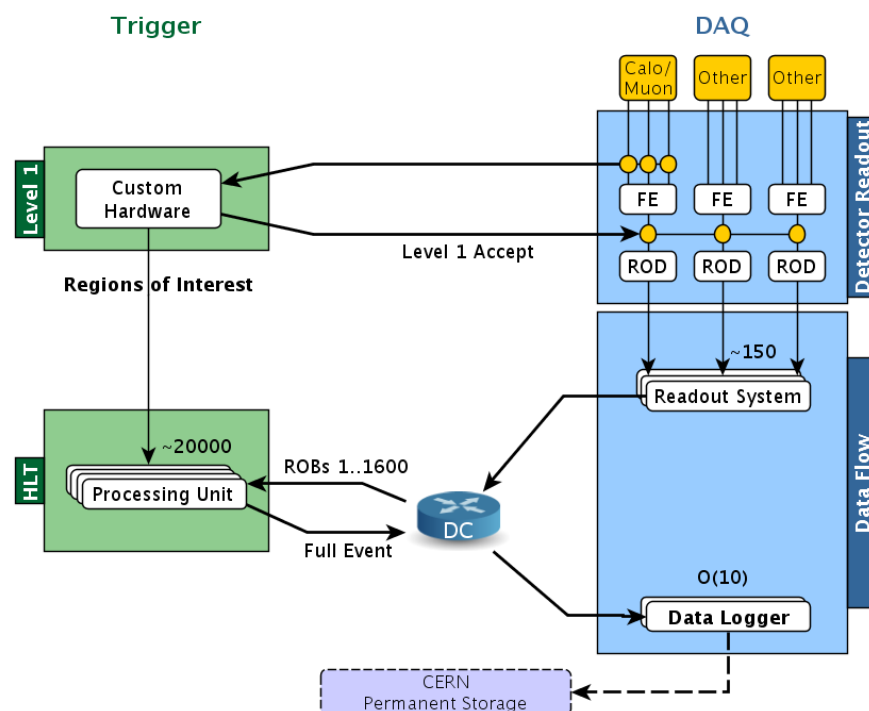
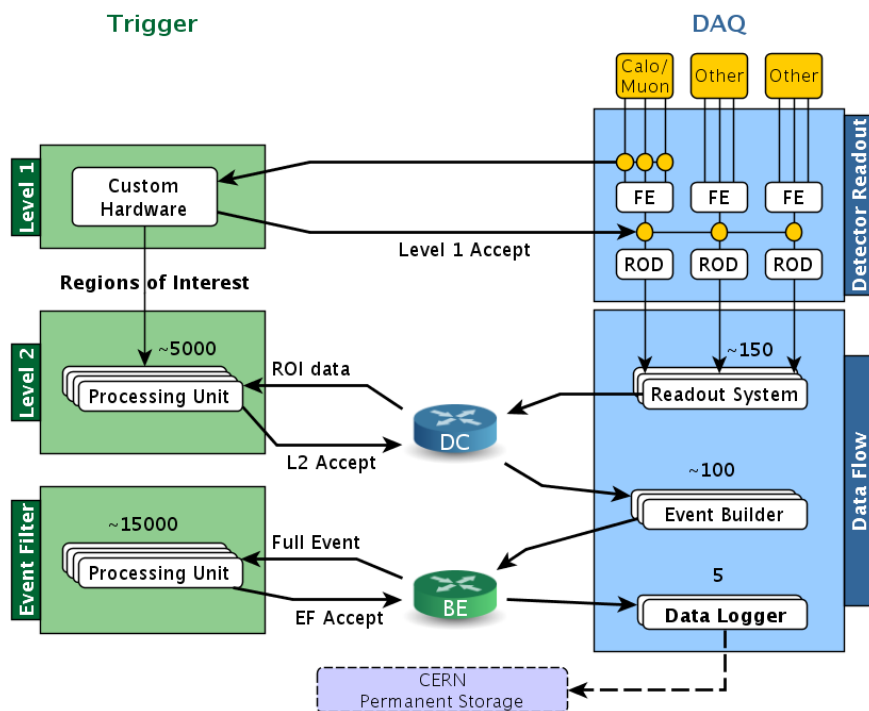
FTK: vertical slice

- Basata su HW di CDF, schede riadattate e prototipi
- Integrata durante il data taking 2012
 - Esperienza utile per l'identificazione delle problematiche e lo sviluppo dei tool di controllo e monitoring
- Prima verifica della compatibilità tra dati e simulazione

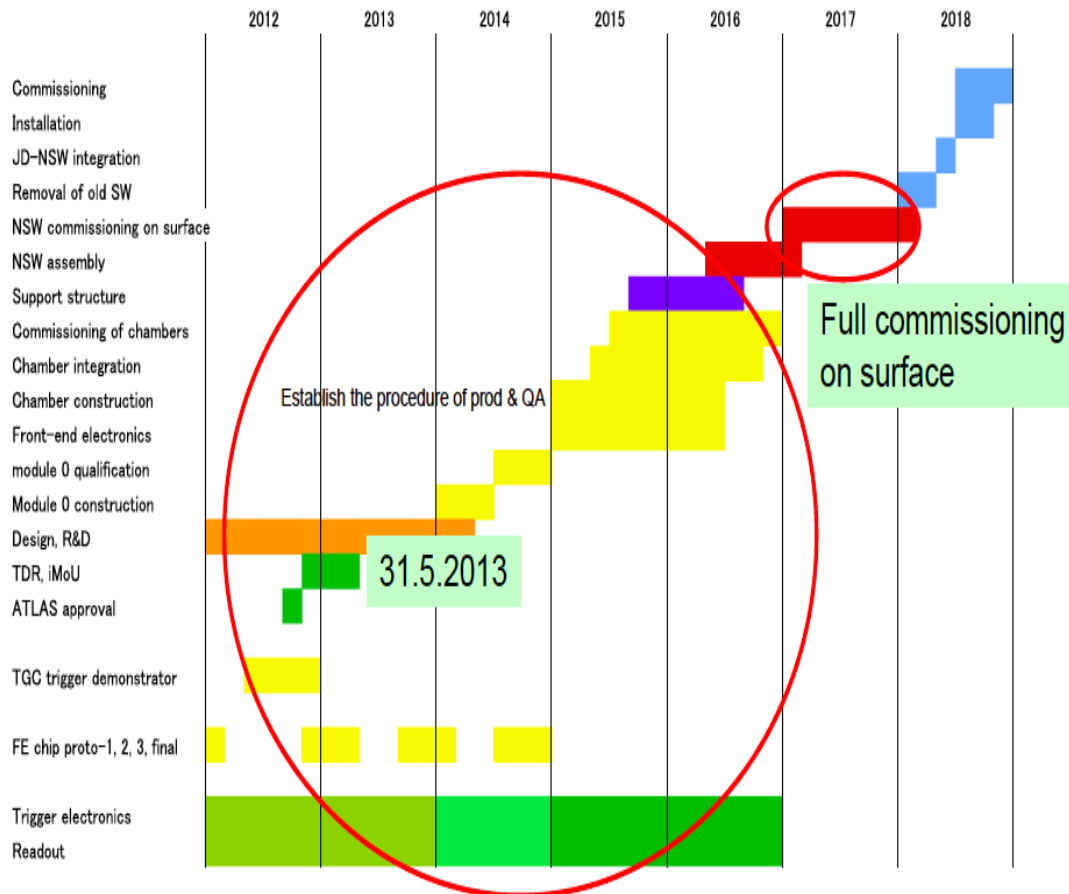


ATLAS Data Flow

- Architettura ri-disegnata (coordinazione pavese)
 - Unificate le farm di Livello 2, Event Filter e Event Builder
 - Semplificati: configurazione, gestione, debugging
- Design ottimizzato per garantire la scalabilità e lo sfruttamento dell'HW corrente e futuro (PC & network)
- Release pronta, validazione in corso al P1



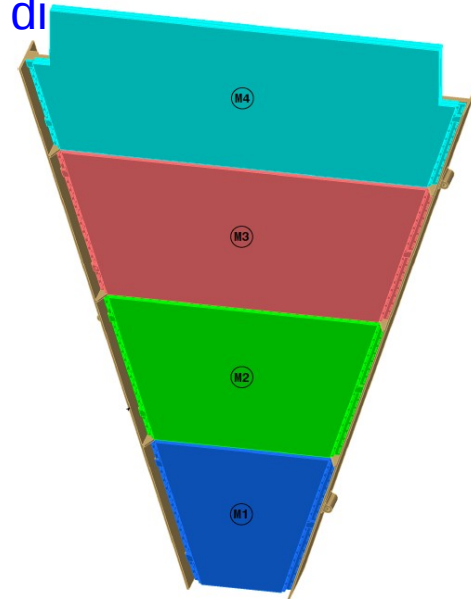
New Small Wheels - Schedule



- TDR reso pubblico a fine maggio (scadenza legata al calendario dei comitati LHCC e RRB)
- Prototipo meccanico di un intero settore (camere micromega + TGC) da ultimare entro luglio
- Costruzione del modulo-0 nella prima metà 2014

NSW- Costruzione prototipo meccanico

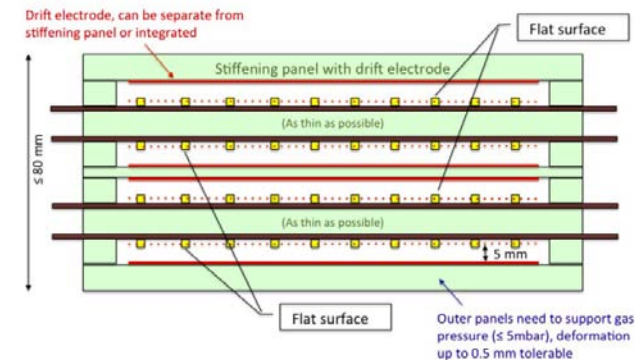
- Costruzione del prototipo meccanico (1 wedge = 1 quadrupletto di layer di camere micromega) del settore large entro luglio 2013
- 4 Istituzioni interessate: M4@Saclay, M3@INFN, M2 & M1 @ LMU e/o USA e/o Dubna
- INFN
 - Centri di attività locale: Frascati, Roma1, Pavia, Lecce
 - Centri di supporto: Roma3, Napoli, Cosenza



Dimensioni modulo M3: 900 x 2170 (1640)

Necessari:

- superficie di riscontro (tavolo di marmo) di dimensioni adeguate
- un sistema di misura accurato ($O(\sim 3 \mu\text{m})$)
- un sistema per l'incollaggio delle pcb alla struttura di supporto e incollaggio dei moduli fra loro ($O(10 \mu\text{m})$)



Pavia: sito ufficiale di costruzione del prototipo meccanico per l'INFN

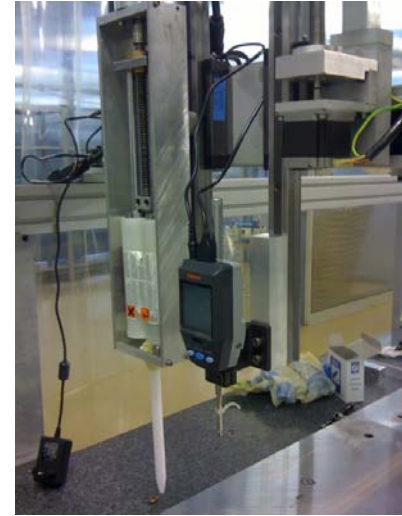
NSW HW: Attività a Pavia

- Per essere in grado di fare prove e misure di incollaggio:

- ripristinate le condizioni di pulizia e temperatura della camera bianca
- ripristinato il piano xy di incollaggio aggiungendo la parte di misura di planarità e relativo software di gestione

- Scala dei tempi:

- Attività iniziata a gennaio 2013: progettazione del sistema e ordini di materiale sia per il setup che per il prototipo inizio 2013
- Misure e costruzione prototipo: giugno-luglio 2013
- Attività del progetto a più lungo termine da definire in base alle decisioni della collaborazione



NSW SW

Attività di coordinamento e gestione:

- Da luglio 2012 coordinamento SW, pianificazione e sharing delle attività
- Creazione del gruppo di software con particolare riguardo alla immissione di nuovi gruppi (Giappone, Grecia, US, Canada, SouthAfrica, Israele)
- Training iniziale dei nuovi membri della collaborazione
- Da marzo 2013 co-coordinamento delle attività SW per la preparazione del TDR

Sul fronte tecnico:

- Definizione e implementazione della infrastruttura software.
 - Creazione del sistema di classi per la digitizzazione delle informazioni, introduzione di identificatori e “id-helpers”
 - Attività di documentazione online per gli item in oggetto
-

Spettrometro a muoni

MDT durante shutdown invernale:

- Terminata installazione delle camere EE nella regione di transizione
 - coprono la regione $1.0 < |\eta| < 1.3$
 - permettono di migliorare l'efficienza e la misura del momento dei muoni
- contributo da parte dei gruppi italiani al commissioning
- cambio di schede di elettronica, controllo cablaggi, controllo connessioni di massa

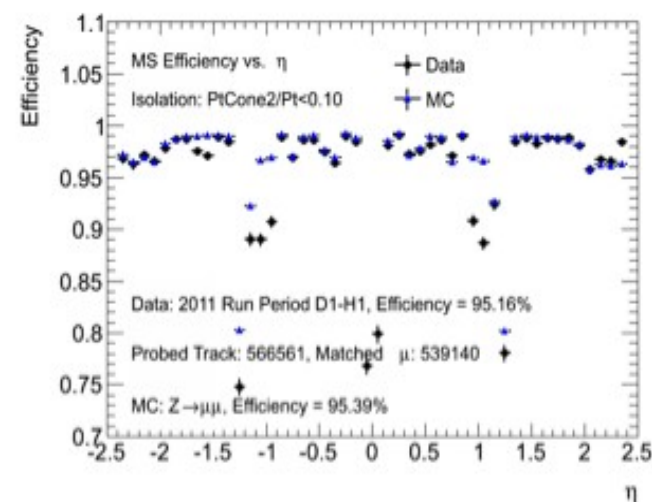
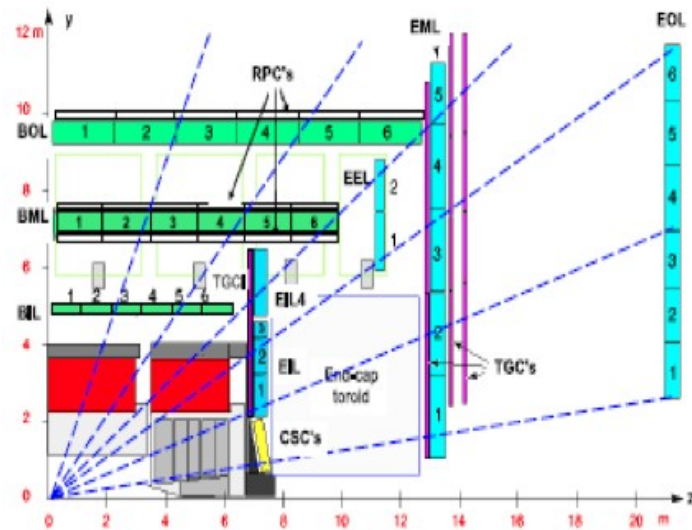
Online Monitoring:

Maintenance e sviluppo

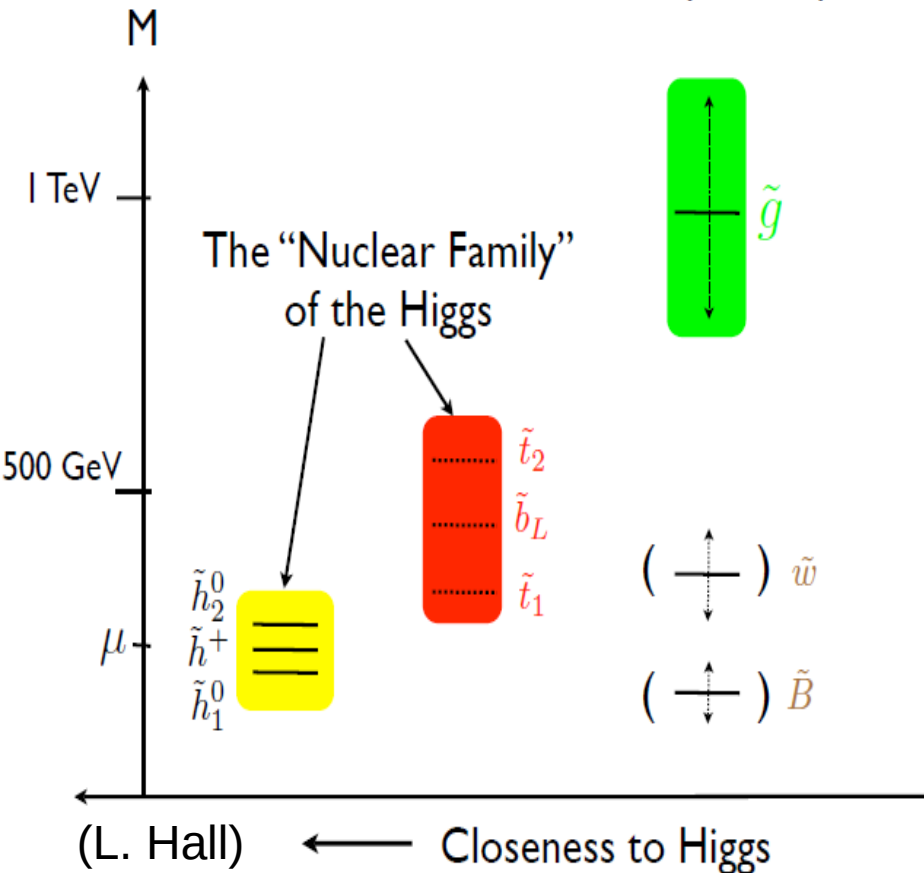
del codice di monitoring per gli MDT a ROD level
e per la stream di calibrazione
del codice di monitoring della TDAQ
del codice di infrastruttura su cui è basato il
monitoring online (gnam)

Software offline:

attività software legata alla simulazione e alla
ricostruzione



Searches for 'Natural' SUSY



Searches in Etmis+ jets excluded squarks of first generations and 'simple' decays of gluinos up to 1.3-1.4 TeV

Still open window of opportunity
For minimal SUSY spectrum ensuring that the SM is 'natural'

Three lines of research:

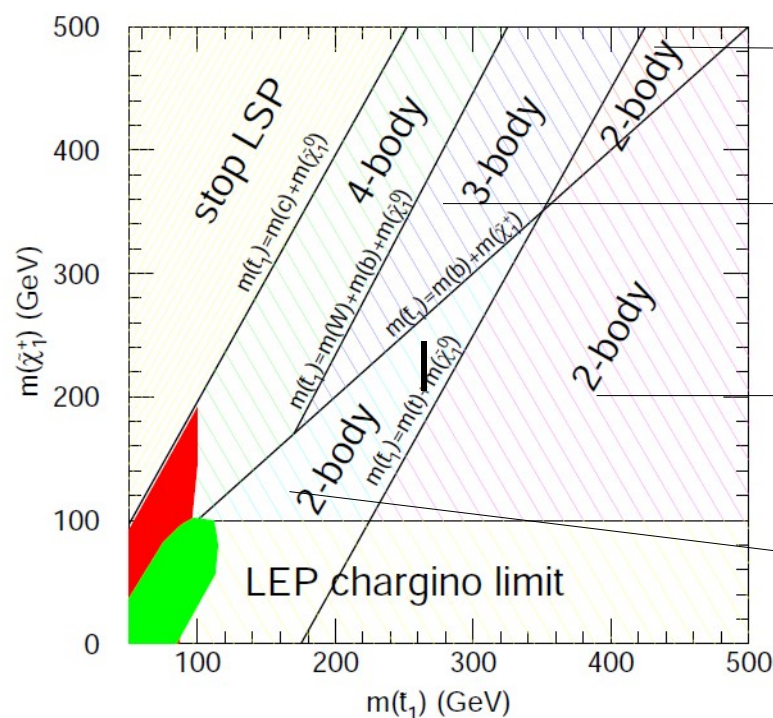
- Search for gluino decay through real/virtual 3rd generation quarks
- Search for direct production of stop/sbottom
- Search for direct production of Ewkino

Driving activity in SUSY group in 2012/13

Leading role of Pavia group in direct search for stop

Stop decay patterns

Depends on three parameters: $m(\text{stop})$, $m(\text{chargino})$, $m(\text{neutralino1})$
 Show 2d-plane assuming $m(\text{chargino})=2m(\text{neutralino1})$



Only $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$

$\tilde{t}_1 \rightarrow c\tilde{\chi}_1^0$
 Or multibody

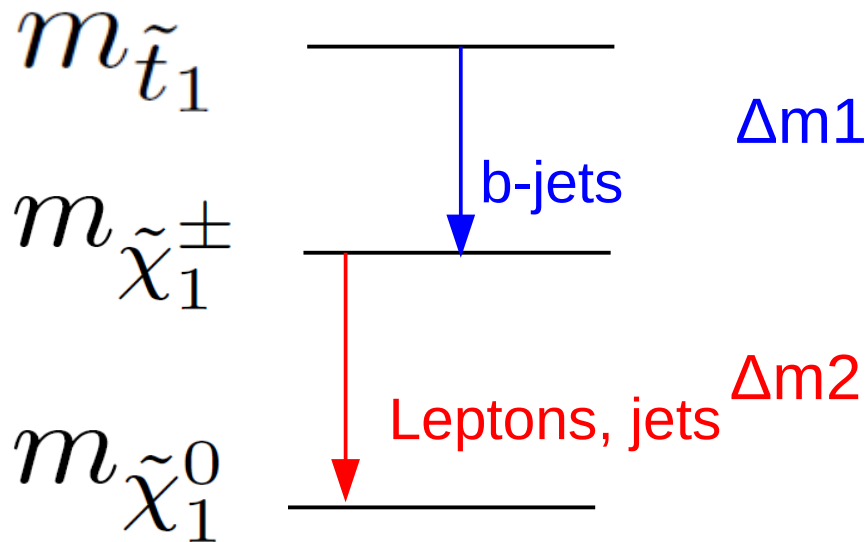
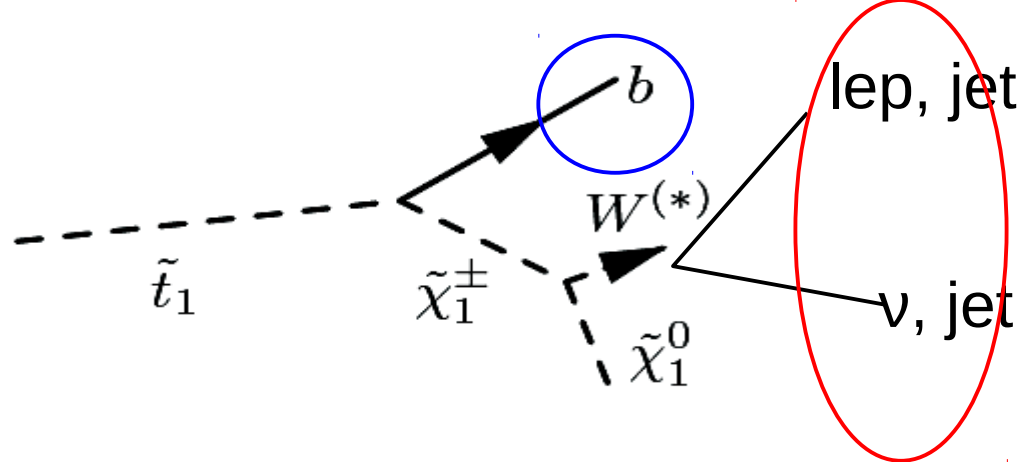
$\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm$ and $\tilde{t}_1 \rightarrow t\tilde{\chi}_1^0$

Only $\tilde{t}_1 \rightarrow b\tilde{\chi}_1^\pm$

In Pavia, study two-lepton channel

- In first half of 2012: decay stop $\rightarrow$ top χ_1^0 : paper
- Second half of 2012 up to now: stop $\rightarrow$ b chargino: two notes

$$\tilde{t}_1 \rightarrow b \tilde{\chi}_1^\pm$$



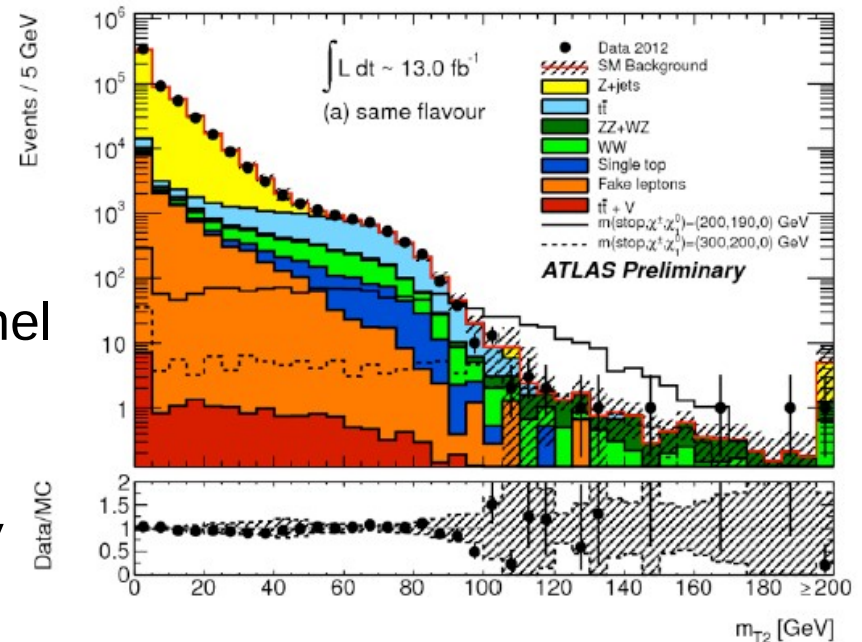
- Basic idea: the dilepton M_{T2} has an upper bound for events where they come from Ws

$$m_{T2}(\mathbf{p}_T^{\ell_1}, \mathbf{p}_T^{\ell_2}, \mathbf{p}_T^{\text{miss}}) = \min_{\mathbf{q}_T + \mathbf{r}_T = \mathbf{p}_T^{\text{miss}}} \left\{ \max[m_T(\mathbf{p}_T^{\ell_1}, \mathbf{q}_T), m_T(\mathbf{p}_T^{\ell_2}, \mathbf{r}_T)] \right\}$$

Study situation in which:

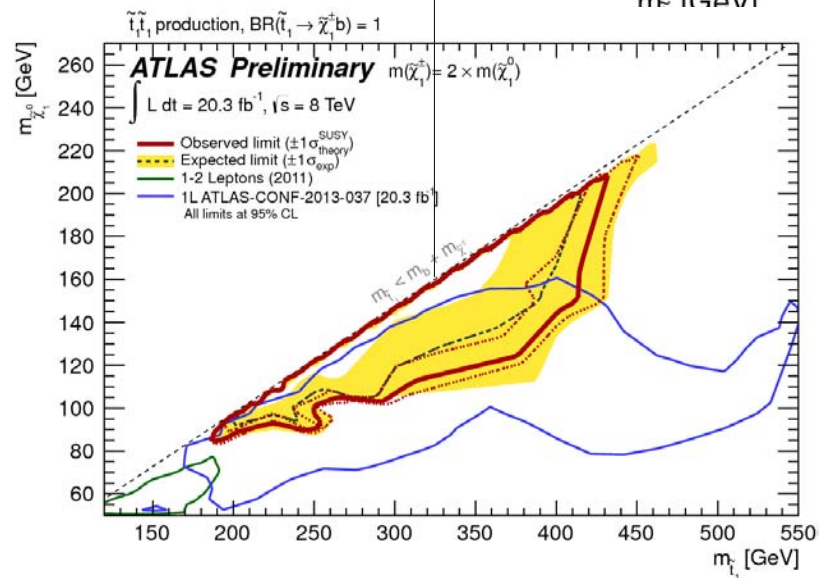
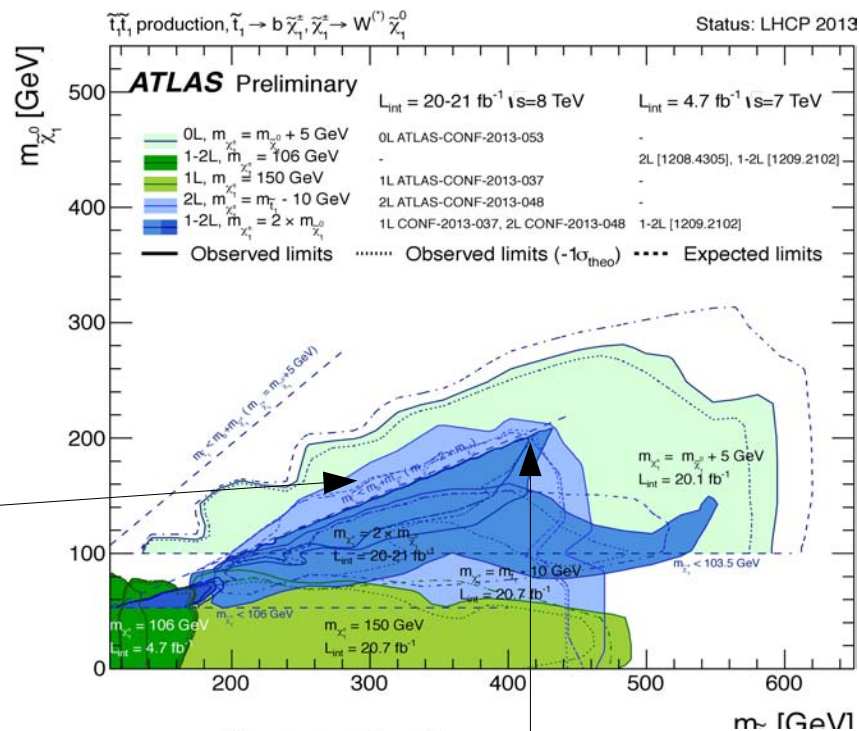
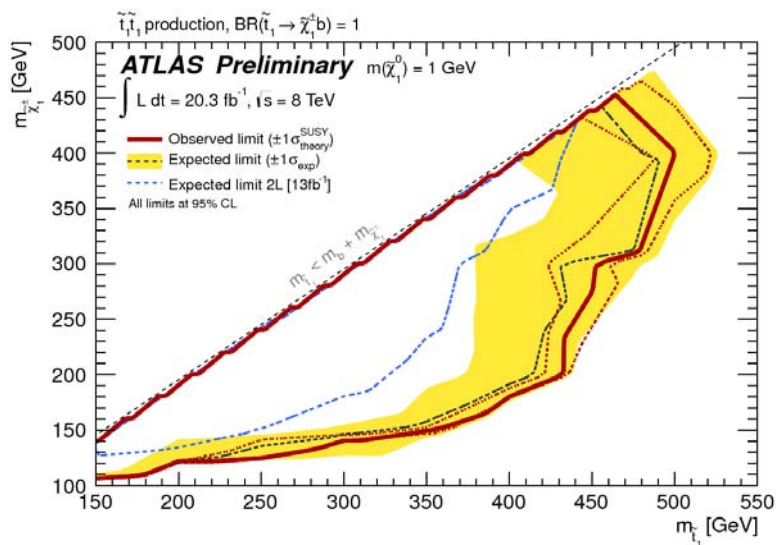
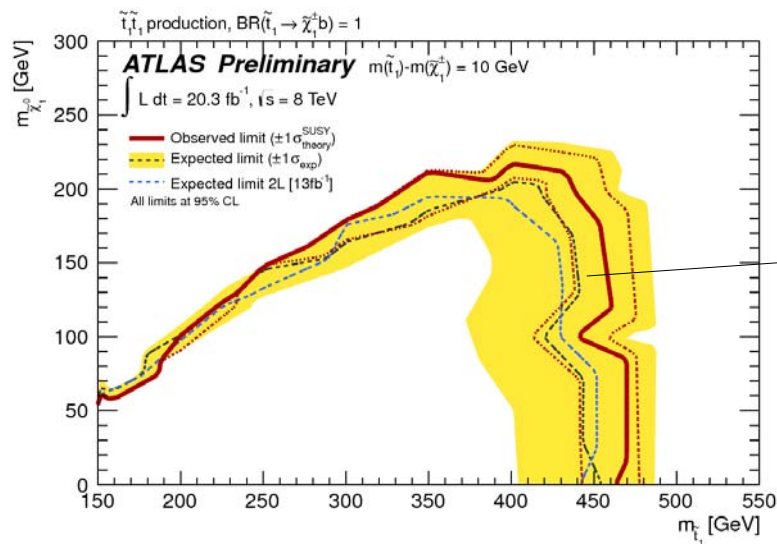
- both stops decay in this channel
- both Ws decay leptonically

Address situation where $\Delta m_2 > 80$ GeV



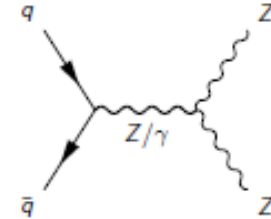
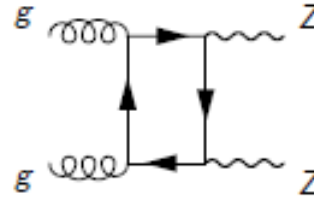
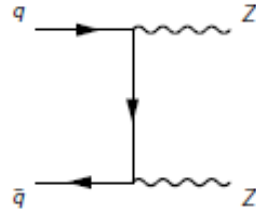
$$\tilde{t}_1 \rightarrow b \tilde{\chi}_1^\pm$$

Results



ZZ -> llvv analysis

- measurement of the ZZ production cross section
- limits on anomalous neutral Triple Gauge Couplings (aTGC)



dataset $\sim 4.6 \text{ fb}^{-1}$ at $\sqrt{s} = 7 \text{ TeV}$

$\sigma \times \text{B.R.} \sim 160 \text{ fb}$

Selection criteria:

2 isolated leptons with $|\eta| < 2.5$ and $P_T > 20 \text{ GeV}$

$M(\text{ll})$ within 15 GeV near $M(Z)$

axial $E_T^{\text{miss}} > 75 \text{ GeV}$ [i.e.: perpendicular to $P_T(\text{ll})$]

$| E_T^{\text{miss}} - P_T(\text{ll}) | / P_T(\text{ll}) < 0.4$

87 events selected (background ~ 47 events):

efficiency $\sim 68\%$

acceptance $\sim 8\%$

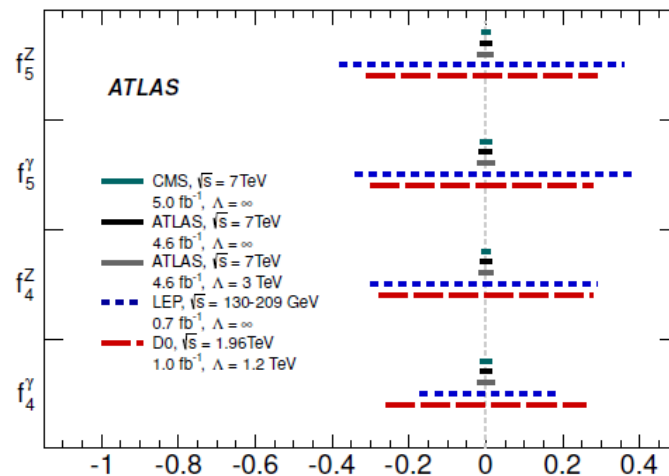
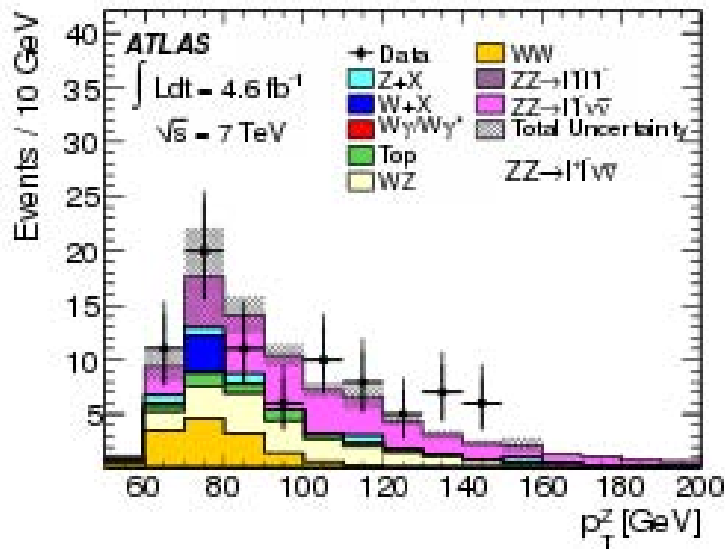
stat. uncertainty $\sim 24\%$

syst. uncertainty $\sim 13\%$ (dom. by background est.)

ZZ → llvv results

$$\sigma_{\text{fid}}(\text{ZZ} \rightarrow \text{ll}\nu\nu) \sim 12.7 \pm 3.0(\text{stat}) \pm 1.7(\text{syst}) \pm 0.5(\text{lumi}) \text{ pb}$$

(expected: 12.5 ± 1.1)



- aTGCs described by two CP-violating (f_4^V) and two CP-conserving (f_5^V) complex parameters (where $V = Z, \gamma$)
- No evidence of aTGC (left plot show the combined results from both $\text{ZZ} \rightarrow 4l$ and $\text{ZZ} \rightarrow 2l2\nu$ analyses)

Higgs Physics at LHC - Theoretical Issues

Theory uncertainties are already becoming non-negligible at LHC!

Experimental accuracy $\Delta\mu(\sigma/\sigma_{\text{SM}}) = \pm 15\%$ (roughly $\pm 10\%$ for both stat and syst)

Theory uncertainty is **$O(\pm 10-15\%)$** (dominated by QCD scale and PDF+ α_s in gg-fusion)

Two prominent pillars for Higgs physics at LHC for post-discovery era:

- Precision measurements on Higgs properties of couplings and spin/parity.
- Direct searches for the signature of BSM Higgs on top of 125 GeV signal

Future improvements in NNNLO prediction in ggF, PDF, Higgs p_T , ..

Important jet issues: reduction of uncertainty in 1-jet bin, ggF+2 jets vs VBF

- Clean separation of ggF, VBF, WH/ZH and ttH is the essential
- Higgs coupling and spin/parity nature with CP-mixing/violation in $0^\pm$

Higgs Boson - contributo pavese

Analisi Higgs

- Collaborazione all'analisi $H \rightarrow ZZ(*) \rightarrow 2l2q$ e $H \rightarrow ZZ(*) \rightarrow 2l2\nu$
- VBF Isolation: studio del contributo della contaminazione dovuto al processo $ggF+2j$ attraverso strategie alternative rispetto al jet-binning (affetto da enormi incertezze teoriche)
- Preparazione di campioni MC per segnale e fondo
- Preparazione di tool di reweighting, handling e merging di eventi MC per l'implementazione di correzioni specifiche

LHC Higgs Cross Section Working Group (gruppo ATLAS+CMS+teorici incaricato di fornire predizioni unificate su sezioni d'urto e branching ratio del bosone di Higgs)

- Corresponsabilità dei sottogruppi per lo studio di VBF e BR
- Stima delle sezioni d'urto per VBF al NNLO QCD + NLO EW a 7 e 8 TeV
- Studi sulle proprietà della risonanza a 125 GeV (confluiti in un terzo Yellow Report): coupling e spin/parità

Pavia in ATLAS

Shift svolti al CERN (Atlas Control Room):

Shift leader, Run Control, Muon desk, Comp@P1

Shift svolti “in remoto” da Pavia:

Ricostruzione, Simulazione e Digitizzazione, Muon data quality, Calibrazione MDT

Expert on call

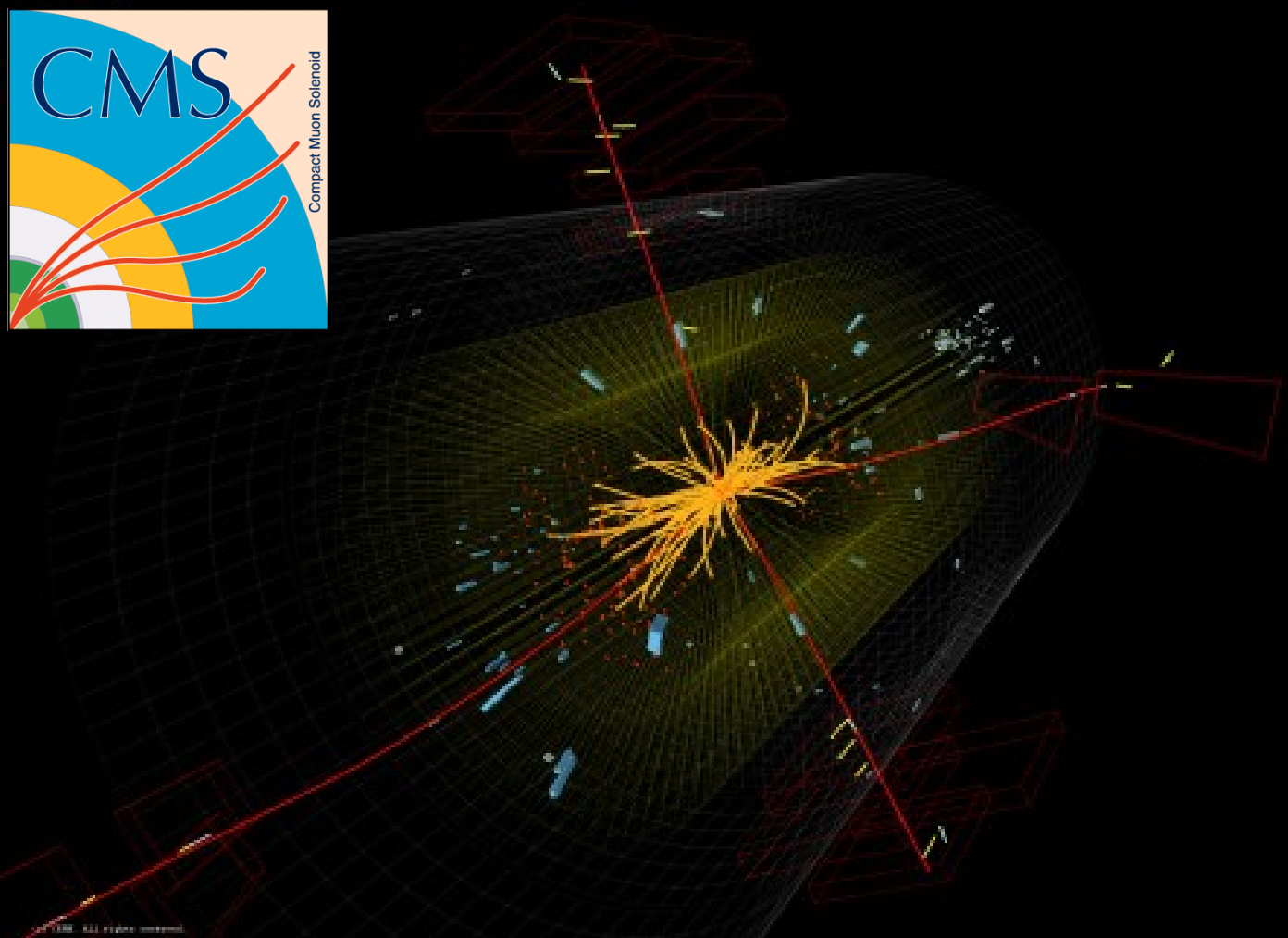
DAQ, MDT/CSC: Primary On-call Expert

Responsabilità gruppo PV in ATLAS:

- **Ferrari**: monitoring online per rivelatori e TDAQ
- **Gaudio**: monitoring online MDT
- **Lanza**: servizi muoni
- **Negri**: coordinatore infrastruttura di EF e del progetto di sviluppo del dataflow
- **Polesello**: chair diversi editorial board, co-editor 1 articolo e 2 Conf Notes
- **Rebuzzi**: co-responsabile gruppi VBF e BR per il “LHC Higgs cross-section Working Group”
- **Rimoldi**: responsabilità software NSW

Responsabilità gruppo PV in ATLAS-Italia:

- **Gaudio**: Responsabile nazionale MDT (secondo mandato)
- **Negri**: Responsabile nazionale TDAQ



CMS Pavia

Michele Gabusi, Alice Magnani, Paolo Montagna, Roberto Nardò,
Sergio Ratti**, Cristina Riccardi, Paola Salvini, Aurora Tamborini*,
Paola Torre**, Ilaria Vai, **Angelo Vicini****, Paolo Vitulo

*(da feb. 2013 al CNAO) **in pensione

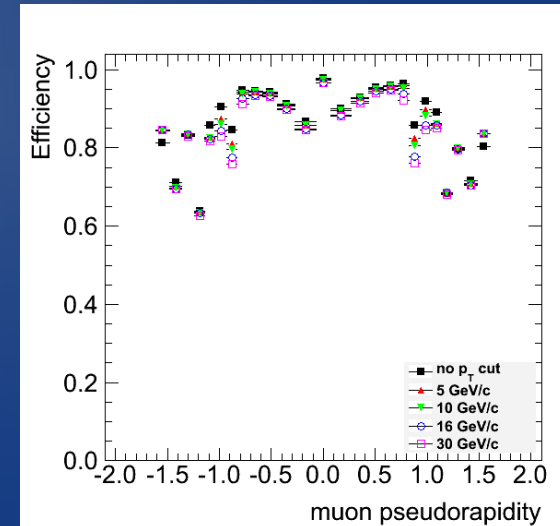
Da RPC status report (S.Bianco-Pisa marzo 2013)

- Downtime: 1,2% (2010),1,02%(2011),1,08%(2012)
- Total active channels: 97.7% (threshold 0.005Hz/cm2)
- Thanks to systematic checks and automatic correction on HV,

$$HV_{app} = HV_{eff} (1 - \alpha + \alpha P/P_0)$$

the chamber efficiency instability went down from 10% to 4-5% and the amplitude of the oscillations due to atmospheric pressure variations has been reduced by a factor 10 for the cluster size and by a factor 4 for the efficiency (1%).

- Stable response for trigger;
Endcap efficiency is lower than barrel by $\sim 10\%$ due to lack of redundancy in detector layer choice (3/3). ($\rightarrow$ MOTIVATION FOR RE4: upgrade in time).



RPC system Upgrade

$\eta < 1,6$

Upscope
project RE4

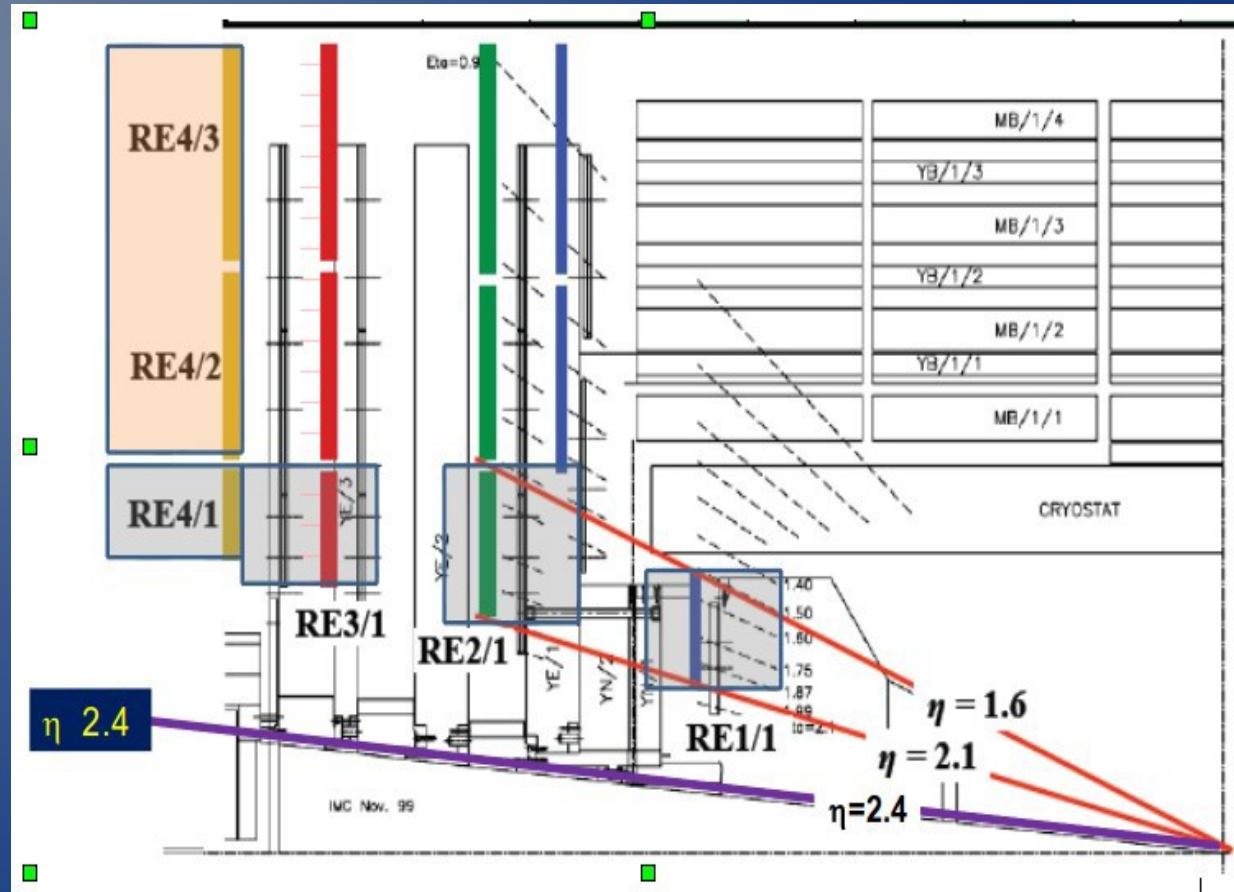
**LS1-
Shutdown
2013-2014**

High Eta project

$1,6 < \eta < 2,1$

GEM, Glass RPC..

**Post LS2-
Shutdown
2018**



Attività pavese sul rivelatore RPC

- **Shifts: “Detector On Contact” (DOC) + at Cern Analysis Facility (CAF)**
- **Lavori di manutenzione: controlli su bakelite, riparazioni e controlli sistema gas (barrel gaps - LS1), controllo performance del rivelatore**
- Test di aging naturale su gap RPC appartenenti alla vecchia produzione del Barrel di CMS e i costruite con il “vecchio” materiale HPL (fornito dalla ditta PanPla, ormai non più operante) e con la stessa tecnologia di oliatura utilizzata per il Barrel. Informazioni utili possono essere dedotte dal confronto di tale test con misure analoghe condotte sui rivelatori del barrel installati su CMS.
 - **Test :**
 - Il test è in sè molto semplice e non distruttivo. Si tratta di estrarre dalla curva caratteristica I-V la resistività degli elettrodi.
 - Per fare ciò è necessario usare un gas come l’Ar che permette di cortocircuitare gli elettrodi stessi in modo che la corrente misurata sia tutta ascrivibile al comportamento elettrico del materiale stesso.
- **Partecipazione progetto Upscope (Endcap - LS1)**
- **Endcap Upgrade**

Progetto di consolidamento RPC: up-scope [responsabilità pavese (P.Vitulo) per quality control HPL]

Quality control of HPL in Pavia

- HPL Technical Specs
- New HPL material and provider
- Study of HPL production Thermal Cycle
- Parametric studies: - volatile, T_{max} , $T \times$ Heating time, stability vs time

panels HPL 3200x1620mm with QC accepted at Pavia, cut at RIVA and washed at GT then sent to Korea



**Contributo:
P.Montagna, P.Torre,
P.Vitulo**

- Terminato R&D per la produzione con standard industriali della bakelite di nuova generazione a resistività controllata e certificata per RE4 di CMS. (Napoli, Pavia, CERN, ditte Riva e Puricelli)
- Sono stati prodotti e certificati 2000 pannelli di Bakelite attualmente in fase di utilizzo per la costruzione delle camere del rivelatore RE4 (quarto strato composto da RE4/2 e RE4/3 di RPC—necessarie 144 camere)

Muon high- η R&D for LS3

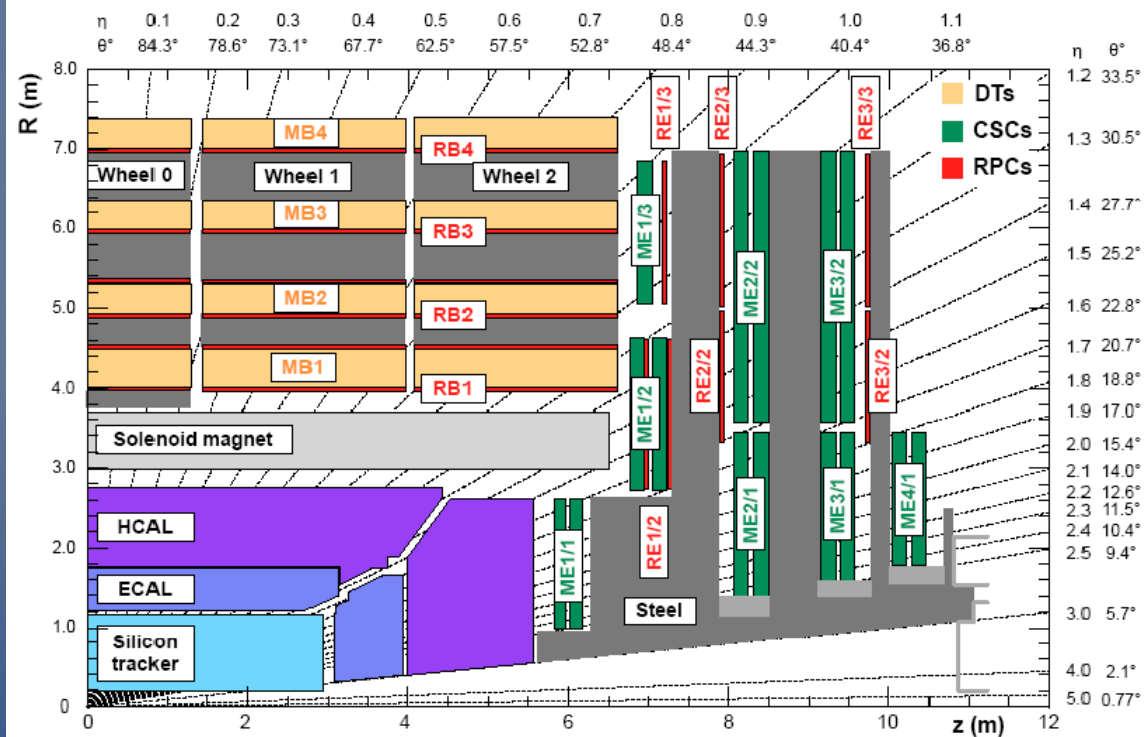
La tecnologia e l'elettronica di FE degli RPC ne limitano le performance nella regione high- η dove il flusso aspettato è kHz/cm².

Interesse nei rivelatori :

GRPC (Bari, **Pavia**)

PAVIA: Studi di SEU da neutroni su FE di nuovi rivelatori (LENA, CNAO,..) irraggiamento LENA

New quadrant figure



Contributo:
Ilaria Vai (tesi di LM)
C.Riccardi, P.Salvini, P.Vitulo

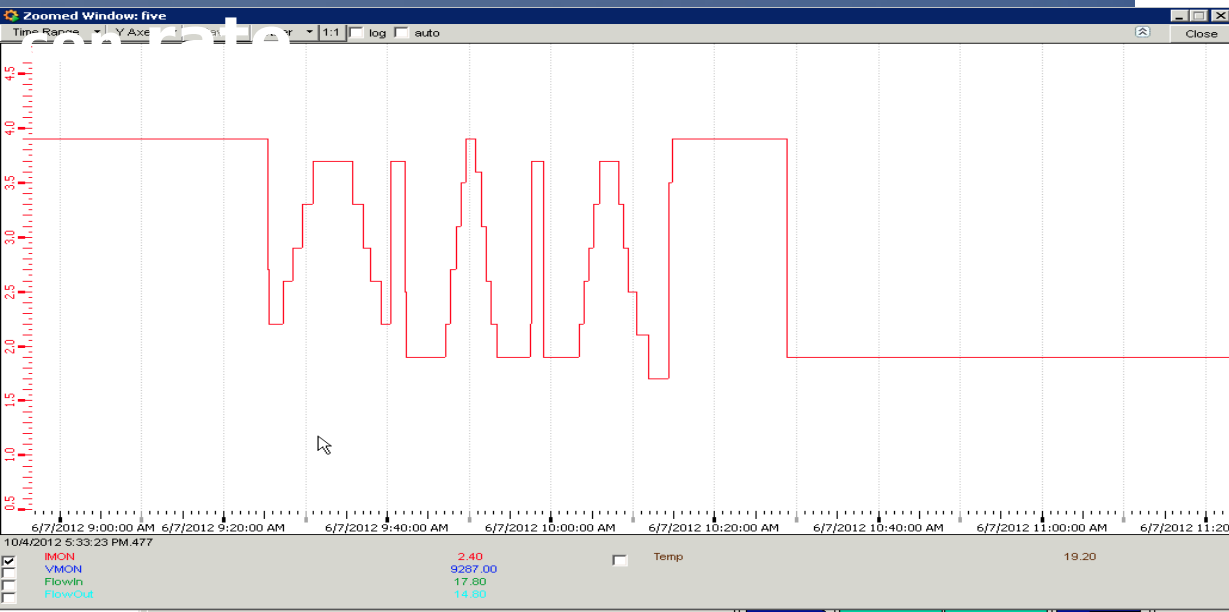
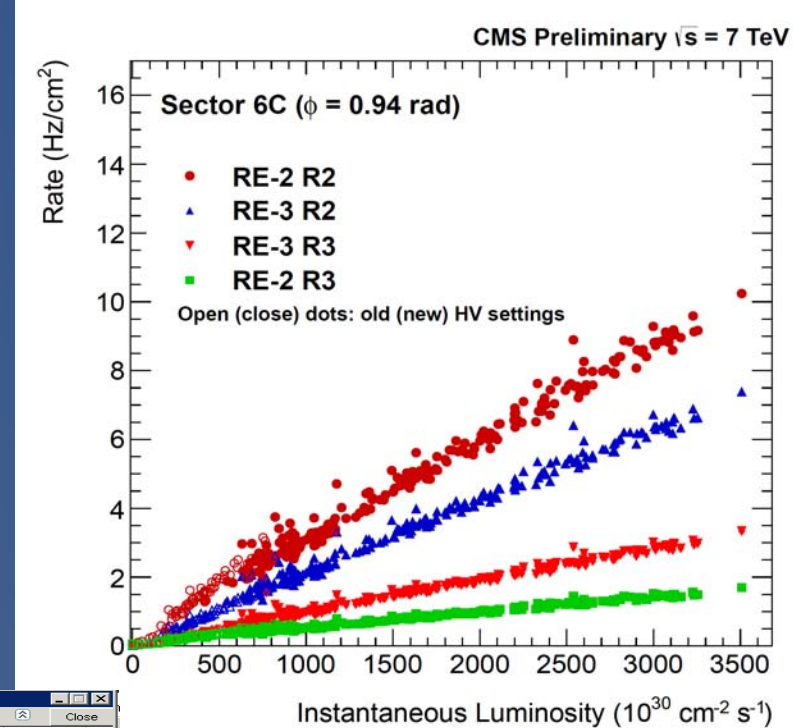
Controllo performance RPC

Il livello di rumore e la corrente del rivelatore hanno confermato anche nel 2012 una dipendenza lineare in funzione della luminosità. I valori massimi di tali grandezze raggiunti per lo più nei dischi esterni sono stati rispettivamente 1 Hz/cm² e 10 μ A per camera.

CMS paper : The performance of the CMS muon detector in proton-proton collisions at $\sqrt{s} = 7$ TeV at the LHC

Continua lo studio:

monitor di luminosità con RPC

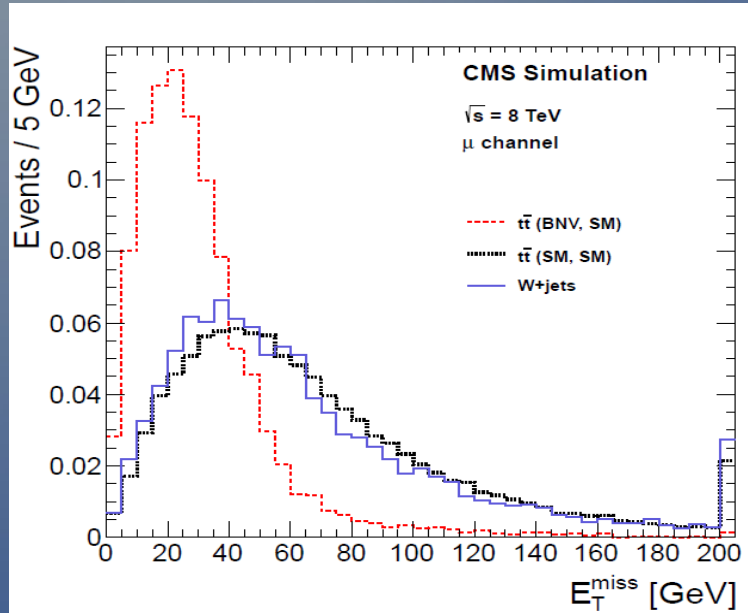


e correnti ?
Calibrazione
assoluta?

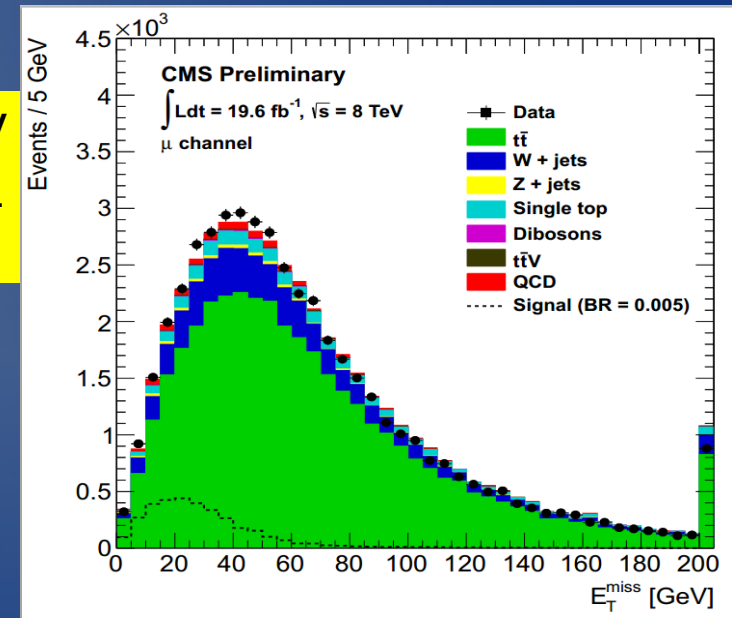
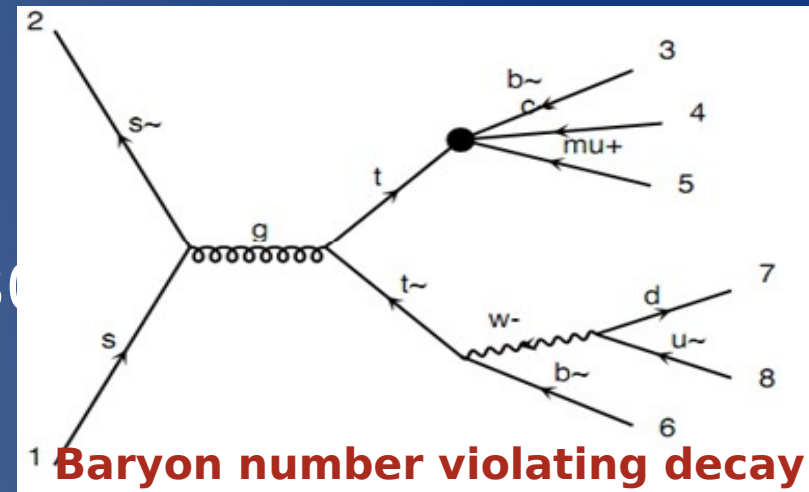
**Contributo:
M.Gabusi e
P.Salvini**

Analisi in B2G Beyond 2 generation

□ Zhe Dong et al. arXiv:1107.3800



$\sqrt{s}=8\text{TeV}$
19.6 fb⁻¹

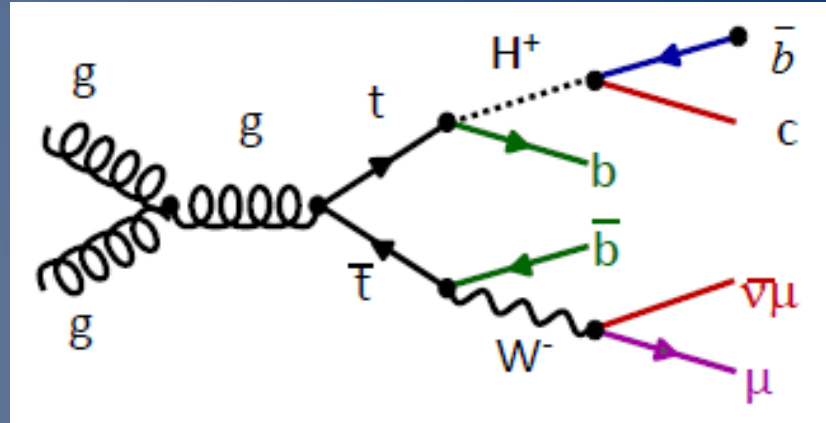


Check of compatibility with the final states produced by $t\bar{t}$ events SM-BNV (where SM is fully hadronic decay of top (through E_{T}^{miss} e X2))

Recente □ PAS B2G-12-023

**Tesi di dottorato di M.Gabusi
in collaborazione con
D.Pagano e G.Bruno (UCL,
Louvain , Belgio)**

Iniziata analisi (gruppo HiggsExo) di



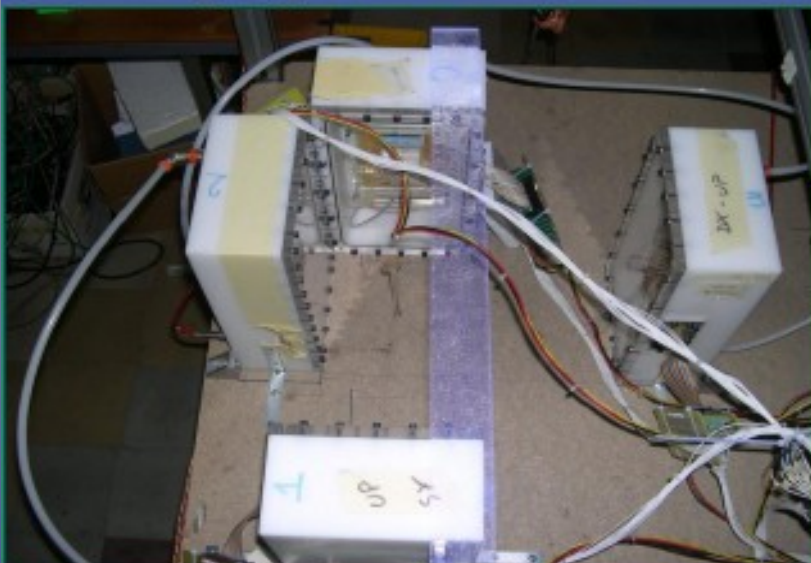
- Djouadi and J. Quevillon: arXiv:1304.1787v1
- BR $\sim 1\%$ stimato a $\tan\beta=2.5$ ($\sim 10\%$ a $\tan\beta=1$)
- Stato attuale: fase produzione campione MC

Contributo:
A.Magnani,
M.Gabusi
C.Riccardi,
P.Salvini

Misura di tempo di volo di fotoni da annichilazione da 511 keV con Multigap RPCs e possibili applicazioni alla ToF-PET

M.Gabusi , A.Tamborini ,P.Vitulo

Setup sperimentale

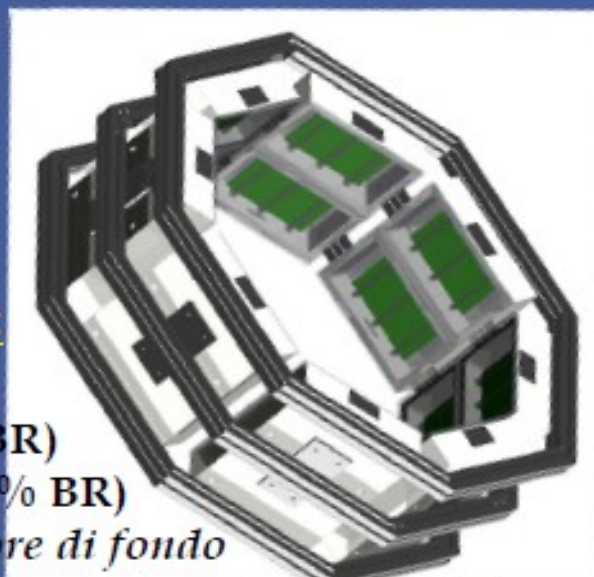


Sorgente di ^{22}Na :

2 γ da 511 keV (90 % BR)

1 γ da 1274 keV (100 % BR)

→ *aumento del rumore di fondo*



Prototipo rivelatore MRPC

5 vetri (200 x 100 mm²) di spessore 400 μm .

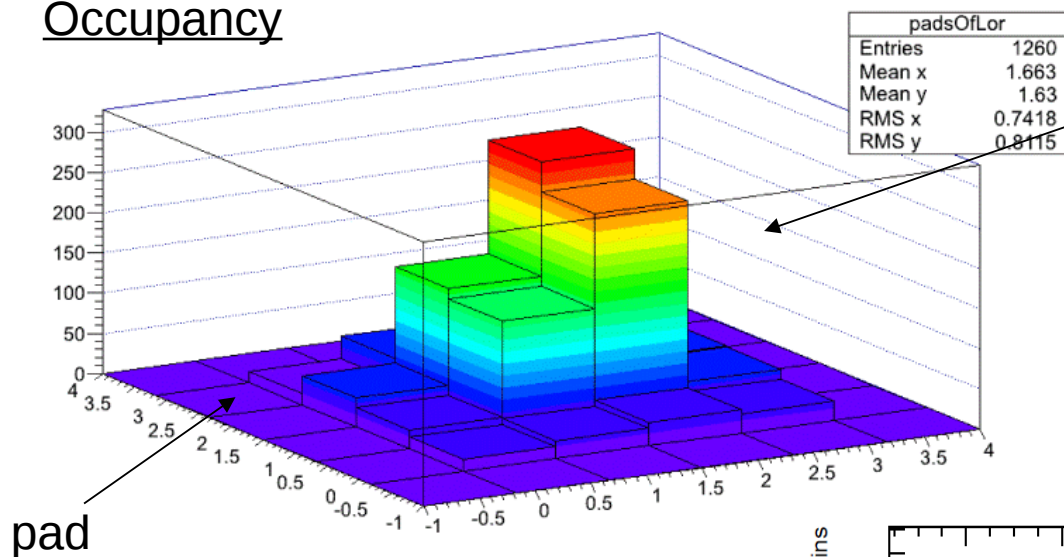
4 gaps ampie 250 μm .

16 pad di lettura

Il segnale indotto sulle pad è mandato ad uno stadio di amplificazione e formazione del segnale



Occupancy

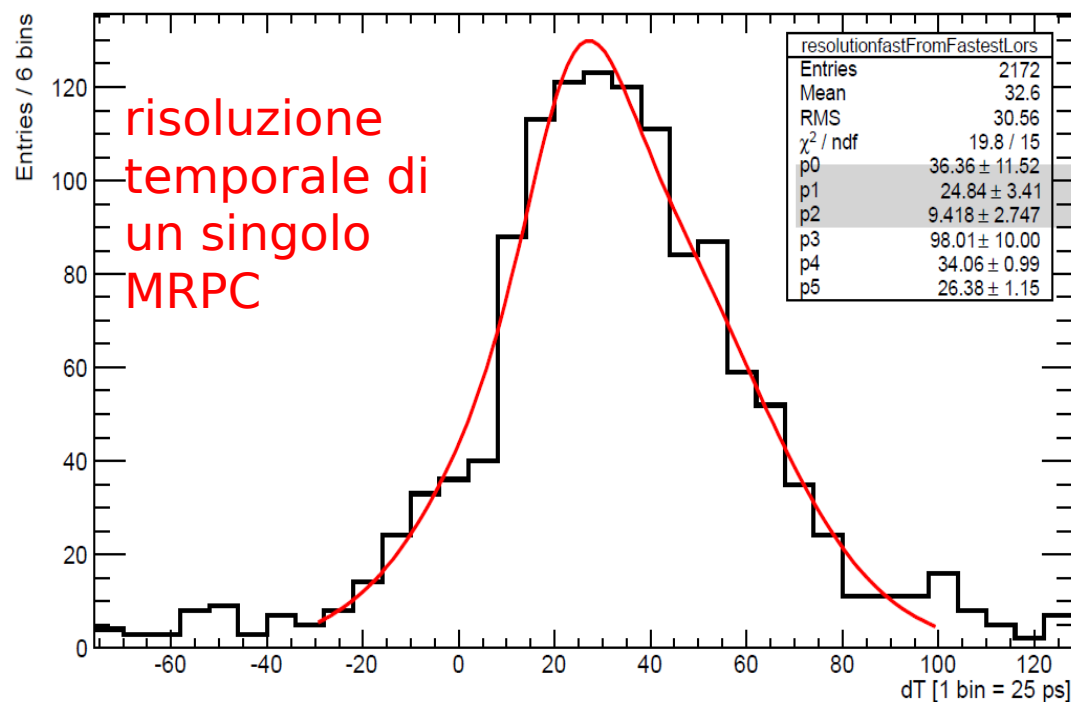


Utilizzando le informazioni sul tempo di volo dei due fotoni di annichilazione si è riusciti ad identificare la posizione della sorgente rispetto al rivelatore.

Da misura su 2 coppie di rivelatori □

$$\sigma_{\text{MRPC}} = 160 \pm 48 \text{ ps}$$

Tesi di dottorato di A. Tamborini



prestazioni competitive rispetto ai cristalli a scintillazione su cui sono basate le PET attuali e minore costo per unità di area.

Scintillator & CCD system for Beam Quality Control

Ccd Used for Beam Evaluation – CUBE

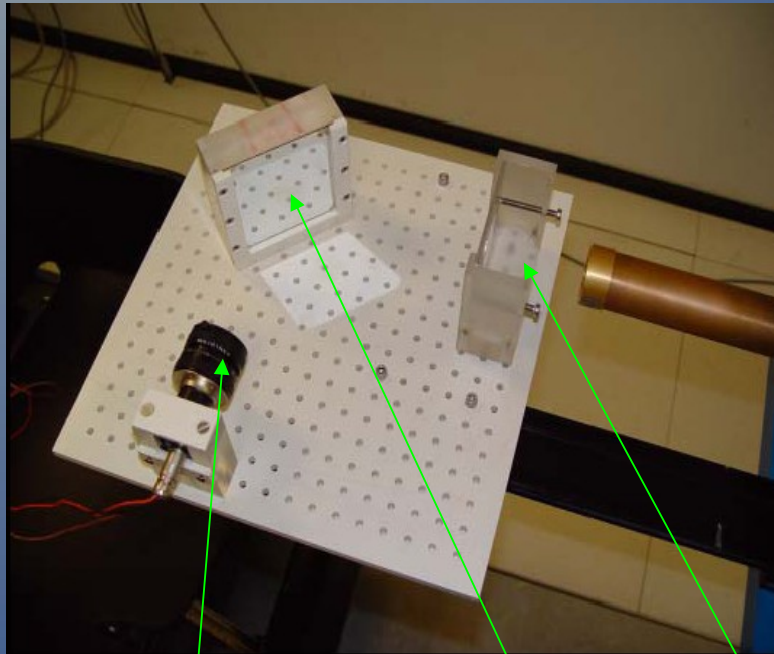
L. Raffaele, A.Tamborini, M. Ciocca

Primo Prototipo sviluppato
@ LNS:

Sistema automatico per la misura del profilo trasversale di fasci di protoni utilizzato presso la facility Catana ai Laboratori Nazionali del Sud (LNS - Catania).

Cirrone, Cuttone et al. *An automatic beam characterization Instrument for proton therapy applications.* , Proceedings of EPAC 2004, Lucerne, Switzerland.

Utilizzo di interfaccia Labview per acquisizione e analisi dati



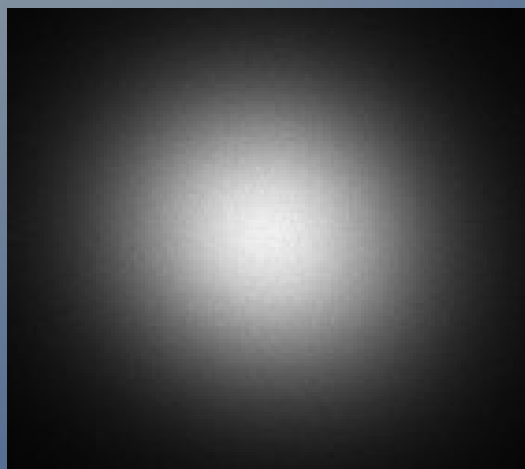
CCD
Camera

Specchio

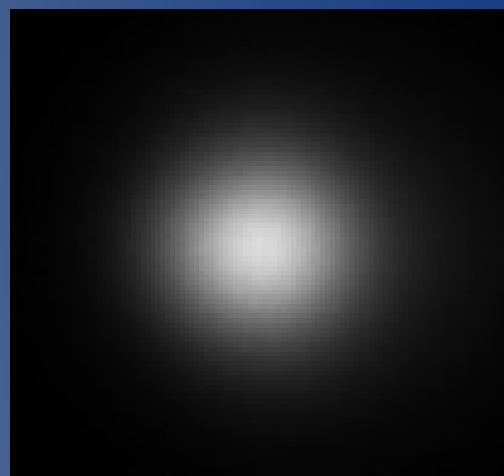
Scintillatore
Organico

Il prototipo è stato migliorato e dotato di una box esterna per schermarlo dalla luce ambientale.

E' stato testato con fasci di protoni, ed è il primo sistema del genere ad essere stato testato con fascio di ioni carbonio.



Spot Protoni, 50 mm, 10^9 particelle



Spot Carbonio, 50mm, $3 \cdot 10^7$

Prime immagini di spot all'isocentro: l'FWHM e i profili sono in accordo con quelli ottenuti con film radiocromici EBT3 → risultati promettenti!

Attualmente sono in corso test di caratterizzazione del rivelatore, ed è in fase di sviluppo un secondo prototipo più performante.

Publicazioni CMS RPC-PET

The Upgrade of the CMS RPC System during the First LHC Long Shutdown

M. Tytgat *et al.*. Sep 2012. 9 pp.

Published in **PoS RPC2012 (2012) 063, JINST 8 (2013) T02002**

CMS Resistive Plate Chamber overview, from the present system to the upgrade phase I

P. Paolucci *et al.*. Sep 2012. 12 pp.

Published in **PoS RPC2012 (2012) 004, JINST 8 (2013) P04005**

Study of gas purifiers for the CMS RPC detector

L. Benussi *et al.*. Dec 2010. 5 pp.

Published in **Nucl.Instrum.Meth. A661 (2012) S241-S244**

A New approach in modeling the response of RPC detectors

L. Benussi *et al.*. Dec 2010. 13 pp.

Published in **Nucl.Instrum.Meth. A661 (2012) S182-S185**

Uniformity and Stability of the CMS RPC Detector at the LHC

S. Costantini *et al.*. Sep 2012.

Published in **PoS RPC2012 (2012) 005, JINST 8 (2013) P03017**

CMS reconstruction improvement for the muon tracking by the RPC chambers

CMS Collaboration (Min Suk Kim (Sungkyunkwan U.) *et al.*). Sep 2012. 9 pp.

Published in **PoS RPC2012 (2012) 045, JINST 8 (2013) T03001**

G. Belli, M. Gabusi, G. Musitelli, R. Nardò, S.P. Ratti, A. Tamborini, P. Vitulo - **Multigap MRPC Time Resolution to 511 keV annihilation photons** - ICTR-PHE 2012, February, 27- March, 2 - Geneva, Switzerland

A. Tamborini, G. Belli, M. Gabusi, G. Musitelli, R. Nardò, S.P. Ratti, P. Vitulo - **Risoluzione temporale di Multigap RPC a fotoni di annichilazione da 511 keV**- *XCVIII Congresso Nazionale della Società Italiana di Fisica (Napoli 17 - 21 Settembre 2012)*

Report on MEG experiment

Search for Lepton Flavor Violation in $\mu \rightarrow e + \gamma$ decay



Paolo Walter Cattaneo
Consiglio di Sezione
14 Luglio 2013

Physics motivation

1) The **cLFV decay** is undetectably small in the **extended SM**, which takes into account the neutrino masses and mixings

Example $\mu \rightarrow e \gamma$ decay

$$\Gamma(\mu \rightarrow e \gamma) \approx \underbrace{\frac{G_F^2 m_\mu^5}{192 \pi^3}}_{\mu - \text{decay}} \underbrace{\left(\frac{\alpha}{2\pi}\right)}_{\gamma - \text{vertex}} \underbrace{\sin^2 2\theta \sin^2 \left(\frac{1.27 \Delta m^2}{M_W^2}\right)}_{\nu - \text{oscillation}}$$
$$\approx \frac{G_F^2 m_\mu^5}{192 \pi^3} \left(\frac{\alpha}{2\pi}\right) \sin^2 2\theta_\odot \left(\frac{\Delta m^2}{M_W^2}\right)^2,$$

$\Rightarrow \mathbf{BP} \sim 10^{-54}$

2) **New Physics** scenarios usually enhance the rate of cLFV decay by many orders of magnitude, through loops of new particles

3) **cLFV decays** are clean, no SM contaminated, evidence of new physics

4) The expected rates are close to the experimental upper bound and within the capabilities of **present and near future experiments**

Signal and Background

Signal

$$\mu^+ \rightarrow e^+ \gamma$$

$$\Theta_{e\gamma} = 180^\circ$$

$$E_e = E_\gamma = 52.8 \text{ MeV}$$

$$T_e = T_\gamma$$

Prompt

e^+ and γ from RMD

$$\mu \rightarrow e\bar{\nu}\nu\gamma$$

$$B_{\text{prompt}} \approx 0.1 \times B_{\text{acc}}$$

Accidental

γ from $e^+e^- \rightarrow \gamma\gamma$

$$\mu \rightarrow e\bar{\nu}\nu\gamma$$

$$e\mathcal{N} \rightarrow e\mathcal{N}\gamma$$

e^+ from $\mu \rightarrow e\bar{\nu}\nu$

$$B_{\text{acc}} \approx R_\mu \Delta E_e \Delta E_\gamma^2 \Delta \theta^2 \Delta t$$

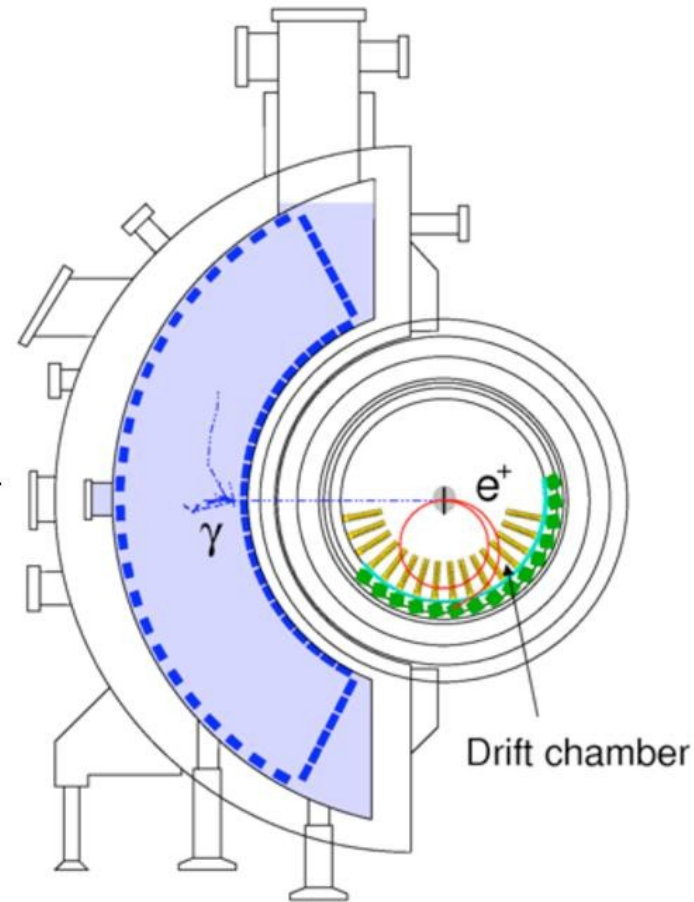
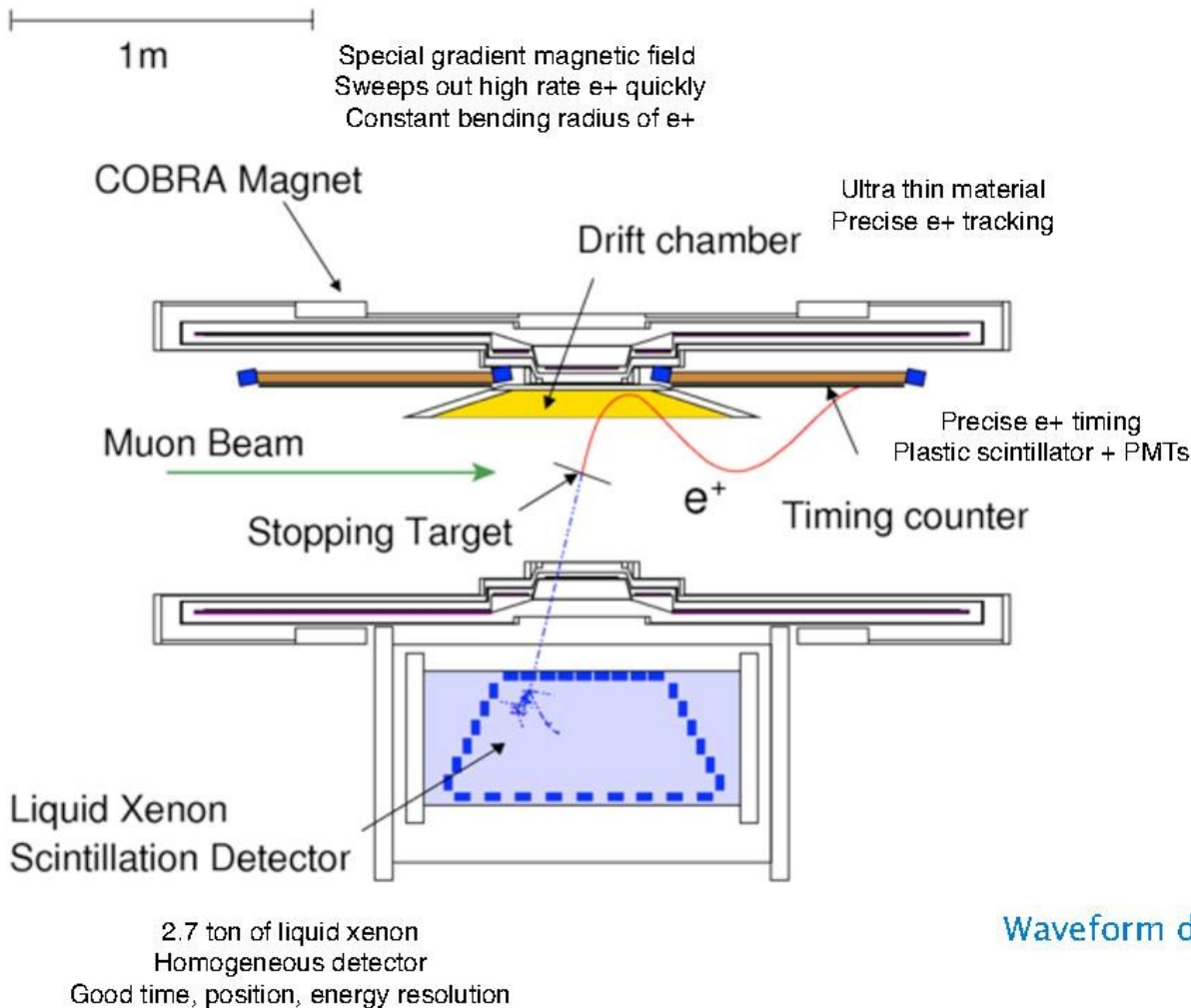
At $3 \times 10^7 \mu/\text{s}$

The **accidental background** is **dominant** and is determined by the experimental resolutions

MEG Experiment



The most intense DC muon beam, $3 \times 10^7 \mu/s$ @ PSI, Switzerland



Waveform digitizer for all detectors

Physics Analysis Overview

✓ Five observables (E_e , E_γ , $\theta_{e\gamma}$, $\Phi_{e\gamma}$, $T_{e\gamma}$) to characterize $\mu \rightarrow e\gamma$ event

✓ Back-to-back ($\theta_{e\gamma} = \Phi_{e\gamma} = 0$)

✓ Monoenergetic ($E_e = E_\gamma = 52.8 \text{ MeV} (=m_\mu/2)$)

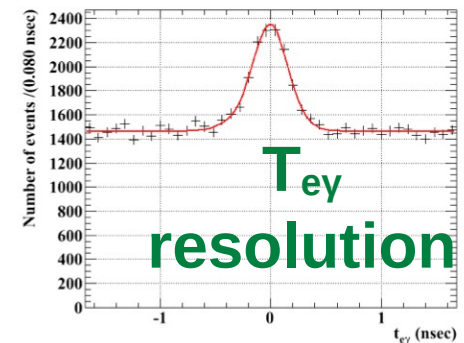
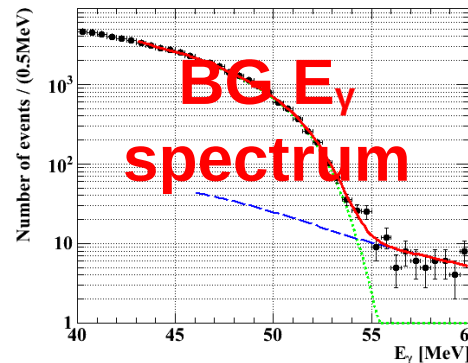
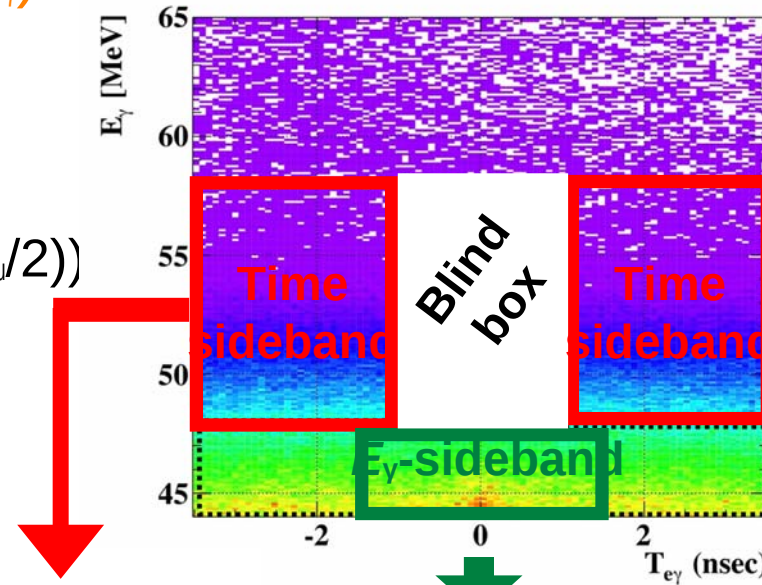
✓ Coincident ($T_{e\gamma} = 0$)

✓ Predominant BG: accidental overlap bw/ Michel e^+ and

✓ (AIF, RMD, brems.)

✓ ML analysis to extract N_{sig}

✓ Blind analysis 1



MEG History

✓ 1999: Approved at PSI

✓ -2007: Detector commissioning/engineering run

✓ 2008: DAQ started

✓ 2011: Result with

2009-2010 dataset

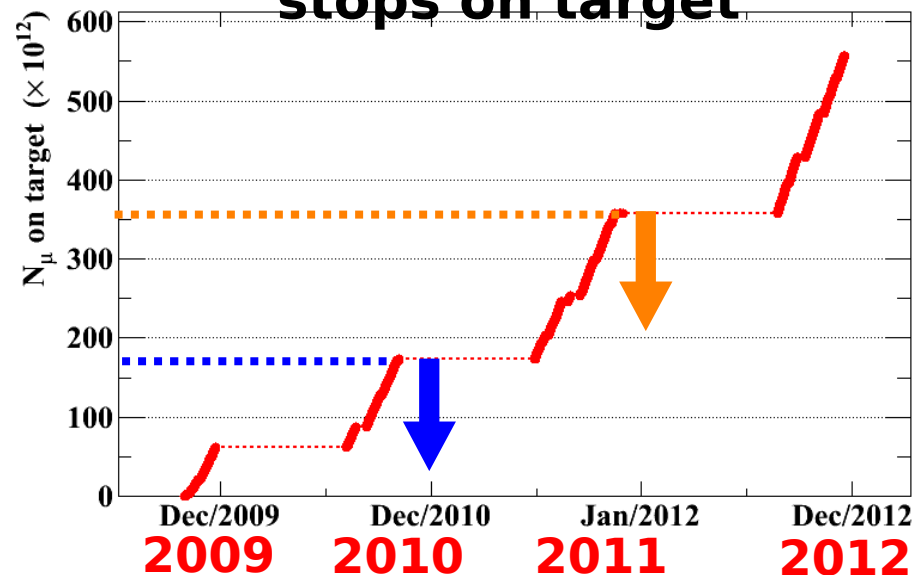
$(1.65 \times 10^{14} \mu^+/\text{s})$

✓ $B < 2.4 \times 10^{-12}$ (90% C.L.)

(x5 better than
previous one)

✓ 2013: Combined analysis of 2009-2011 with
reanalysis 2009-2010 ($3.6 \times 10^{14} \mu^+/\text{s}$)

**Accumulated # of μ^+
stops on target**



Sensitivity

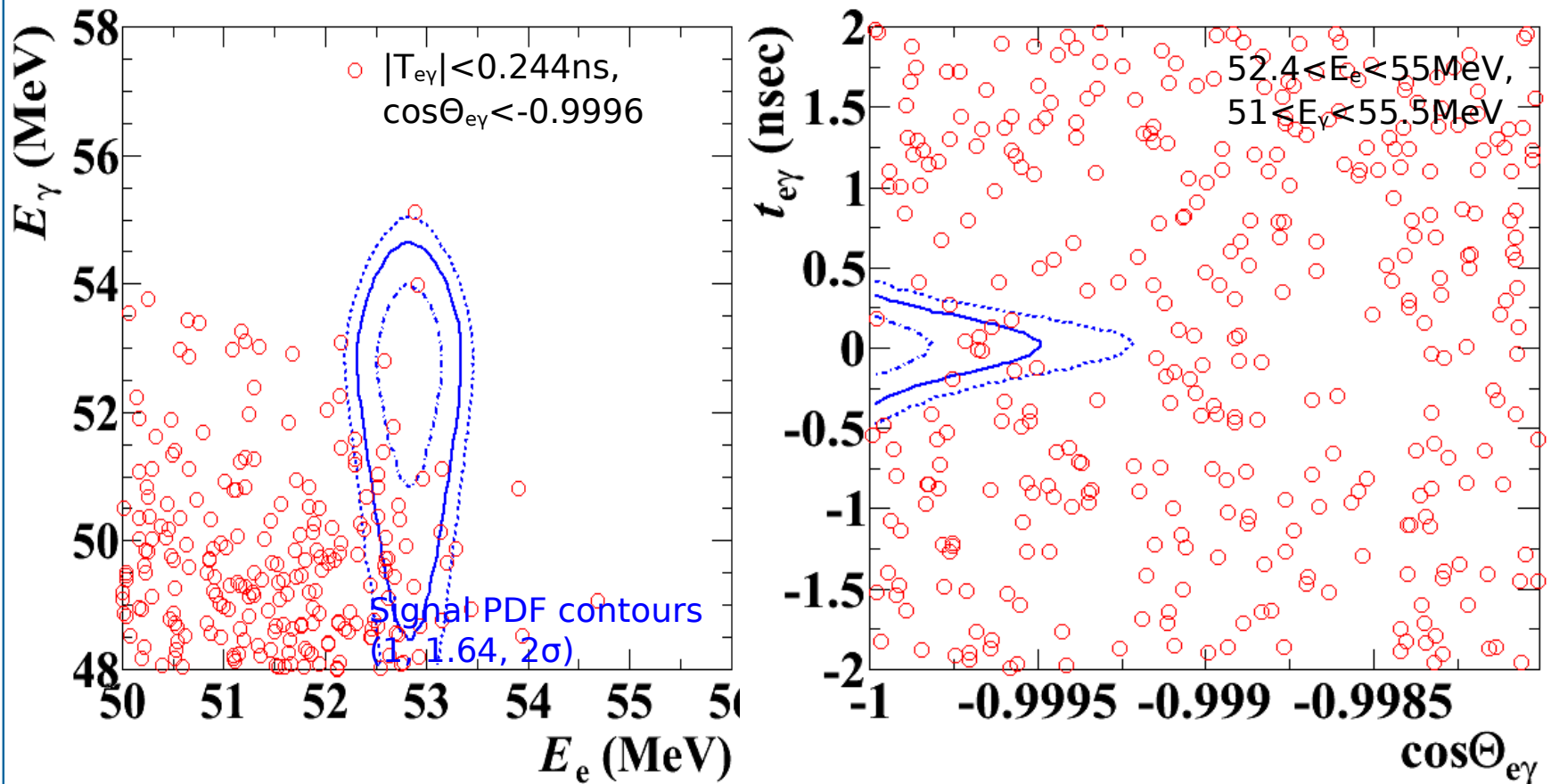
- ✓ **Sensitivity**: 90% C.L. UL based on null-signal hypothesis with expected rates of RMD and BG.
- ✓ **~20% improvement** in total with new algorithms

	μ^+ stops	Sensitivity
2009-2010	1.75×10^{14}	$1.3 \times 10^{-12*}$
2011	1.85×10^{14}	1.1×10^{-12}
2009-2011	3.60×10^{14}	7.7×10^{-13}

* 1.6×10^{-12} in previous analysis

Event Distribution

✓ 2009-2011 all combined



Likelihood Analysis Summary

Fit results on branching ratio

	Best fit	UL (90% C.L.)	Sensitivity
2009-2010	0.09×10^{-12}	1.3×10^{-12}	1.3×10^{-12}
2011	-0.35×10^{-12}	6.7×10^{-13}	1.1×10^{-12}
2009-2011	-0.06×10^{-12}	5.7×10^{-13}	7.7×10^{-13}

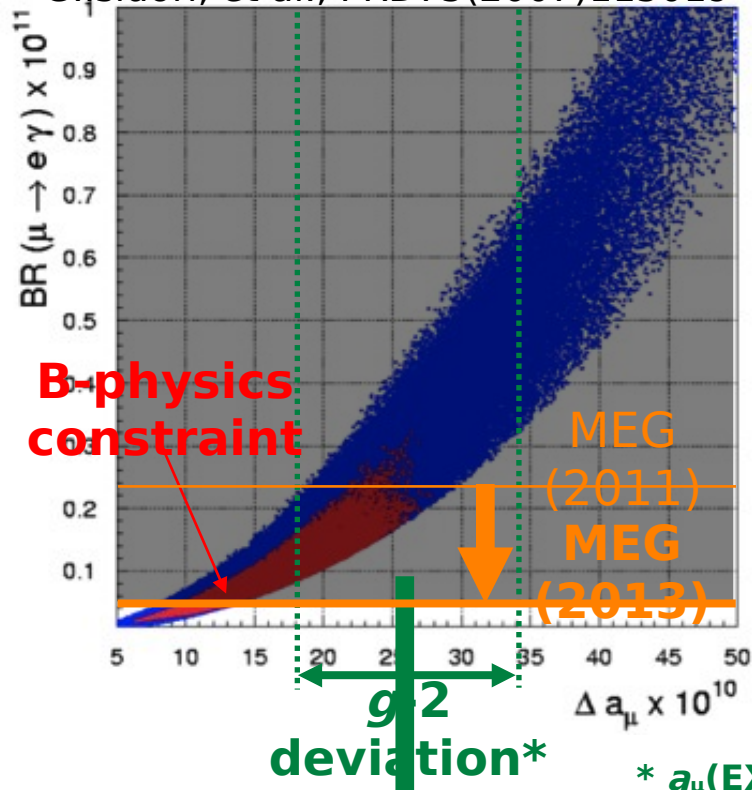
✓ UL from all combined dataset $B < 5.7 \times 10^{-13}$ (90% C.L.)

✓ ×4 more stringent than the present upper limit

Constraints on BSM Physics

SUSY-GUT

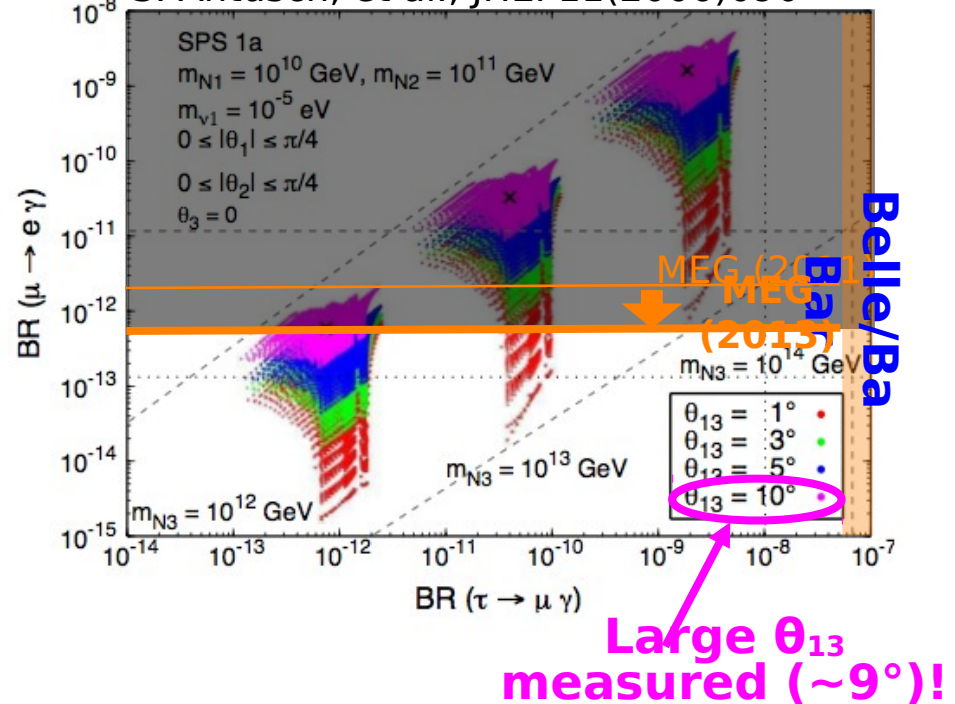
G. Isidori, et al., PRD75(2007)115019



* $a_\mu(\text{EXP}): \text{PRD73(2006)072,}$
 $a_\mu(\text{SM}): \text{Hagiwara et al.,}$
 JPG38(2011)085003

SUSY-Seesaw

S. Antusch, et al., JHEP11(2006)090



Papers in 2012/2013

- 1) M. De Gerone et al., Development and commissioning of the Timing Counter for the MEG Experiment,

Trans. Nucl. Scie. Vol.59, No.2, (2012) 379-388

- 2) J. Adam et al., New constraints on the existence of the $\mu^+ \rightarrow e^+ \gamma$ decay, Phys. Rev. Lett. 110, 201801 (2013)

- 3) J. Adam et al., The MEG detector for $\mu^+ \rightarrow e^+ \gamma$ decay search, Europ. Physic. J. 73, 2365 (2013)

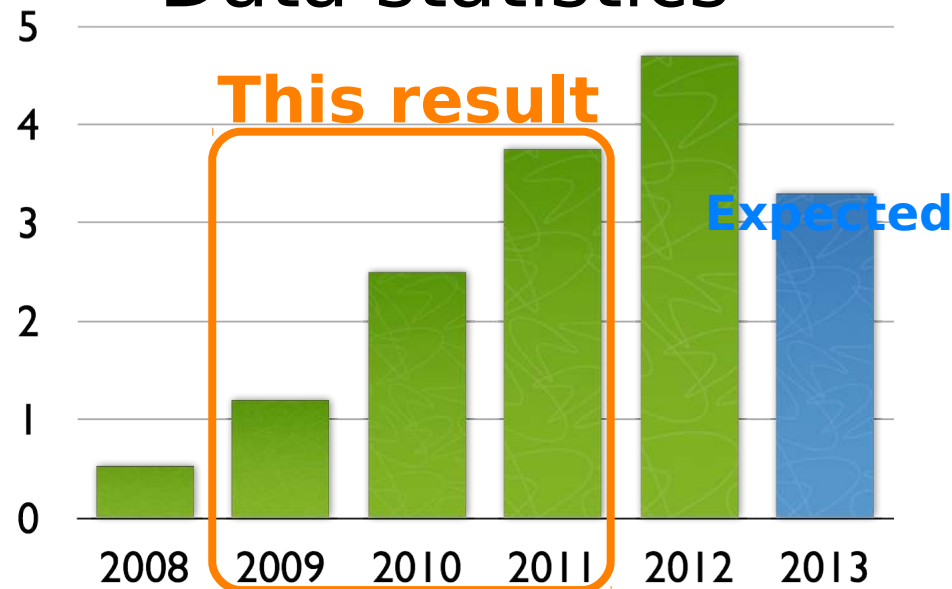
For (3) P. Cattaneo corresponding editor

Prospects

- ☑ MEG will continue DAQ till summer in 2013.
- ☑ Data statistics will be doubled with 2012+2013
- ☑ But this is not the end of the story...

Normalization-factor/ 10^2

Data statistics

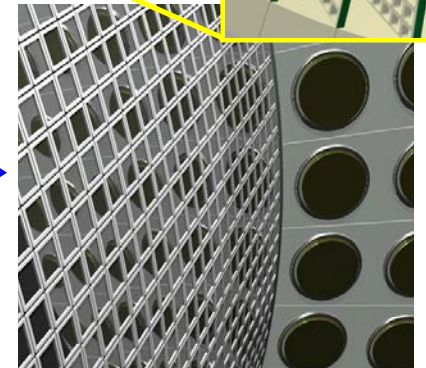
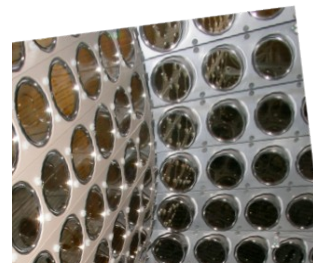
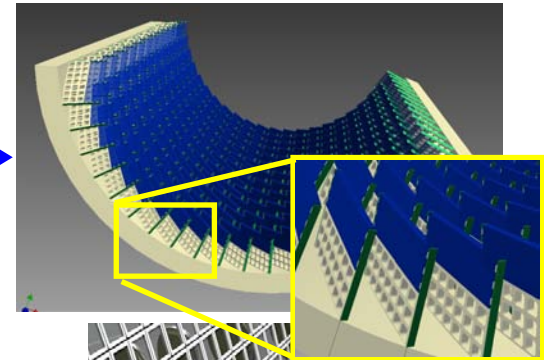
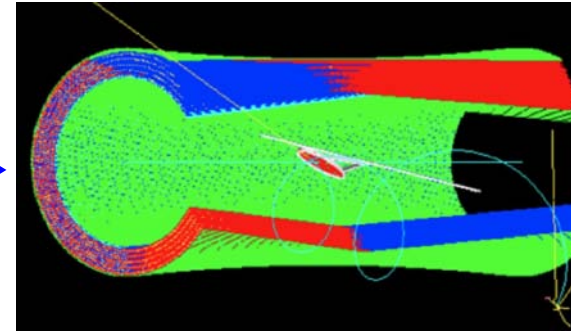
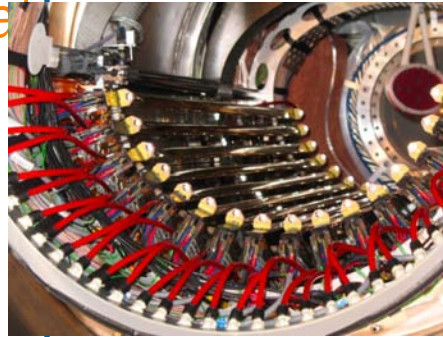


MEG Upgrade

✓ MEG upgrade approved at PSI in Jan. 2013

✓ Upgraded items

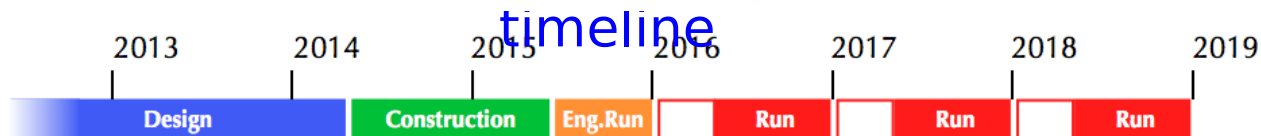
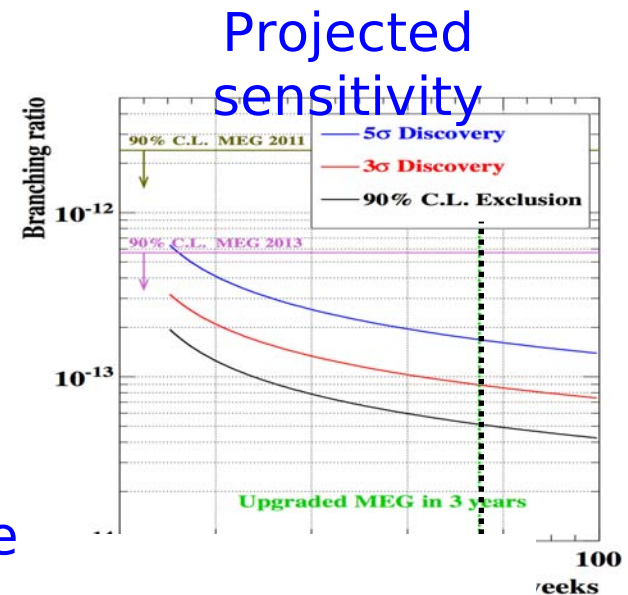
- ✓ Higher μ intensity
- ✓ Single volume drift chamber with stereo angle configuration
- ✓ Pixelated timing counter with SiPM readout
- ✓ LXe detector with SiPM readout
- ✓ Thinner target



MEG Upgrade

- ☑ Upgraded MEG is expected to search for $\mu \rightarrow e\gamma$ down to $B \sim 5 \times 10^{-14}$ in three years!
- ☑ $\times 10$ improvement w.r.t. current MEG
- ☑ More details in arXiv:1301.7225

PDF parameters	Present MEG	Upgrade scenario
e^+ energy (keV)	306 (core)	130
e^+ θ (mrad)	9.4	5.3
e^+ ϕ (mrad)	8.7	3.7
e^+ vertex (mm) Z/Y(core)	2.4 / 1.2	1.6 / 0.7
γ energy (%) ($w < 2$ cm)/($w > 2$ cm)	2.4 / 1.7	1.1 / 1.0
γ position (mm) $u/v/w$	5 / 5 / 6	2.6 / 2.2 / 5
γ - e^+ timing (ps)	122	84
Efficiency (%)		
trigger	≈ 99	≈ 99
γ	63	69
e^+	40	88



Upgrade Pavia

Pavia started an R&D to upgrade the TC for MEG2 (2015-2017)

Use of SiPM reading scintillator bars
with simpler mechanics and better timing
(to be proved)

Just started more in request for funding 2013

Summary

- ✓ MEG has searched for lepton flavor violating decay, $\mu \rightarrow e\gamma$, with combined data sample for 2009-2011.
- ✓ The events observed found to be consistent with null-signal hypothesis.
- ✓ Established $\times 4$ more stringent UL on branching ratio
 - ✓ $B(\mu^+ \rightarrow e^+\gamma) < 5.7 \times 10^{-13}$ (90% C.L.)
- ✓ Data statistics expected to be doubled by summer 2013.
- ✓ MEG upgrade program approved by PSI in Jan. 2013.
- ✓ Upgraded MEG with an ultimate sensitivity ($\times 10$ higher than current MEG) is planned to start in 2016.

P - SuperB

Consuntivo

Sezione di Pavia

Giugno 2013

Gruppo P-SUPERB Pavia

Responsabile: Valerio Re

- Università di Pavia
- Università di Bergamo

Attività principali

- Sviluppo di MAPS (Monolithic Active Pixel Sensors) CMOS per il Layer 0 di SVT
- Chip di lettura rivelatori a strip di SVT, opzione a pixel ibridi per Layer 0

The SuperB cancellation

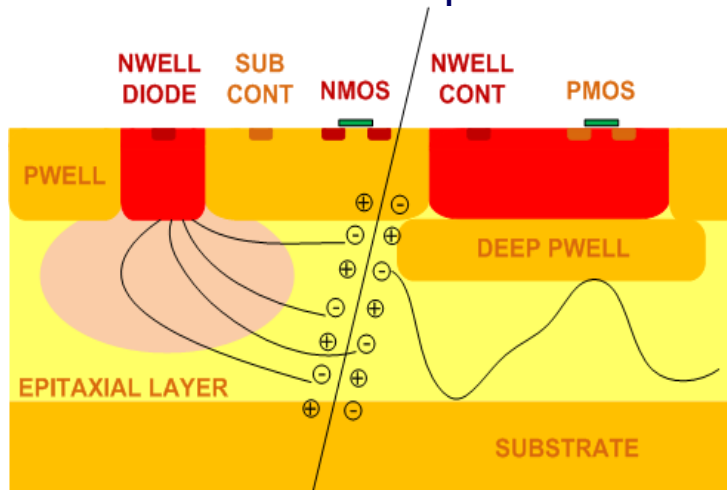
- ✂ “The SuperB flagship project failed getting the extra support needed to meet the financial planning of a fresh costing reassessment, even in the case of substantial but foreseeable external contributions
- ✂ The negotiation of additional resources requested already by the original proposal has been refused by the government due to the general economic situation” (from R. Petronzio, Dec. 2012)
- ✂ The SuperB project was cancelled. However, some interesting R&D activities on front-end electronics and CMOS sensors were carried out with important results in view of future (and hopefully real) applications.

SuperB – driven R&D at INFN-Pavia

- 1) CMOS Monolithic Active Pixel Sensors (MAPS) in a quadruple well process (INMAPS)
- 1) CMOS MAPS and readout chip for Hybrid pixels in a 3D integration technology
- 2) Design of a front-end chip for silicon strip detectors

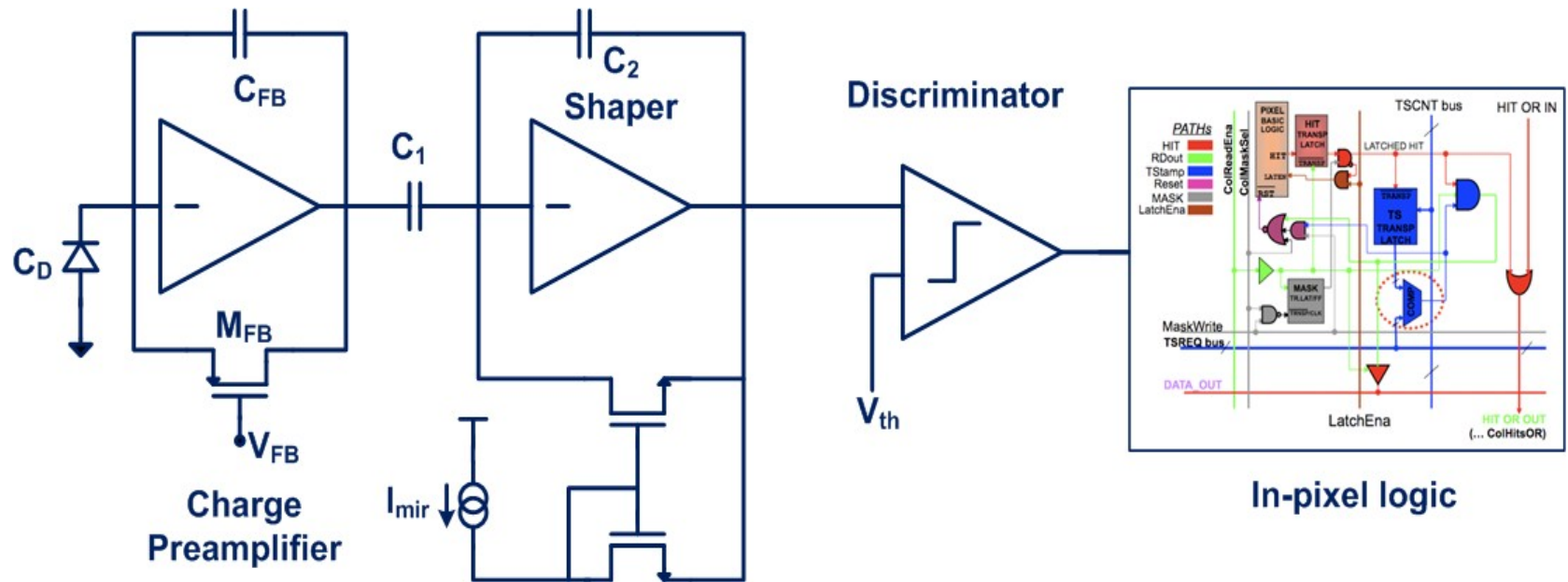
CMOS MAPS in a quadruple well process

- Motivation: design of high granularity monolithic active pixel sensors (MAPS) for application to the Layer0 of the SuperB SVT
 - Low material budget ($<1\% X_0$)
 - Fine granularity ($\leq 50 \mu\text{m}$)
 - High Back rate (100 MHz/cm^2) & fast timestamp ($< 1 \mu\text{s}$) - challenging for CMOS MAPS
 - High radiation hardness (3 Mrad/yr and $5 \cdot 10^{12} \text{ 1 MeV neutron equivalent/cm}^2\text{/yr}$) – challenging for CMOS MAPS
- 180 nm CMOS INMAPS process: deep P-wells make it possible to use PMOS transistors in the pixel readout cell without degrading the charge collection efficiency



The availability of full CMOS electronics in the pixel opens the way to advanced readout architectures for high data rates, with pixel-level sparsification and time stamping

Advanced pixel-level electronics

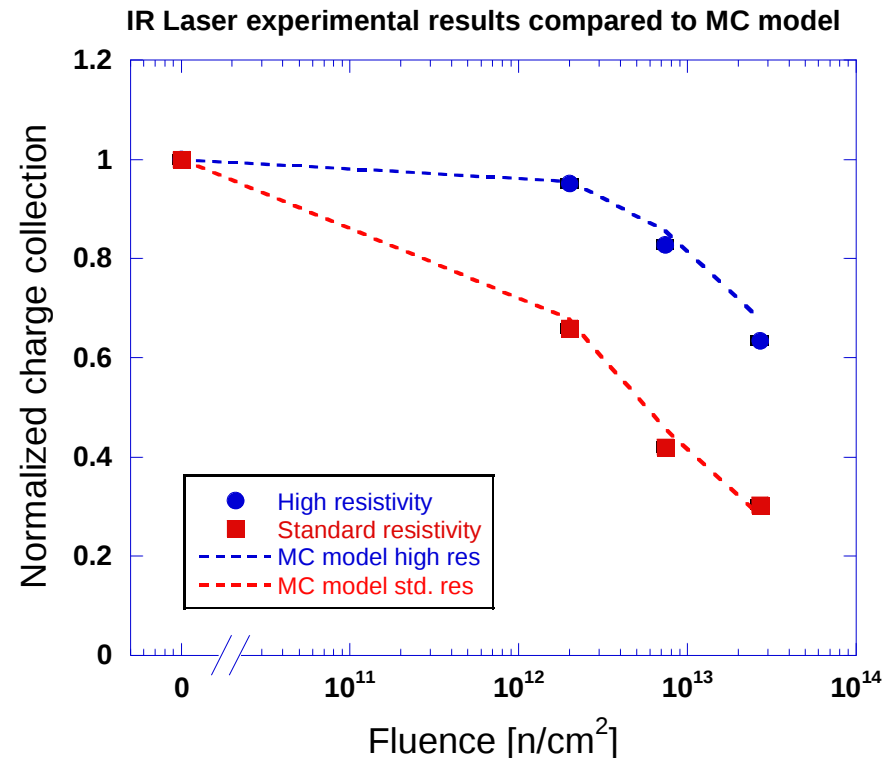
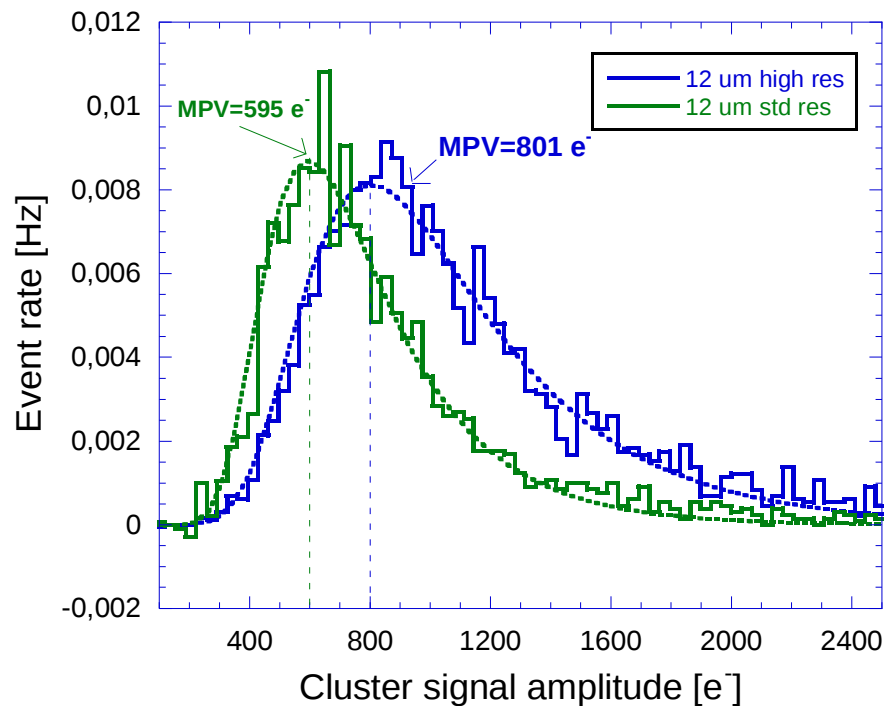


- In-pixel logic with time stamping capabilities, readout can be data-push or triggered. Readout efficiency >98% (triggered) and TS granularity down to 100 ns with 100 MHz/cm² target hit rate

CMOS MAPS in a quadruple well process with high resistivity epitaxial layer

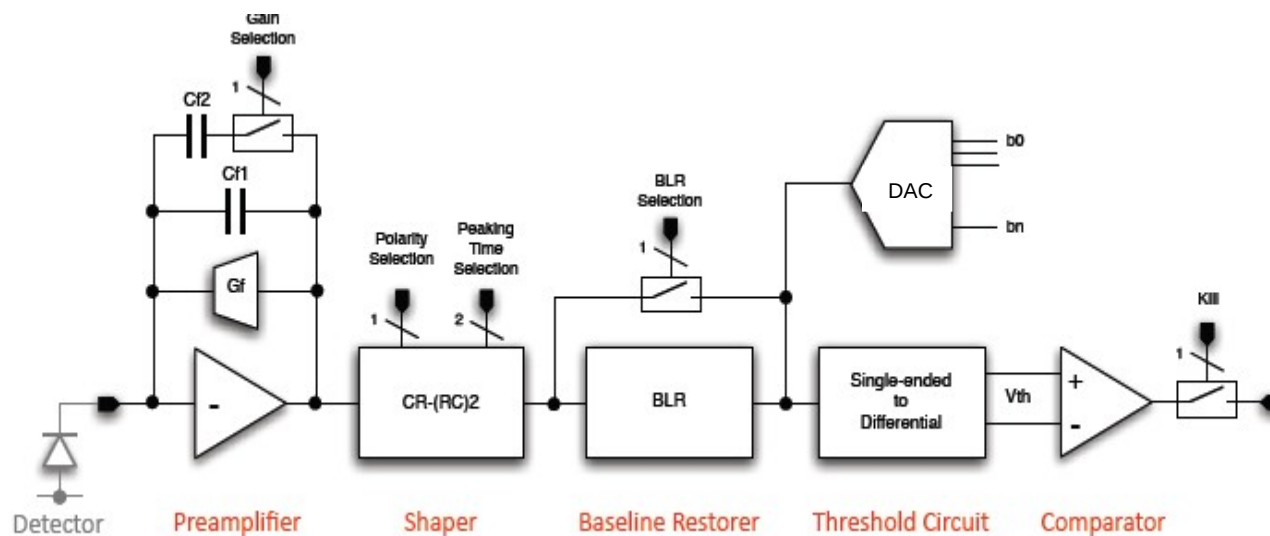
In this process, a high-resistivity epitaxial layer can be used as the particle-sensitive region.

This gives sizable advantages in terms of charge collection efficiency and tolerance to bulk damage (neutrons) => potential interest for other applications (LHC).



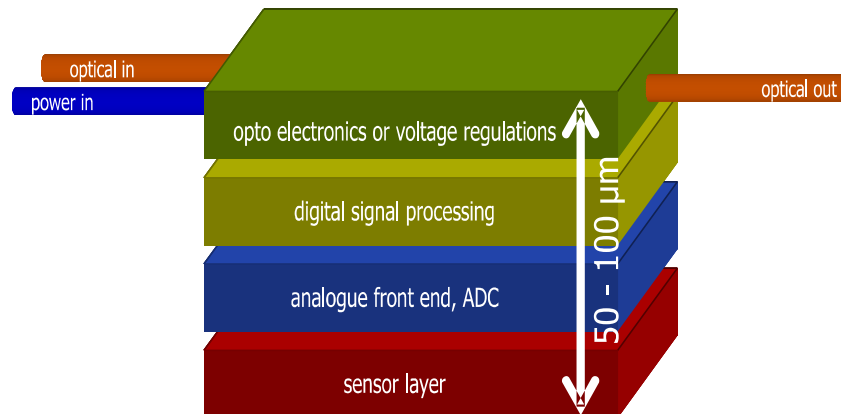
Front-end for triplets/strips

- Triplets (layer 0) and strips (layer 1 to 5) were the baseline option for the SuperB vertex detector
- Need to cope with a large span of detector capacitances (from 10 pF in the innermost to 70 pF in the outermost layer) and hit rate values (from 1 MHz/strip to 20 kHz/strip) with a single design
- The design of the analog channel (CMOS 130 nm) and the simulation of the sparsified readout architecture was carried out. The chip submission was put on hold, in view of finding another (real) application.



Advanced pixels and 3D integration for SuperB

- The microelectronic industry has developed 3D integration of **thinned and bonded CMOS tiers with vertical interconnections through the silicon layers** as an alternative or complementary way to device scaling, with the goal of enhancing memory capacity and microprocessor speed (by reducing length of interconnections) and of improving the performance of image sensors (by including pixel level high-speed signal processing).
- The semiconductor detectors and front-end electronics communities in HEP and photon science plan to take benefit from 3D integration for **new pixel sensor with advanced functionalities, smaller form factor, less material and dead area, separation and optimization of sensing, analog and digital functions,...** New concepts may also be enabled by this technology.



SuperB-driven 3D vertically integrated pixels

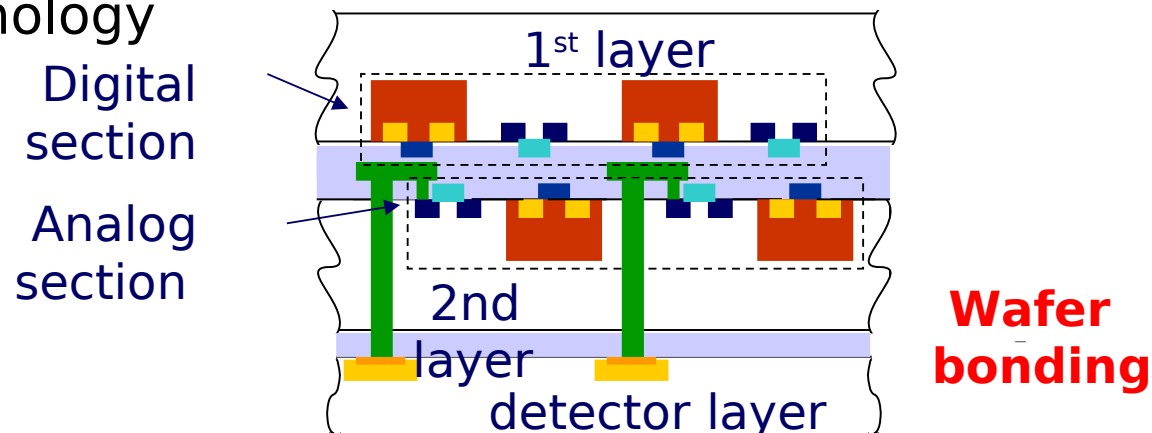
The following devices are at a very advanced design stage (see more in the VIPIX presentation for CSN5):

Large-scale 3D deep n-well MAPS : 100x128, 50 μm pitch with high rate sparsified readout architecture (60 mm^2)

3D readout chip for high resistivity pixel sensors (similar architecture) : 128x32, 50 μm pitch (40 mm^2)

The yield, reliability and turnaround time of the aggressive 3D process we used so far still seem to be an issue.

Since an experimental proof of 3D-related performance advantages was provided by the first 3D-IC run, we are willing to submit these new 3D chips, whenever a viable access is provided to the technology



Conclusions

Very interesting technologies, devices and integrated circuit architectures were studied in the SuperB framework especially for advanced pixel sensors and readout electronics.

We believe that INFN groups in SuperB SVT acquired a know-how that will greatly benefit other applications in high energy physics (e.g., HL-LHC) and photon science (FEL).

Personale impegnato nel progetto

NOME e COGNOME	Qualifica	Gruppo di afferenza	Percentuale
RICERCATORI			
Valerio Re (responsabile locale)	PO		50%
TECNOLOGI			
Luigi Gaioni	Assegnista		100%
Alessia Manazza	Dottorando		20%
Massimo Manghisoni	RU		80%
Lodovico Ratti	RU		50%
Gianluca Traversi	RU		30%
Stefano Zucca	Assegnista		100%
NUMERO TOTALE DI RICERCATORI		1 (0.5 FTE)	
NUMERO TOTALE DI TECNOLOGI		6 (3.8 FTE)	
PERSONALE FULL TIME EQUIVALENT		4.3	