Busca da origem da assimetria matéria antimatéria no Universo,

na experiencia LHCb.

Ignacio Bediaga

Centro Brasileiro de Pesquisas Físicas

1- Questões gerais sobre anti matéria.

2- Condições de Sakharov e a violação de CP.

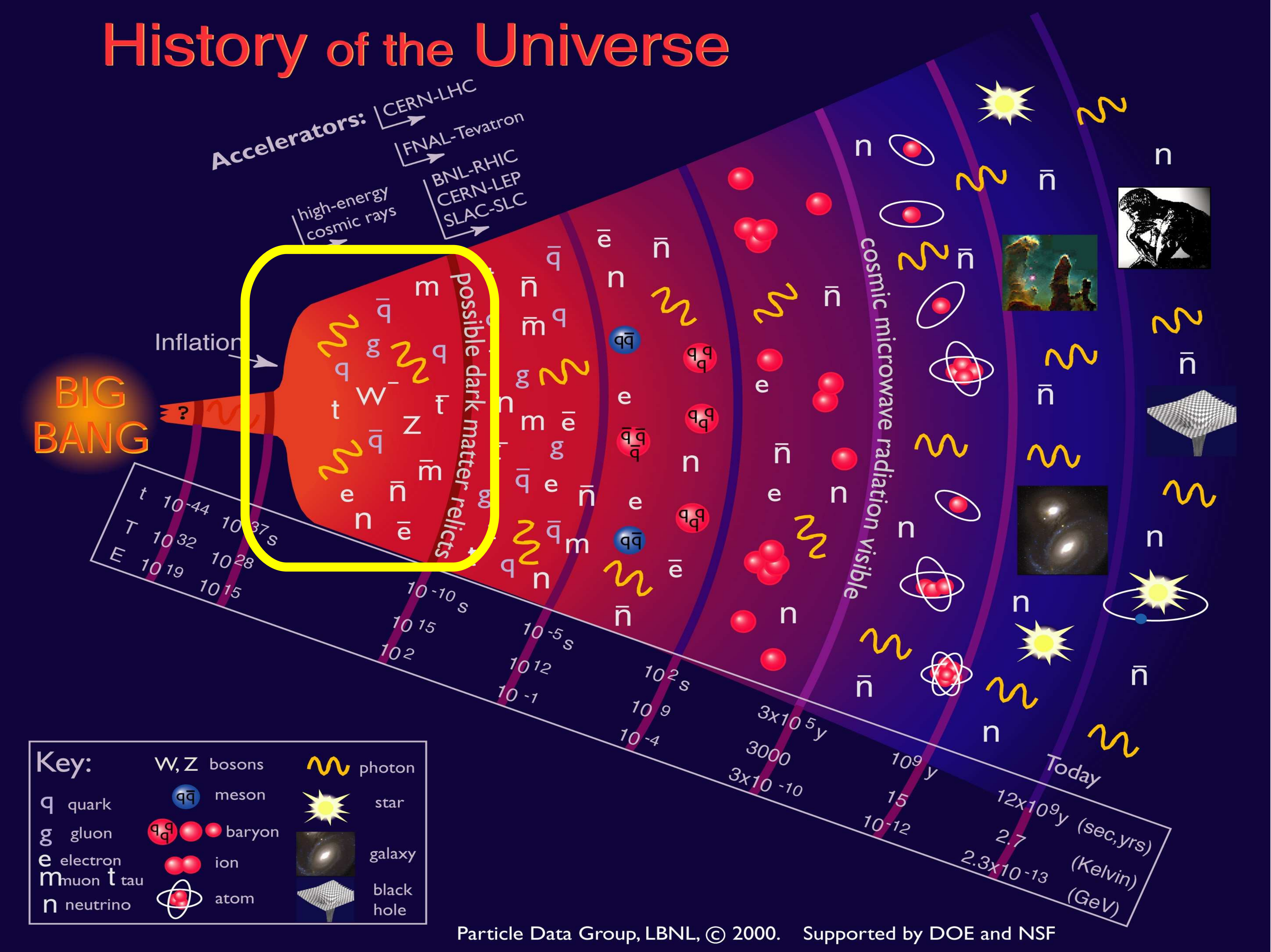
3- Força fraca, estrutura de famílias.

4- Produção e desintegração de partículas e o boson de Higgs.

5- Desintegração de partículas em três corpos e busca por violação de CP.

6- Sumário

Questões gerais sobre anti matéria


History of the Universe
Accelerators:
CERN-LHC
FNAL-Tevatron
BNL-RHIC
CERN-LEP
SLAC-SLC
high-energy cosmic rays
Inflation
BIG BANG
possible dark matter relicts
cosmic microwave radiation visible
t 10^-44 10^-37 s 10^-10 s 10^-5 s 10^2 s 3x10^5 y 10^9 y Today 12x10^9 y (sec,yrs)
T 10^32 10^28 10^15 10^12 10^9 3000 15 2.7 (Kelvin)
E 10^19 10^15 10^2 10^-1 10^-4 3x10^-10 10^-12 2.3x10^-13 (GeV)
Key:
W, Z bosons
q quark
g gluon
e electron
m muon
t tau
n neutrino
meson
baryon
ion
atom
photon
star
galaxy
black hole
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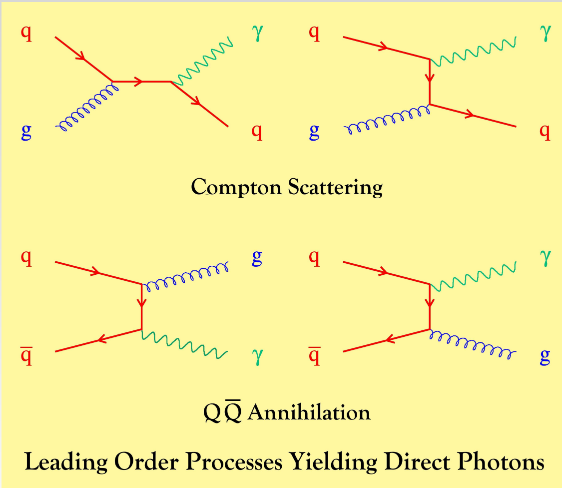
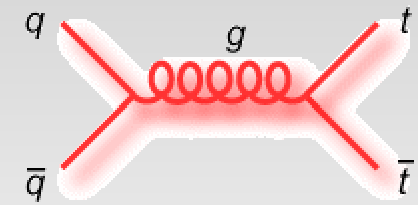
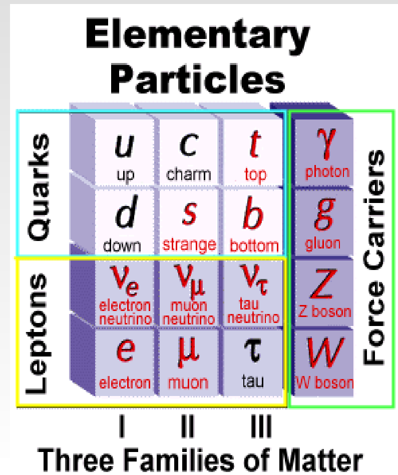
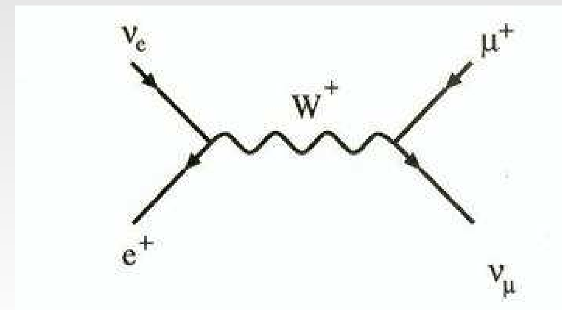
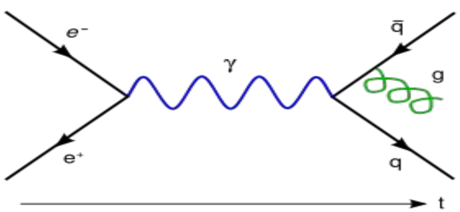
Criação – aniquilação - criacao-.....

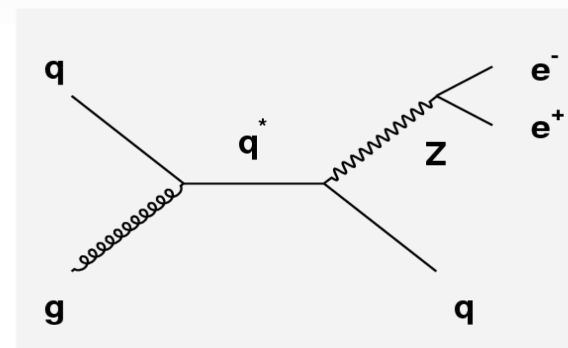


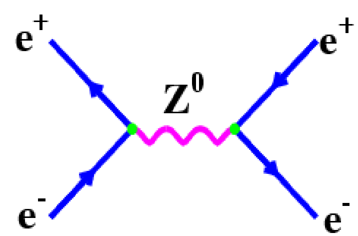


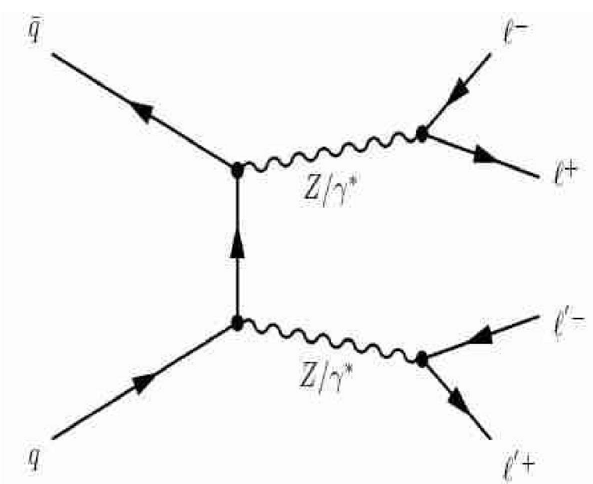


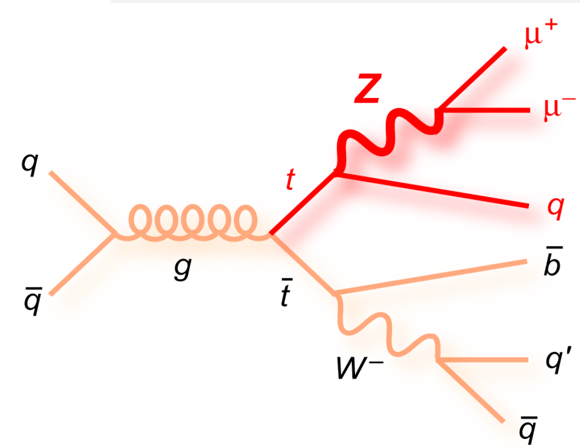


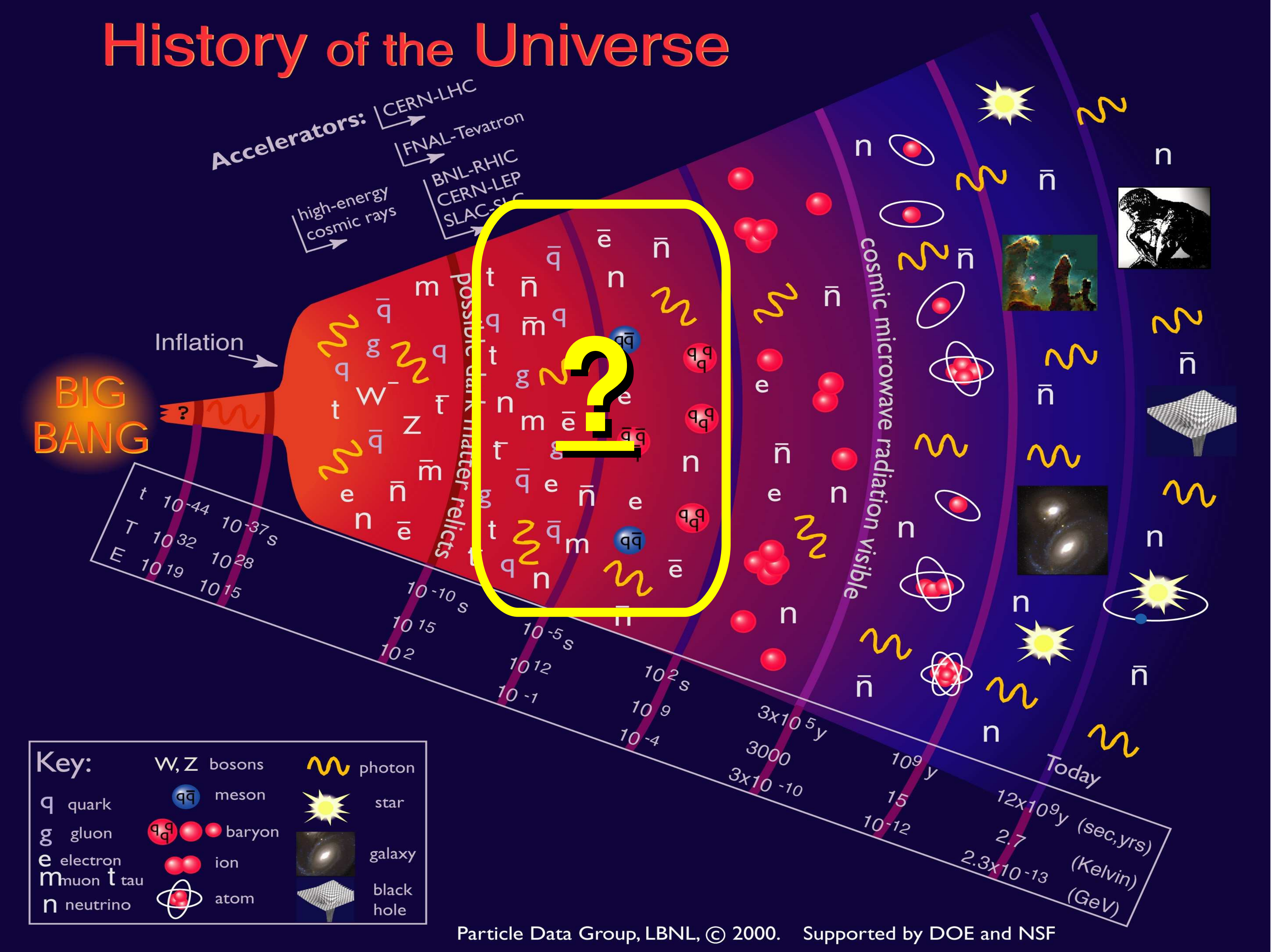








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T 10 32 10 28
E 10 19 10 15
10 -10 s
10 15
10 2
10 -5 s
10 12
10 -1
10 2 s
10 9
10 -4
3x10 5 y
3000
3x10 -10
10 9 y
15
10-12
Today
12x10 9 y (sec,yrs)
2.7 (Kelvin)
2.3x10 -13 (GeV)
Key:
q quark
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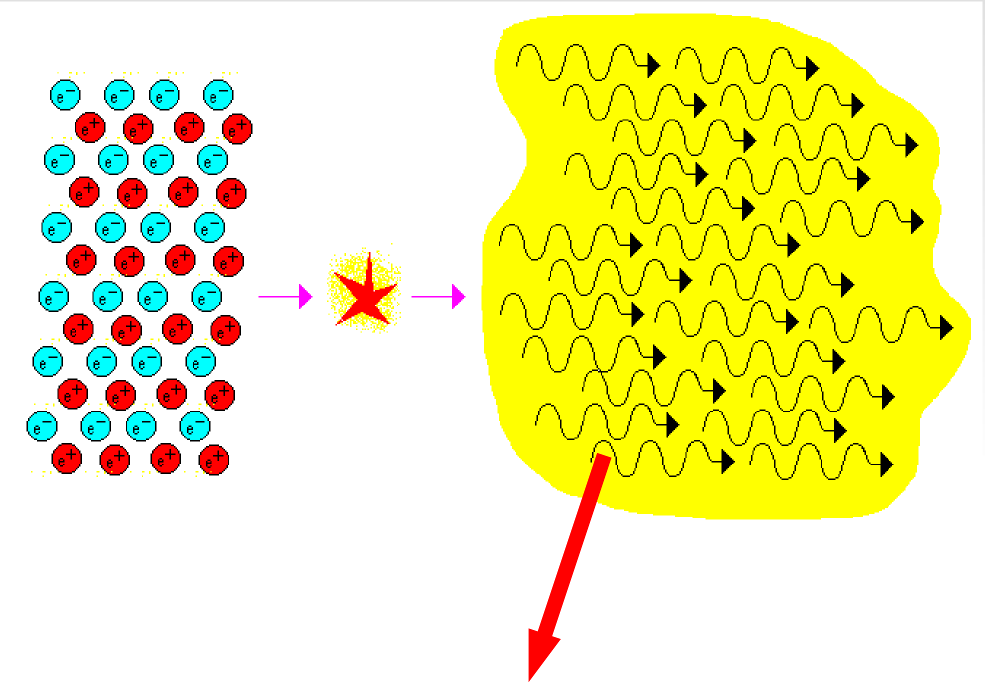
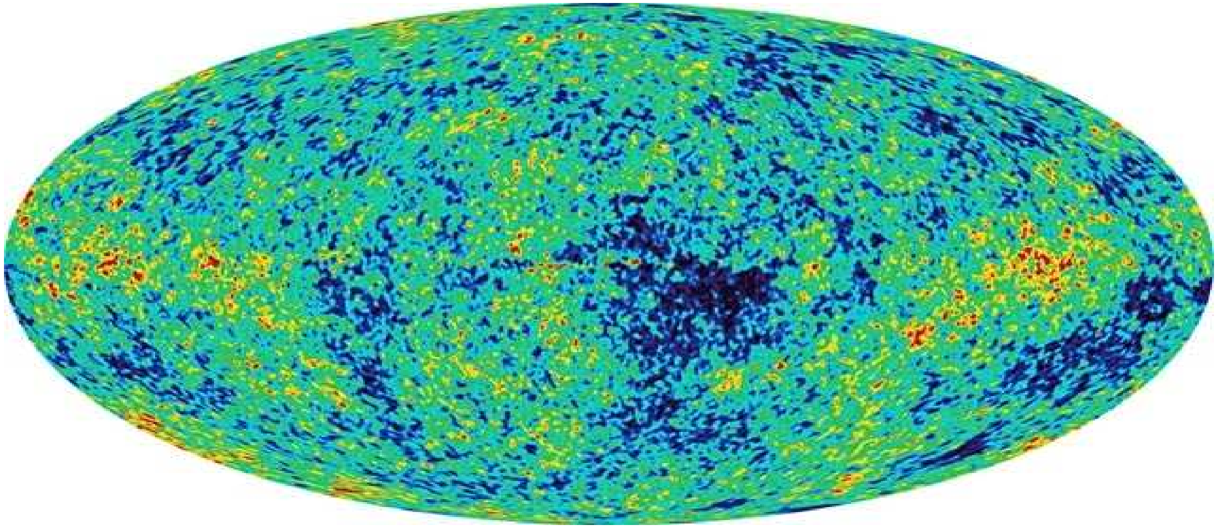
black hole
Particle Data Group, LBNL, © 2000. Supported by DOE and NSF

Expansão e resfriamento

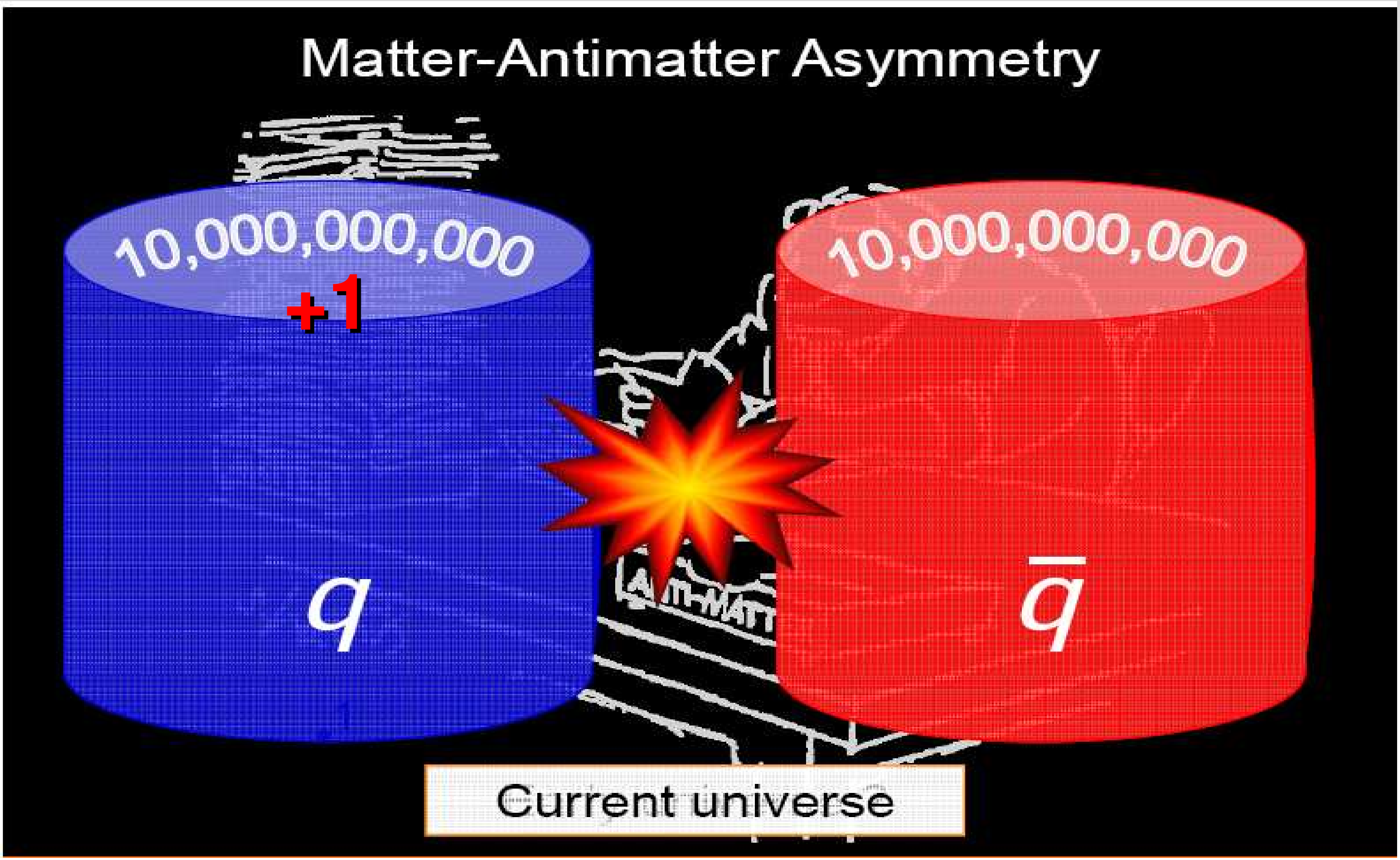
Uma infinidade de pares partícula anti-partícula



Leva a uma infinidade de Fótons com mesma energia pairando pelo Universo



Proporção partícula anti-partícula

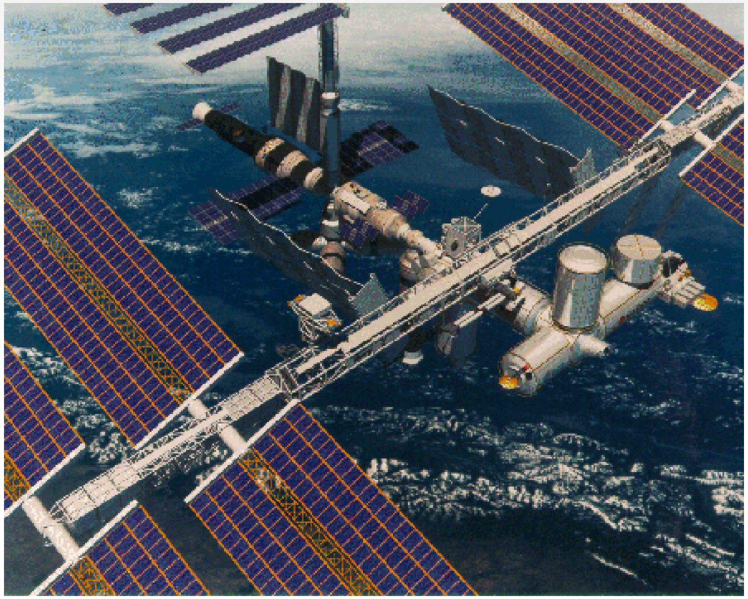


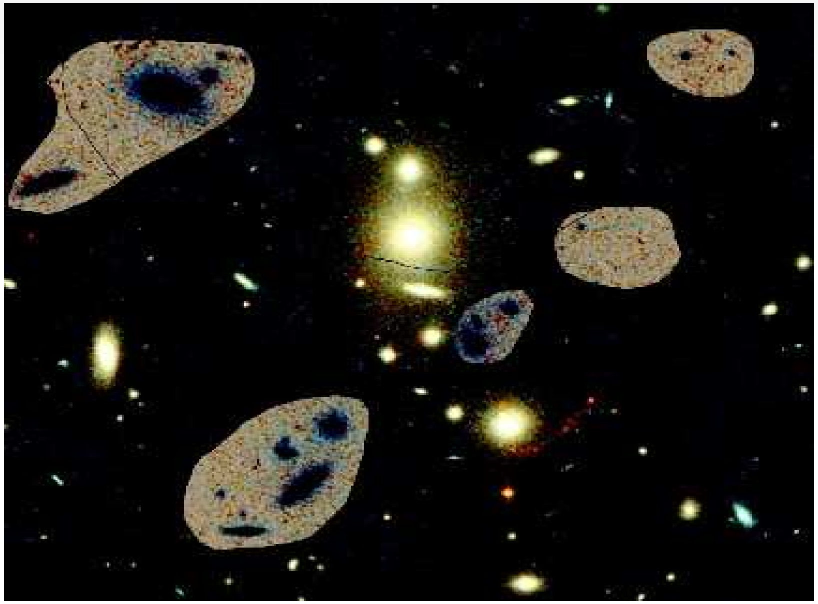
$$\frac{\Delta n_{\text{baryon}}}{n_\gamma} = \frac{n_{\text{baryon}} - n_{\overline{\text{baryon}}}}{n_\gamma} \sim O\left(10^{-10}\right)$$

Onde esta a Anti-Matéria?

Balões com detectores de anti-partículas.

Radio telescópios, satélites com detecção de raios gamma e raios X.





Nenhuma evidência de anti-matéria em ~ 1 Bilhão de anos luz

Condições de Sakharov e a violação de CP.

Condições de Sakharov

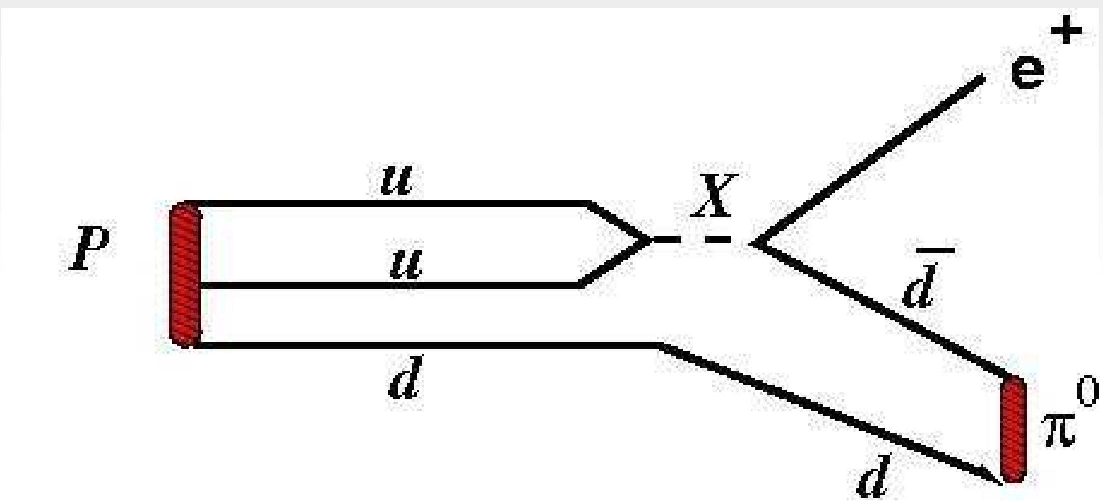
Para a produção da assimetria entre a matéria e a antimatéria, observada no universo atual, são necessárias duas condições:

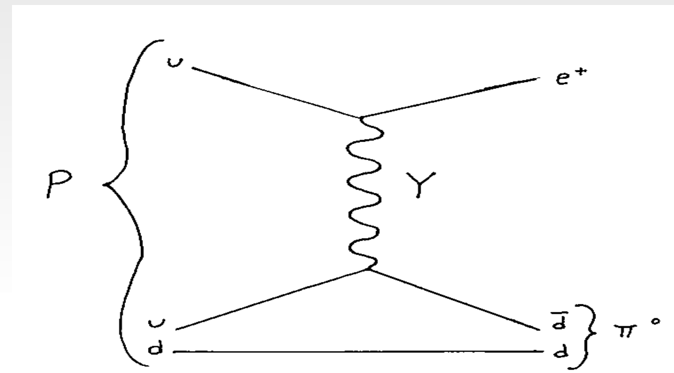
1- O número bariônico ser violado.
2- Violação de C e de CP.

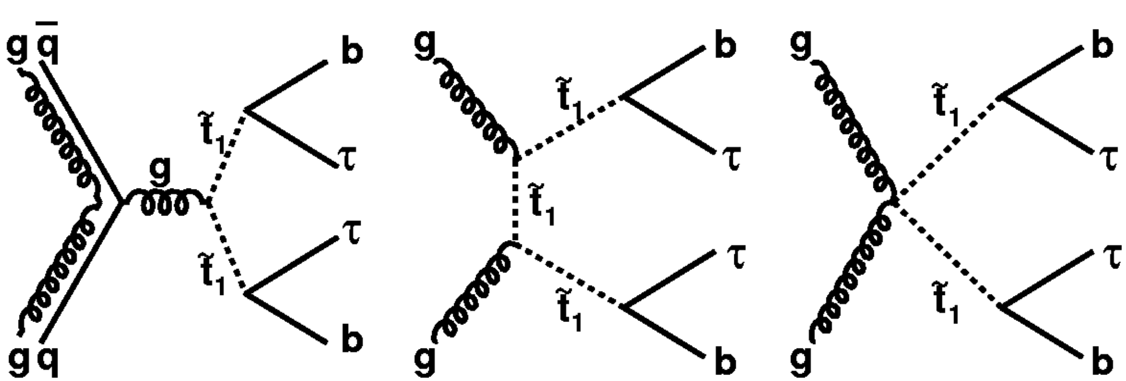
Estas duas condições seriam possíveis, segundo Sakharov, somente em um sistema fora do equilíbrio termodinâmico, ou seja no Universo em forte expansão.

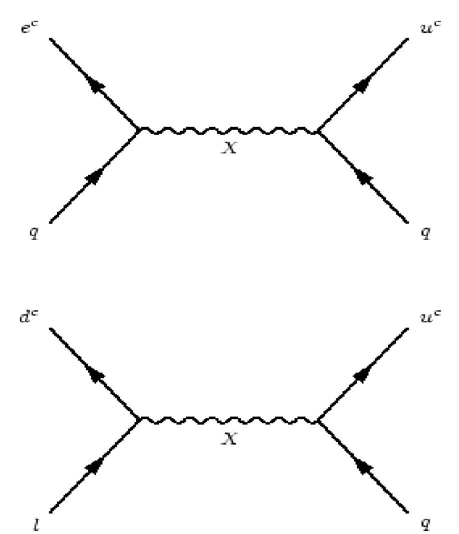
<u>1º condição:</u> <u>violação do número Bariônico</u>

Processos onde: o número de quarks, menos o número de anti-quarks, é diferente entre o estado inicial e final.









Dimension 6 proton decay mediated by the X boson $(3,2)_{-\frac{5}{6}}$ in $SU(5)$ GUT.

Resultados Experimentais: PDG

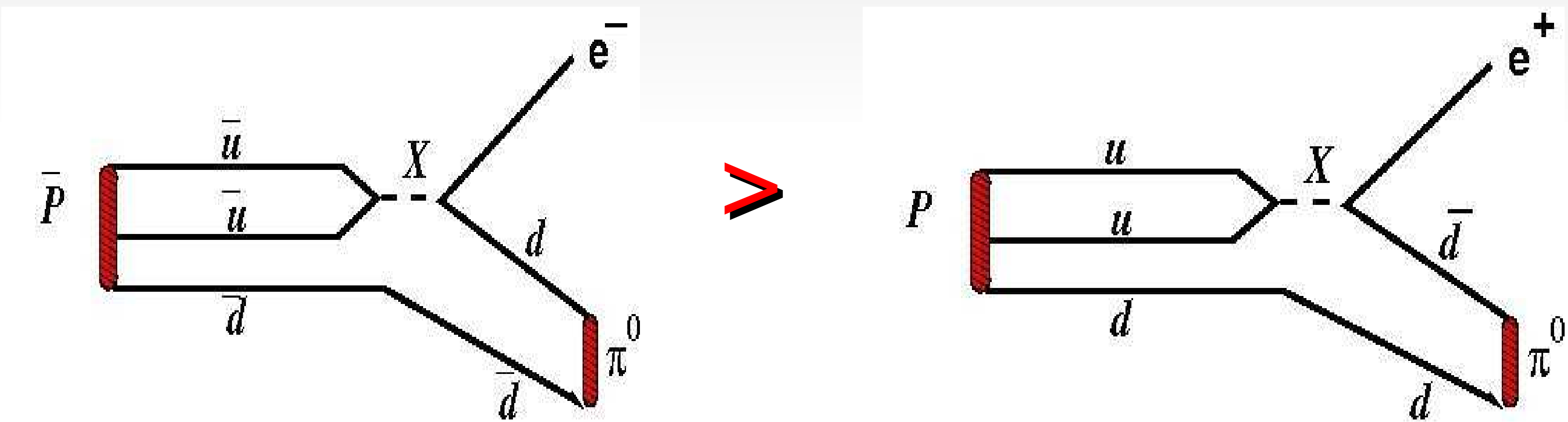
p DECAY MODES	Partial mean life (10^{30} years)
Antilepton + meson	
$N \to e^+ \pi$	> 158 (n), > 1600 (p)
$N \to \mu^+ \pi$	> 100 (n), > 473 (p)
$N \to \nu \pi$	> 112 (n), > 25 (p)
$p \to e^+ \eta$	> 313
$p \to \mu^+ \eta$	> 126
$n \to \nu \eta$	> 158
$N \to e^+ \rho$	> 217 (n), > 75 (p)
$N \to \mu^+ \rho$	> 228 (n), > 110 (p)
$N \to \nu \rho$	> 19 (n), > 162 (p)
$p \to e^+ \omega$	> 107
$p \to \mu^+ \omega$	> 117
$n \to \nu \omega$	> 108
$N \to e^+ K$	> 17 (n)
$p \to e^+ K^0_S$	> 120
$p \to e^+ K^0_L$	> 51
$N \to \mu^+ K$	> 26 (n)
$p \to \mu^+ K^0_S$	> 150
$p \to \mu^+ K^0_L$	> 83
$N \to \nu K$	> 86 (n)
$n \to \nu K^0_S$	> 51
$p \to e^+ K^*(892)^0$	> 84
$N \to \nu K^*(892)$	> 78 (n)

Antilepton + mesons	
$p \to e^+ \pi^+ \pi^-$	> 82
$p \to e^+ \pi^0 \pi^0$	> 147
$n \to e^+ \pi^- \pi^0$	> 52
$p \to \mu^+ \pi^+ \pi^-$	> 133
$p \to \mu^+ \pi^0 \pi^0$	> 101
$n \to \mu^+ \pi^- \pi^0$	> 74
$n \to e^+ K^0 \pi^-$	> 18
Lepton + meson	
$n \to e^- \pi^+$	> 65
$n \to \mu^- \pi^+$	> 49
$n \to e^- \rho^+$	> 62
$n \to \mu^- \rho^+$	> 7
$n \to e^- K^+$	> 32
$n \to \mu^- K^+$	> 57
Lepton + mesons	
$p \to e^- \pi^+ \pi^+$	> 30
$n \to e^- \pi^+ \pi^0$	> 29
$p \to \mu^- \pi^+ \pi^+$	> 17
$n \to \mu^- \pi^+ \pi^0$	> 34
$p \to e^- \pi^+ K^+$	> 75
$p \to \mu^- \pi^+ K^+$	> 245
Antilepton + photon(s)	
$p \to e^+ \gamma$	> 670
$p \to \mu^+ \gamma$	> 478
$n \to \nu \gamma$	> 28
$p \to e^+ \gamma\gamma$	> 100
$n \to \nu \gamma\gamma$	> 219

Aparentemente somente em sistemas fora do equilíbrio termodinâmico.

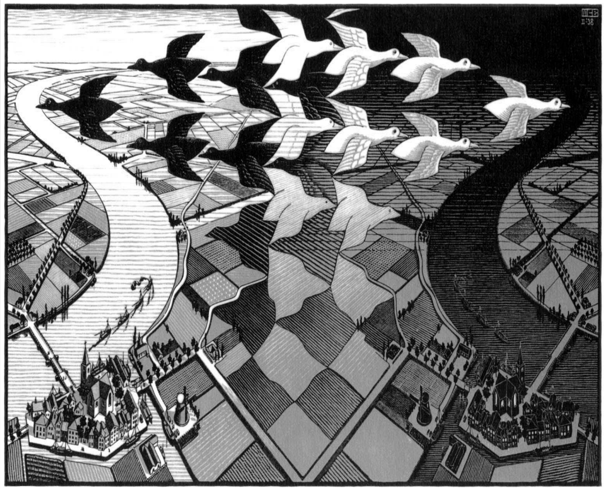
2º condição: violação de CP

Desintegração do próton seria menor que a do antipróton

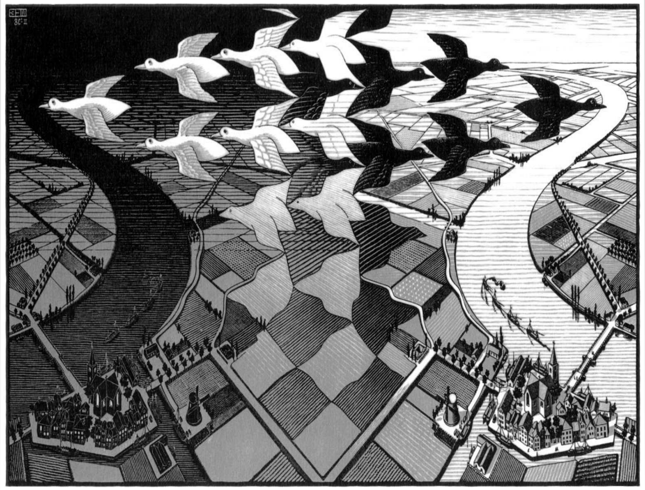


Isto daria conta do fato de que a soma das cargas elétrica do Universo é zero

Simetria de P



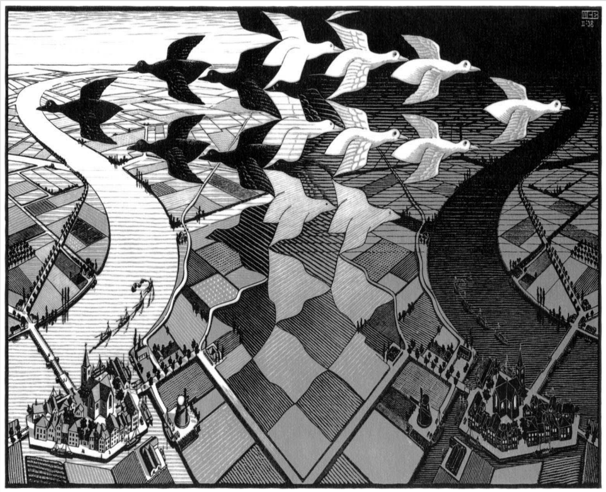
P



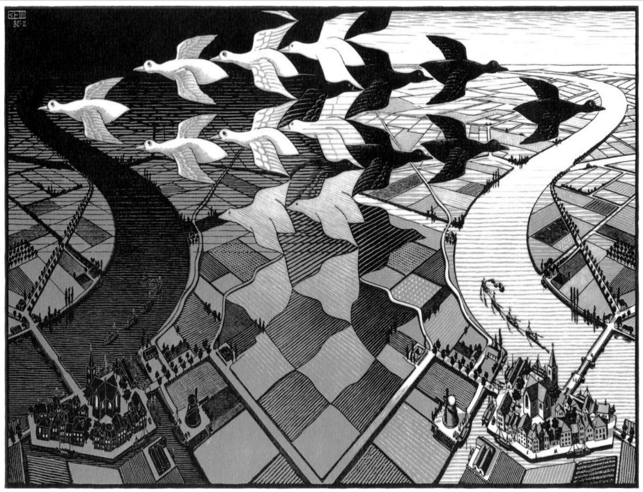
Simetria de reflexão:
Partículas aves pretas
Antipartículas aves brancas

Simetria conservada nas interações eletromagnéticas e fortes
Violada nas interações fracas

Simetria de Conjugação de Carga



C

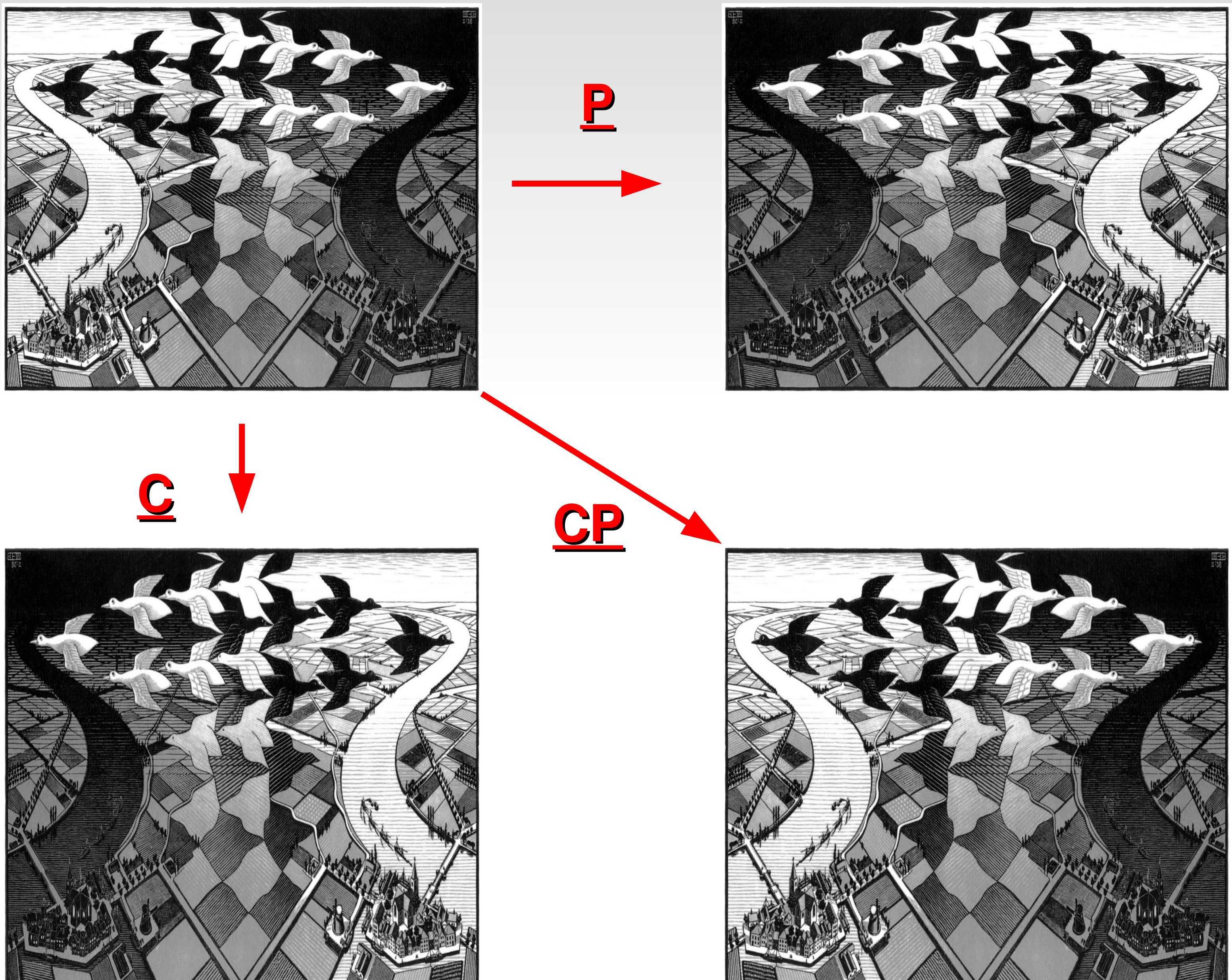


Simetria de conjugação de carga:
Partículas aves pretas
Antipartículas aves brancas

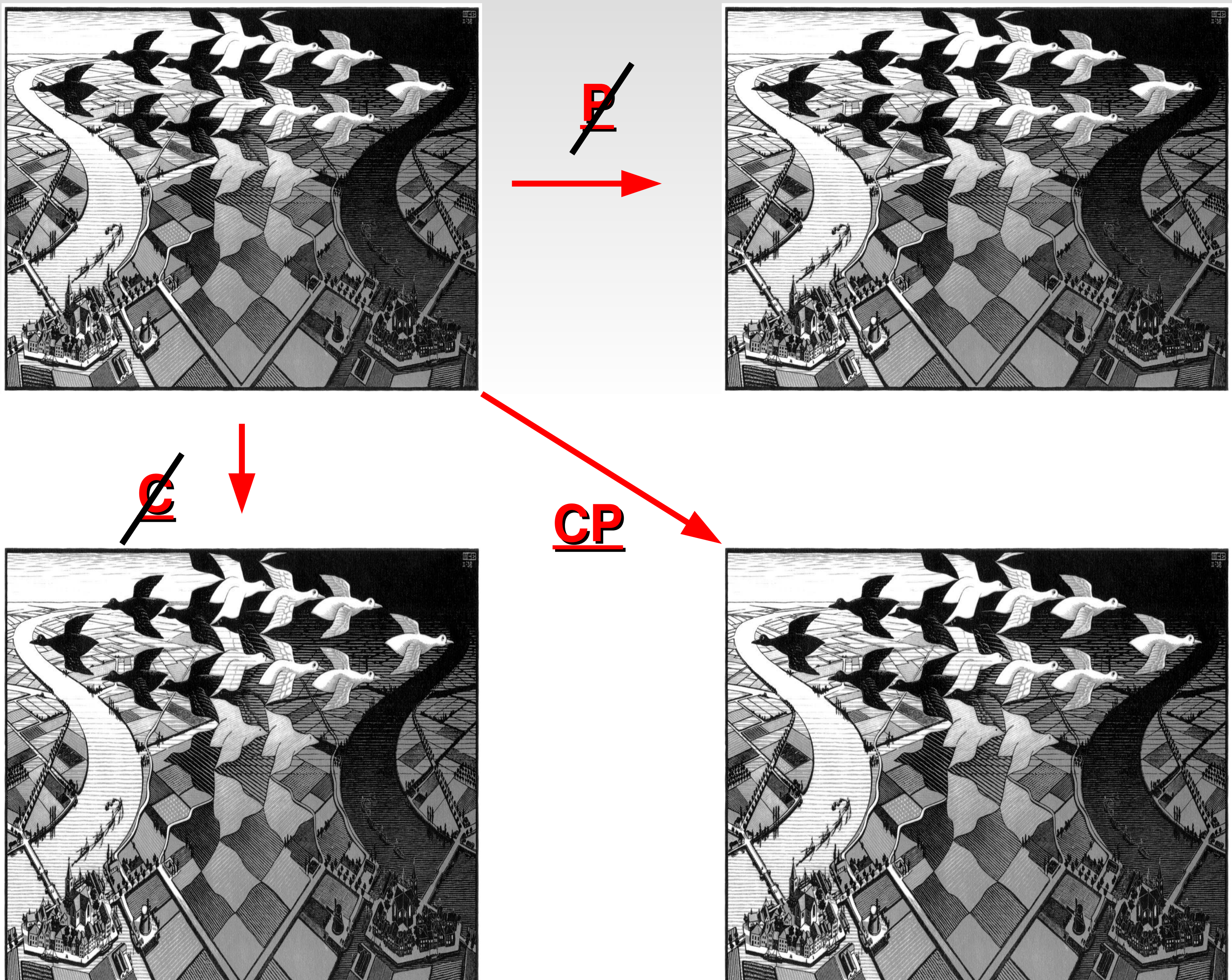
Simetria conservada nas interações eletromagnéticas e fortes

Violação as interações fracas na mesma proporção de P, para a conservação de CP.

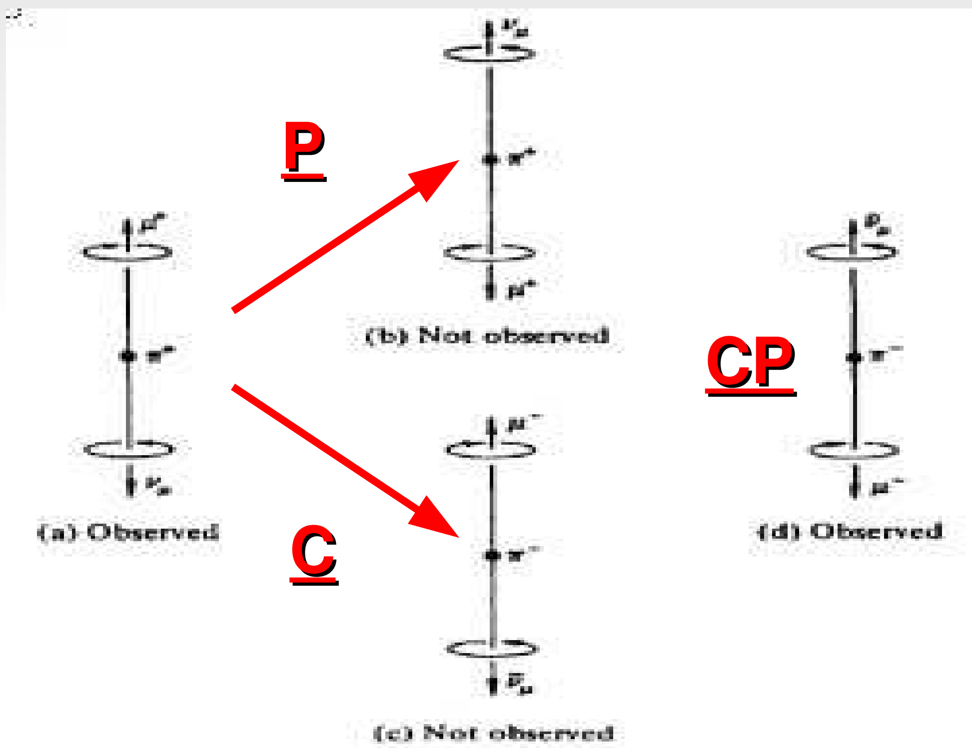
Simetria de CP



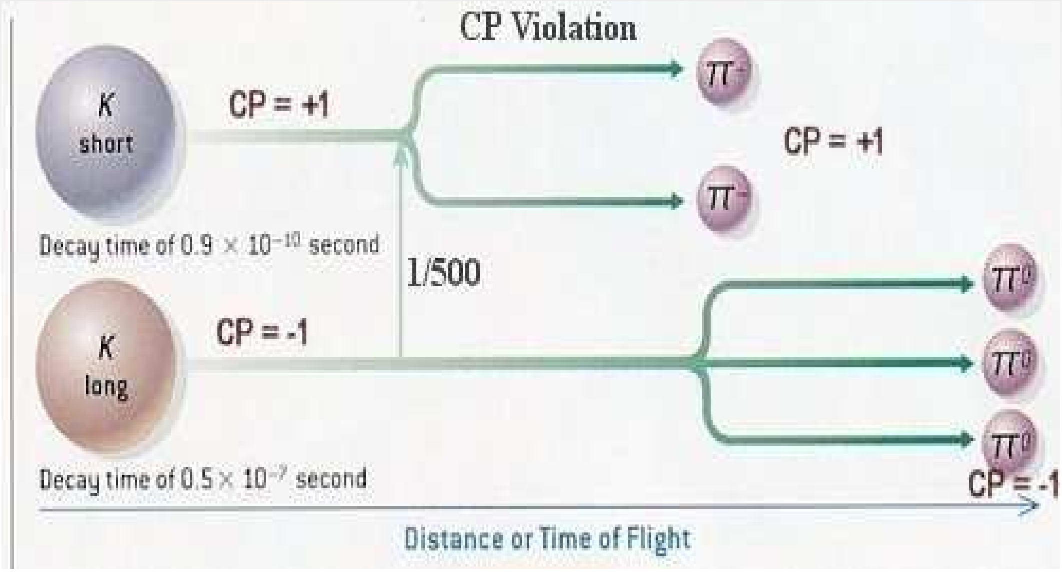
Simetria de CP

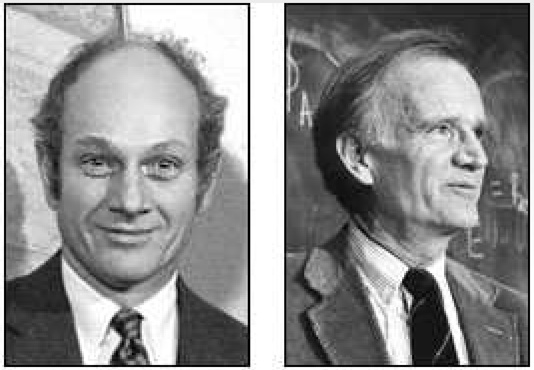


Simetria de CP: decaimento do méson $\pi^{\pm} \rightarrow \mu^{\pm}\nu$



Observação de Violação da Simetria de CP

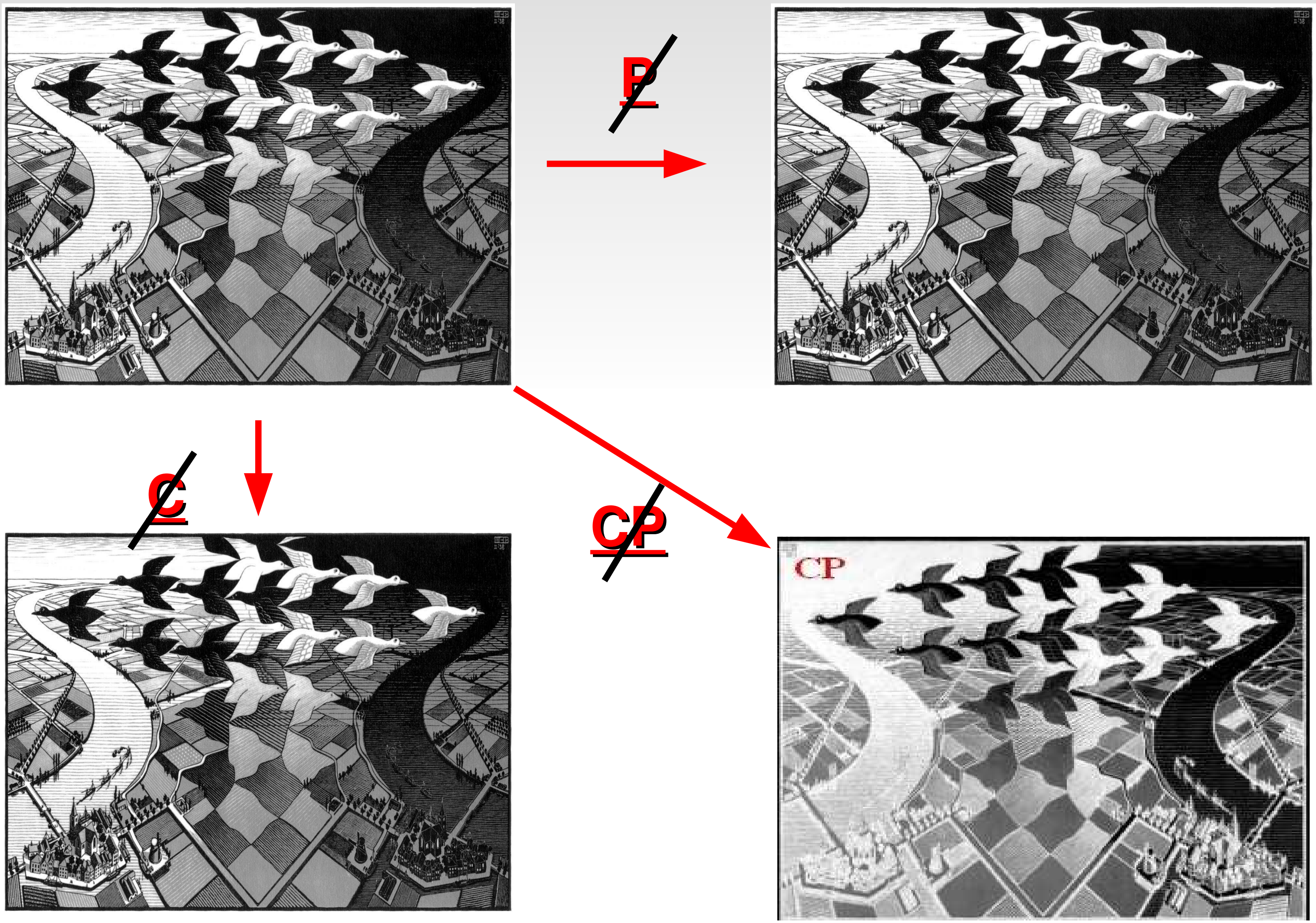




James Cronin Val Fitch

1/500 dos K_{long} se desintegravam em 2 píons, violando CP .

Simetria de C~~P~~



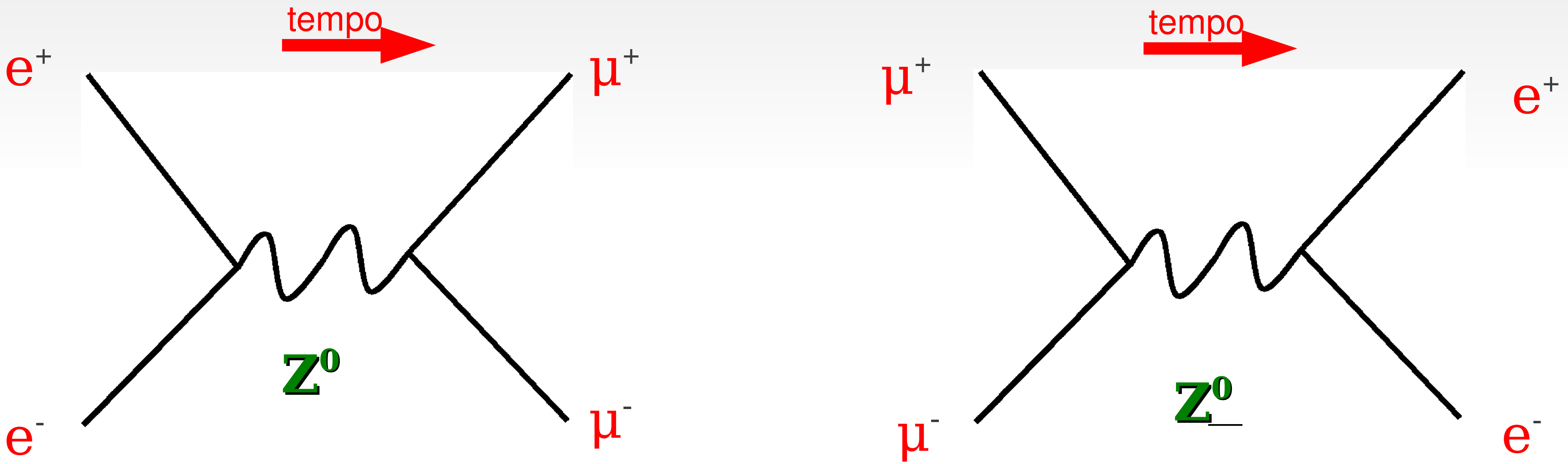
Simetria conservada nas interações eletromagnéticas e fortes

Violação em pequenas proporções nas interações fracas.

Teorema de CPT

Se aplica a qualquer teoria invariante de Lorentz, onde os observáveis são representados por operadores hermitianos.

Violação de CP → Irreversibilidade.



Transformação em tempo deve ser descrita por

uma transformação unitária e complexa $e^{-iEt} \rightarrow T \rightarrow e^{iEt}$.

Violação de CP implica na existência de uma fase.

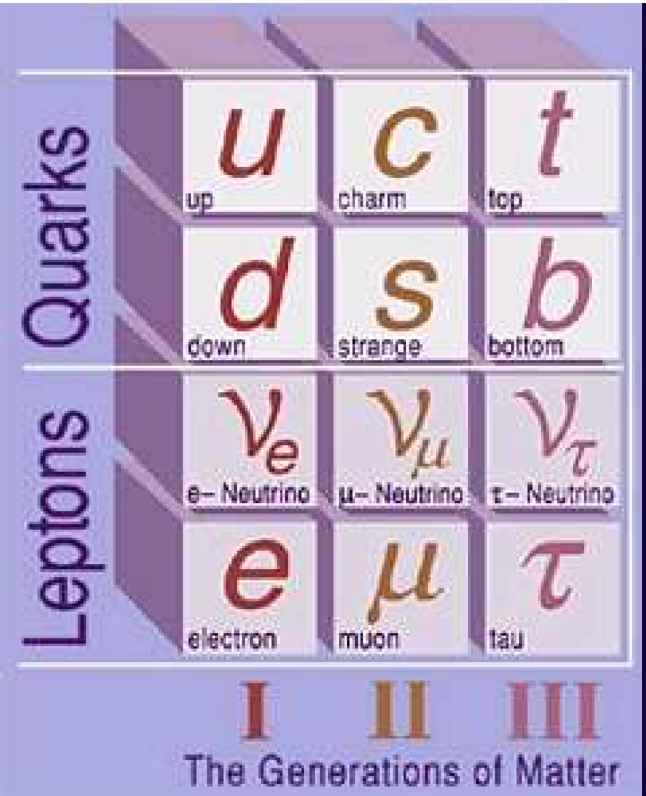
Força fraca e a estrutura de famílias.

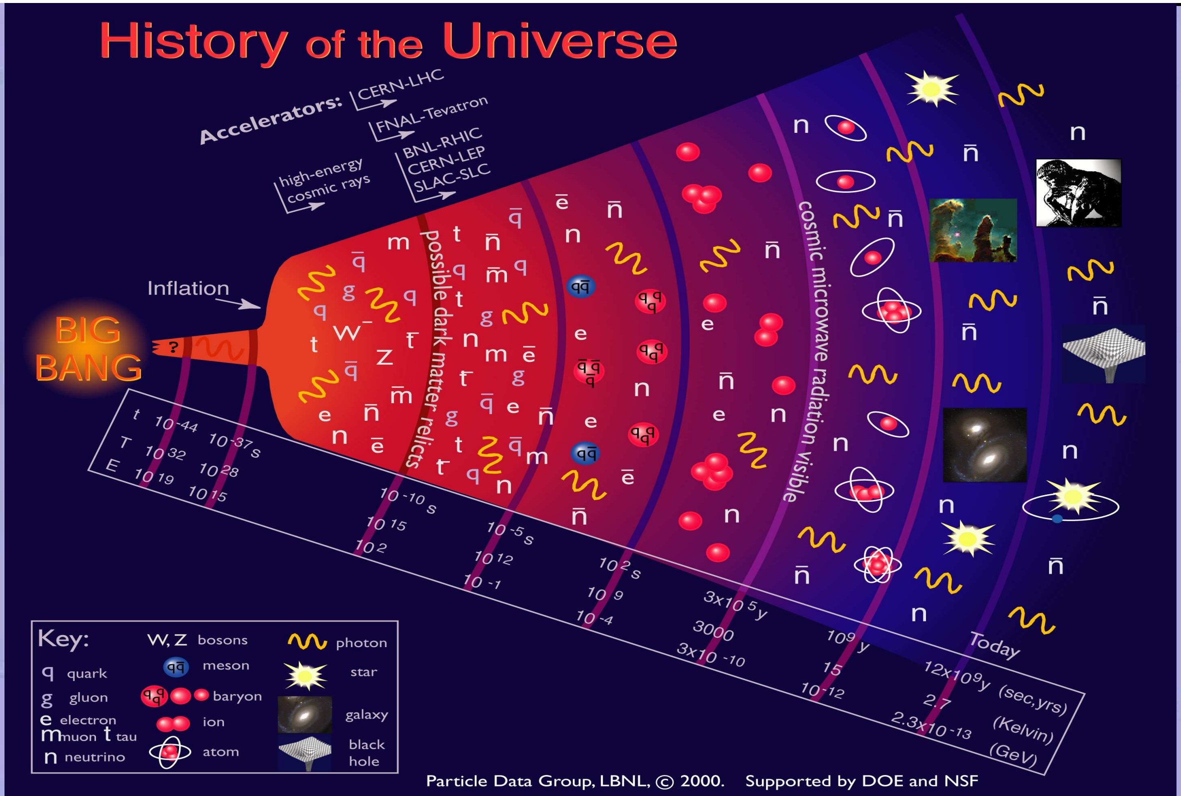
Força Fraca

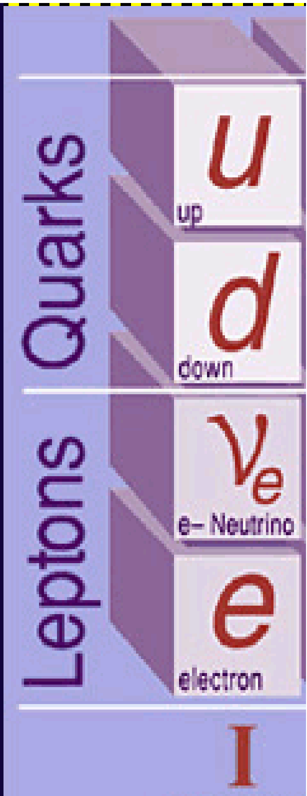
Três famílias de Quarks
e
três famílias de Leptons
no início do universo

Desintegração →

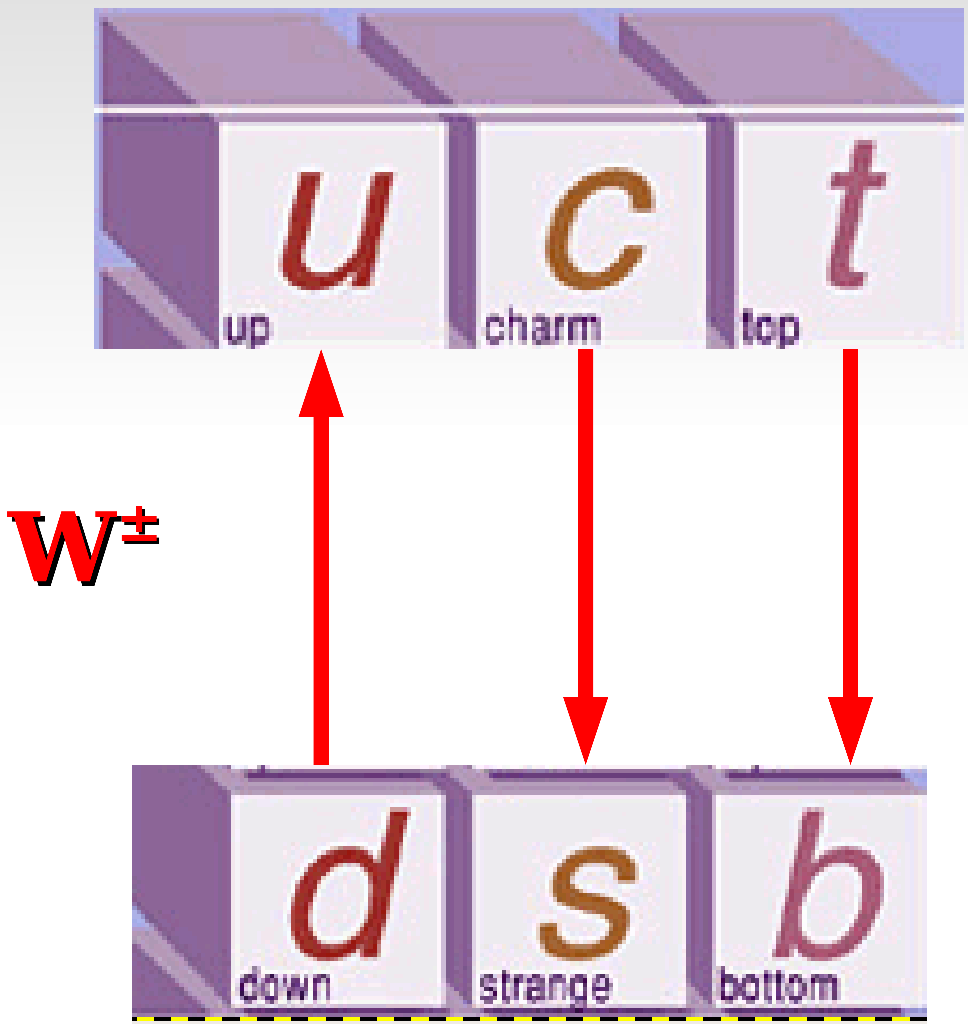
Reduzidos a uma família de cada



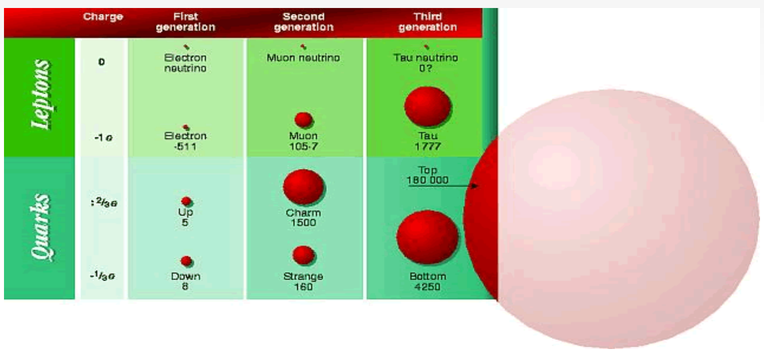




Matrix de transicão entre quarks

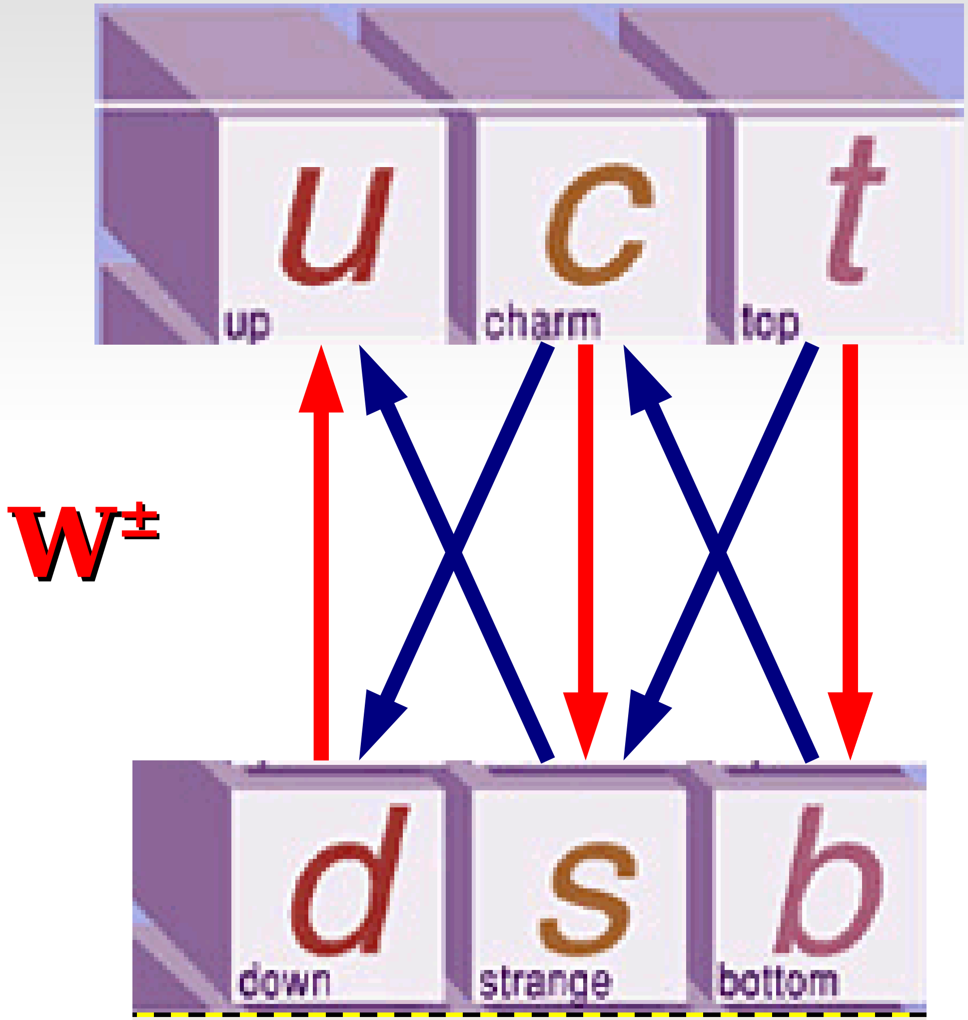


Grande probabilidade



$$
\begin{array}{c|ccc|c}
 & d & s & b & \\
 & V_{ud} & & & u \\
 & & V_{cs} & & c \\
 & & & V_{tb} & t
\end{array}
$$

Matrix de transicão entre quarks

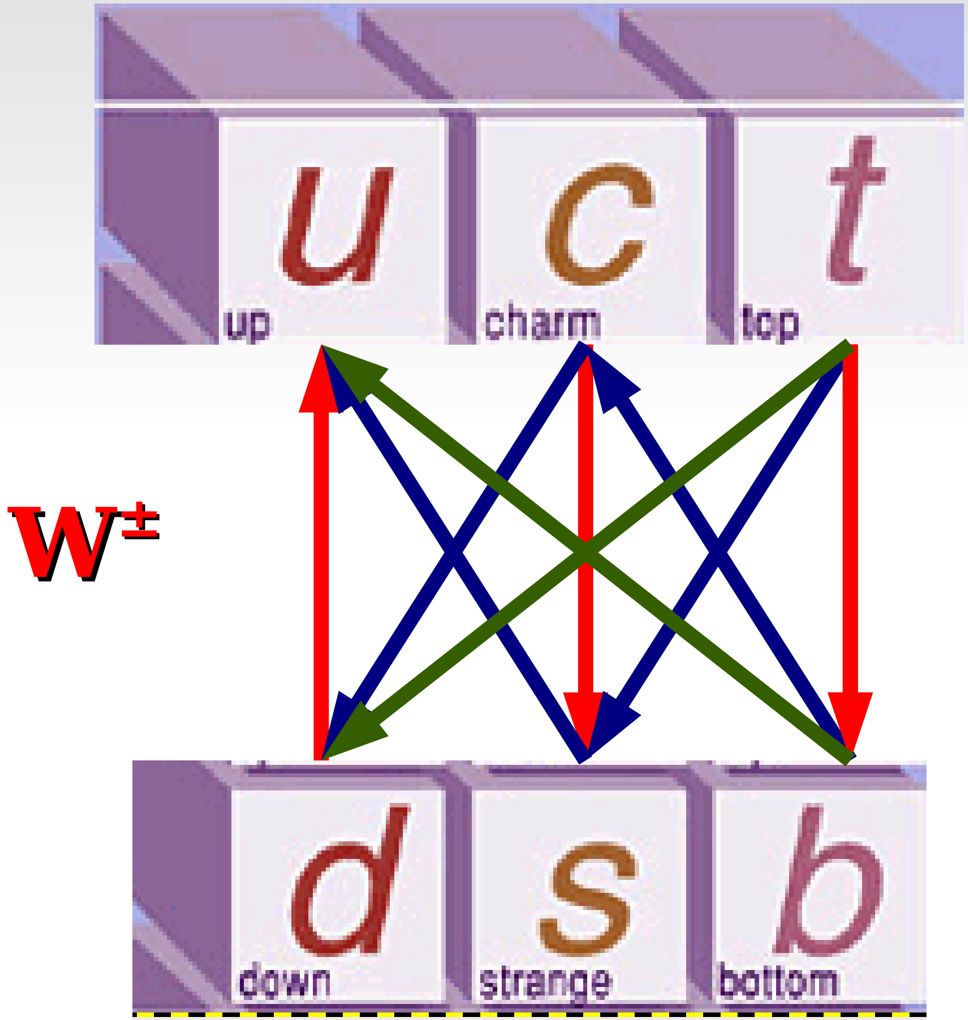


→ **Grande probabilidade**

→ **Média probabilidade**

$$\begin{array}{c|ccc|c} & d & s & b & \\ \hline & V_{ud} & V_{us} & & u \\ & V_{cd} & V_{cs} & V_{cb} & c \\ & & V_{ts} & V_{tb} & t \end{array}$$

Matrix de transicão entre quarks



Grande probabilidade

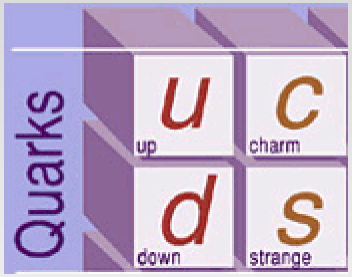
Média probabilidade

Pequena probabilidade

$$\begin{array}{c} \begin{matrix} \quad d & \quad s & \quad b \end{matrix} \\ \begin{vmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{vmatrix} \begin{matrix} u \\ c \\ t \end{matrix} \end{array}$$

Matriz de Cabibbo Kobayashi-Maskawa

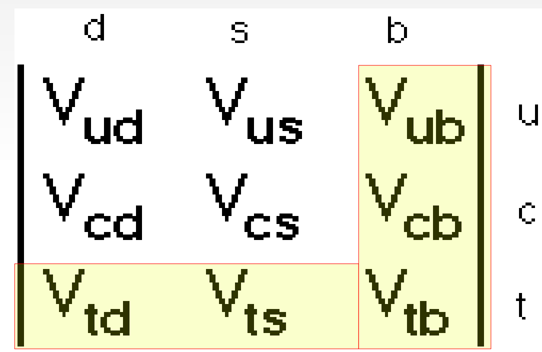
Kobayashi-Maskawa Nobel de 2008



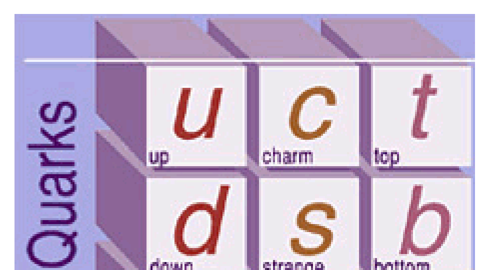
Matriz unitária tem (N-1)(N-2)/2 fases.

Matriz de Cabibbo de mistura 2X2: não permite violação de CP, falta o termo complexo.

2 → 3 famílias de quarks
Matriz de mistura 2X2 > 3X3, permite um termo complexo que poderia explicar a violação de CP

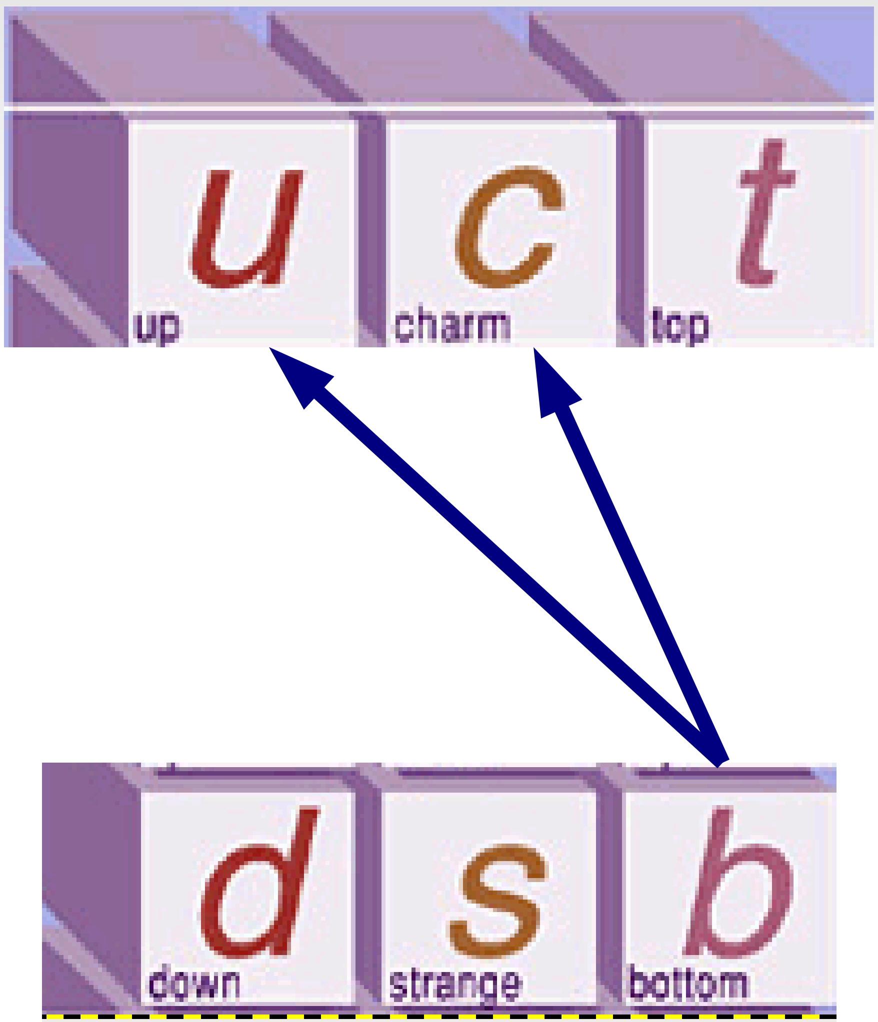


Kobayashi e Maskawa propuseram dois novos quarks o ***b*** e ***t*** além de abrir a possibilidade de explicar a violação de **CP.**



Quark b: maior fonte de violação de CP

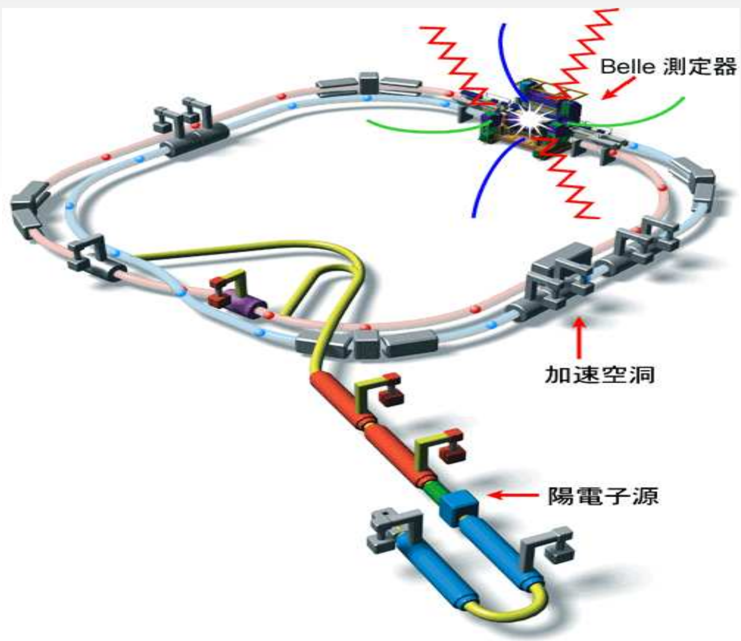
I. Bigi e A. Sanda



Decaimentos de partículas envolvendo o quark b, apresentam forte componente de violação de CP

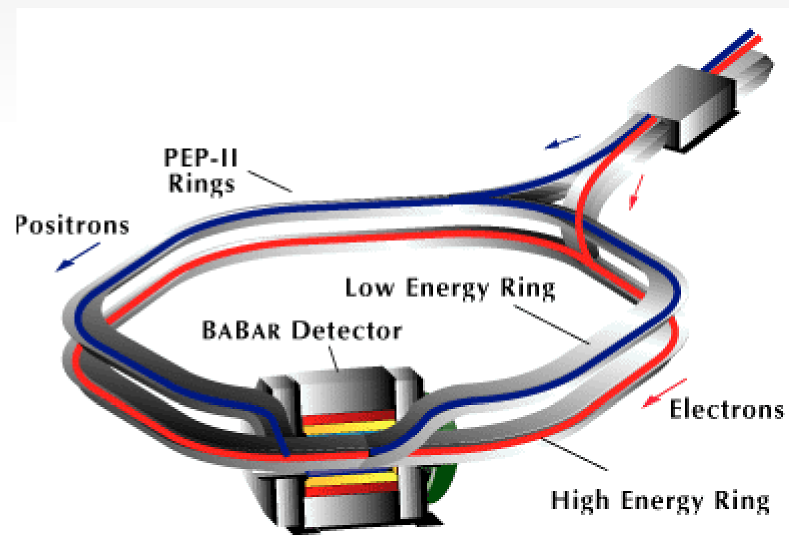
Colaborações Belle e BaBar

KEK Japão



657 milhões de Mésons B's produzidos

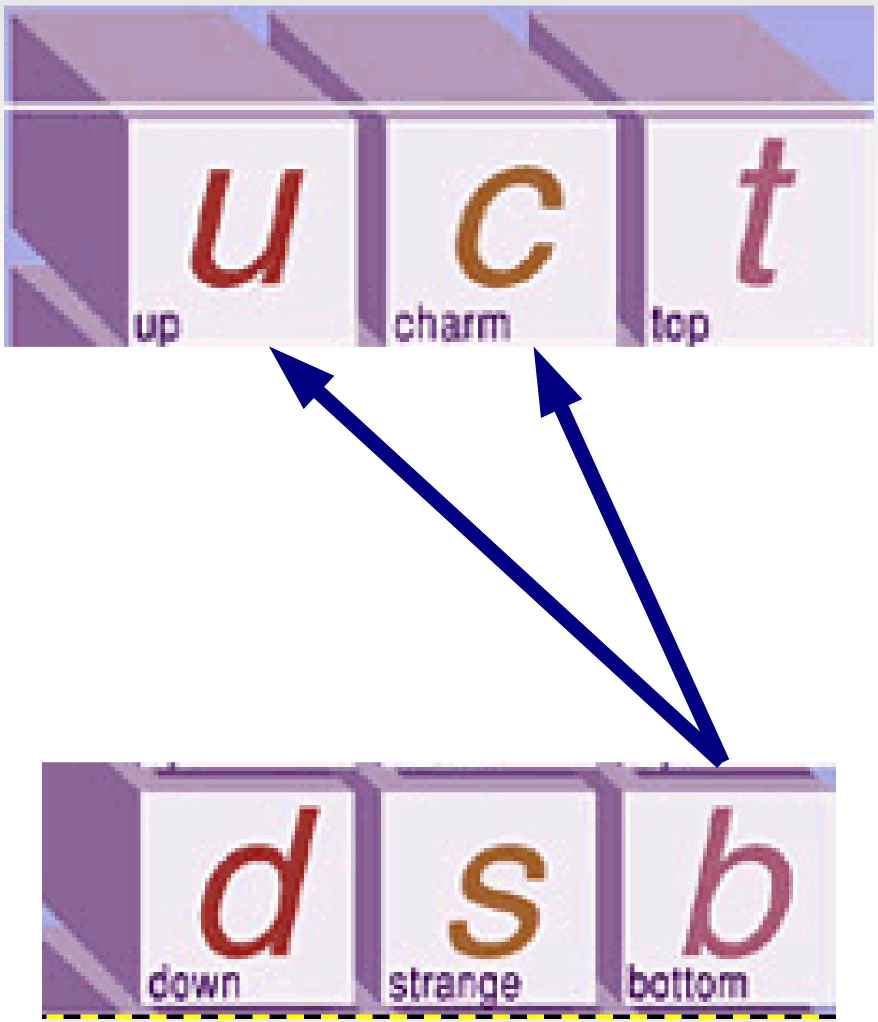
PEP II- Stanford-EUA



383 milhões de Mésons B's produzidos

b quark is the biggest source of CP violation in the CKM matrix.

I. Bigi e A. Sanda



Example: Directly CP asymmetry

- $B^0 \to K^+ \pi^-$

ACP = -9.7 ± 1.2 % (PDG 2012)

Violação da Simetria de CP

Violação de CP nos decaimentos dos mésons K's e B's, podem ser "explicados" pelo Modelo Padrão

Entretanto ela não explica toda a violação de CP necessária para entender a assimetria matéria anti-matéria do Universo

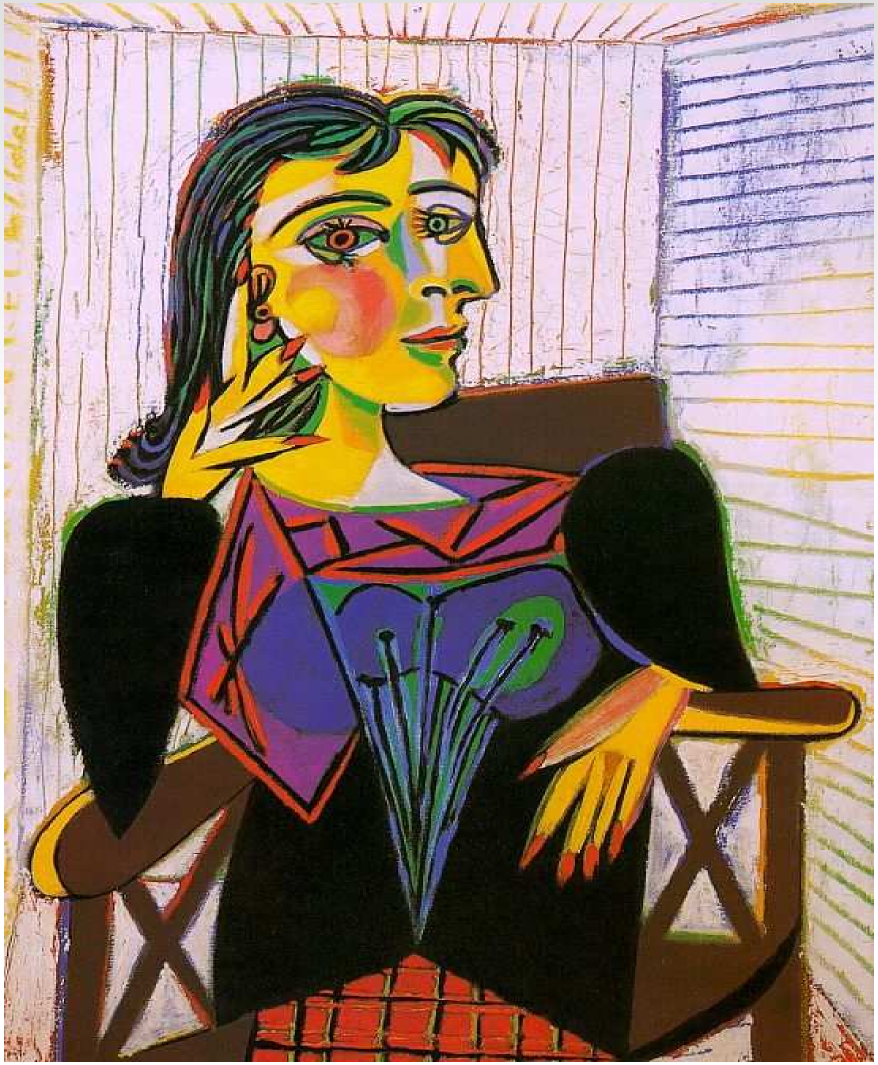
$$\text{Universe:} \quad \frac{N_B - N_{\bar{B}}}{N_B + N_{\bar{B}}} = 10^{-9} \sim 10^{-10}$$

$$\text{Standard Model:} \quad \frac{N_B - N_{\bar{B}}}{N_B + N_{\bar{B}}} = \sim 10^{-20}$$

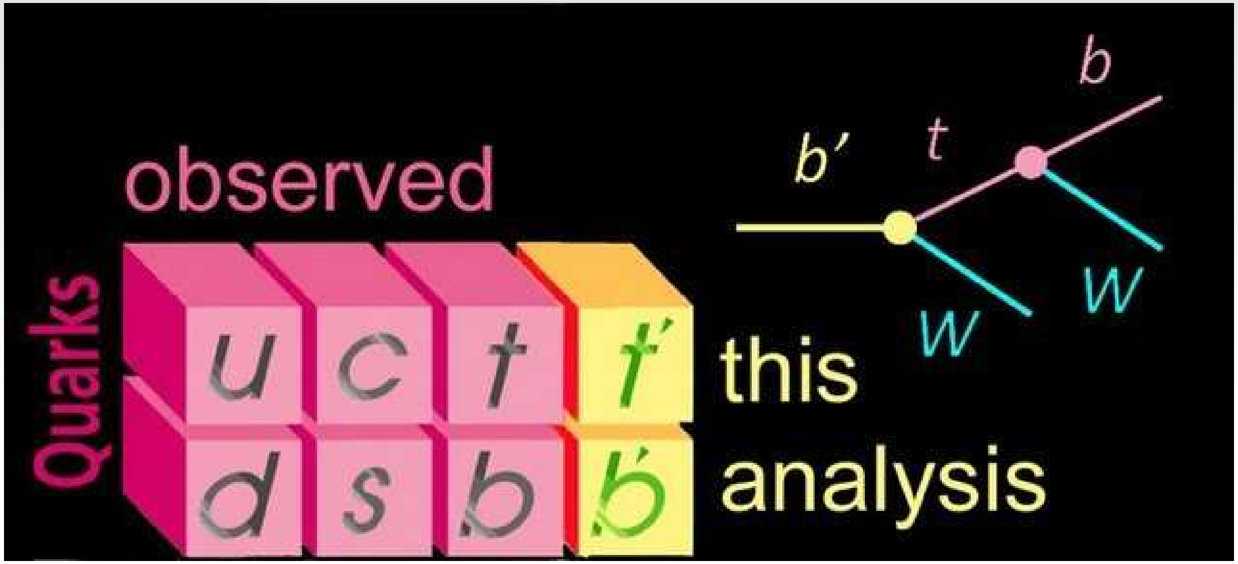
Necessária uma nova fonte importante de violação de CP

Las Meninas de Velásquez a Picasso

Onde encontrar novas fontes de violação de CP? Suspeito de sempre: interações fracas



Novas fontes de violação de CP no equilíbrio termodinâmico?



Nova matriz de Cabibbo-Kobayashi-Maskawa

?

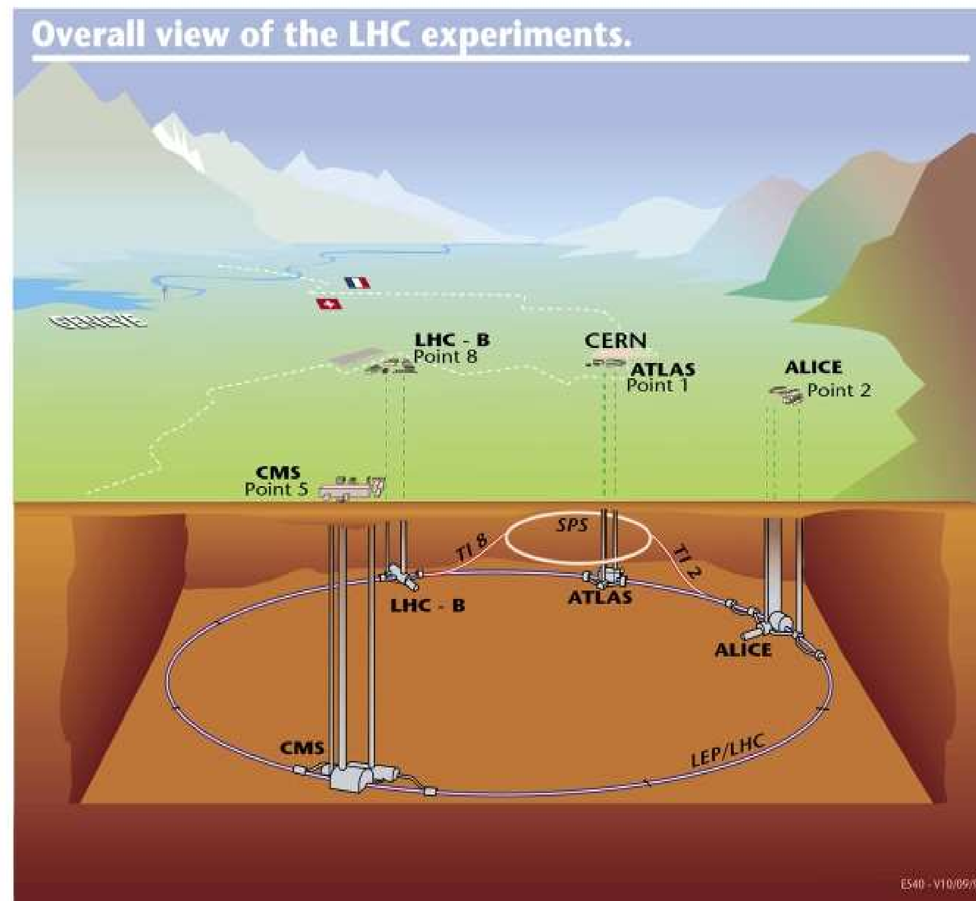
$$V_{CKM}^{4\times4} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} & V_{ud_4} \\ V_{cd} & V_{cs} & V_{cb} & V_{cd_4} \\ V_{td} & V_{ts} & V_{tb} & V_{td_4} \\ V_{u_4 d} & V_{u_4 s} & V_{u_4 b} & V_{u_4 d_4} \end{pmatrix}$$

(N-1)(N-2)/2 = 3 fases

Produção e desintegração de partículas e o boson de Higgs.

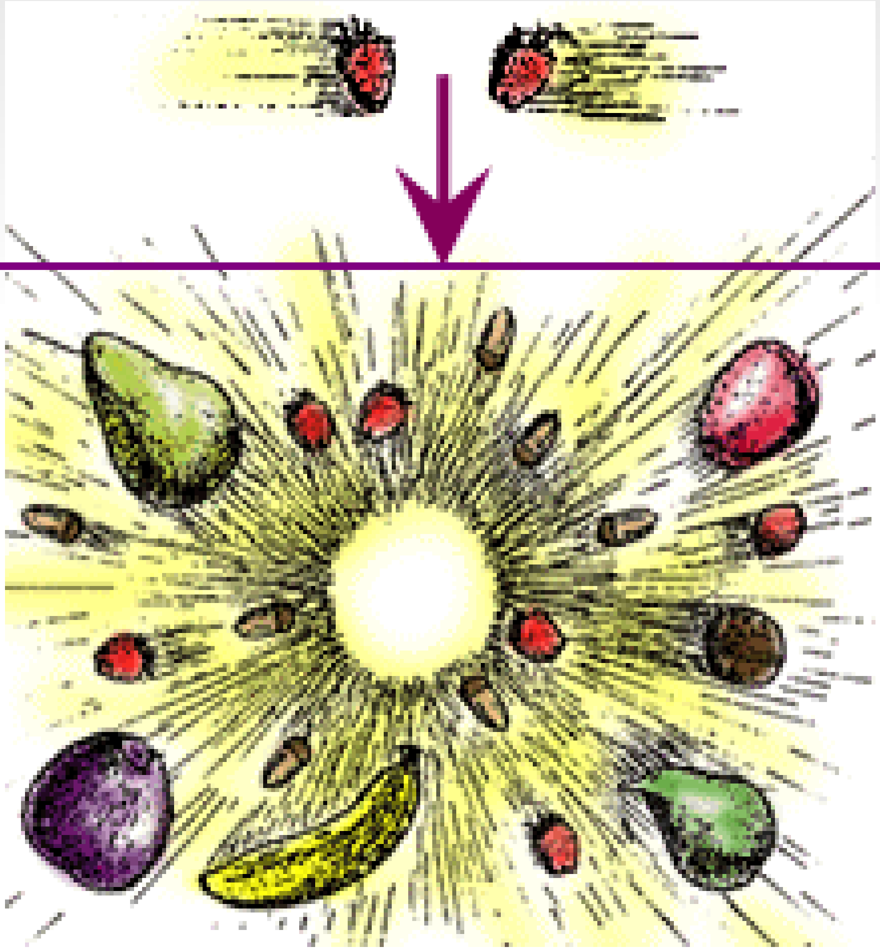
Como se descobre novas partículas? Aceleradores.

Colisão entre partículas a altas energias



Como se descobre novas partículas?
Colisão e criação

- Colisão



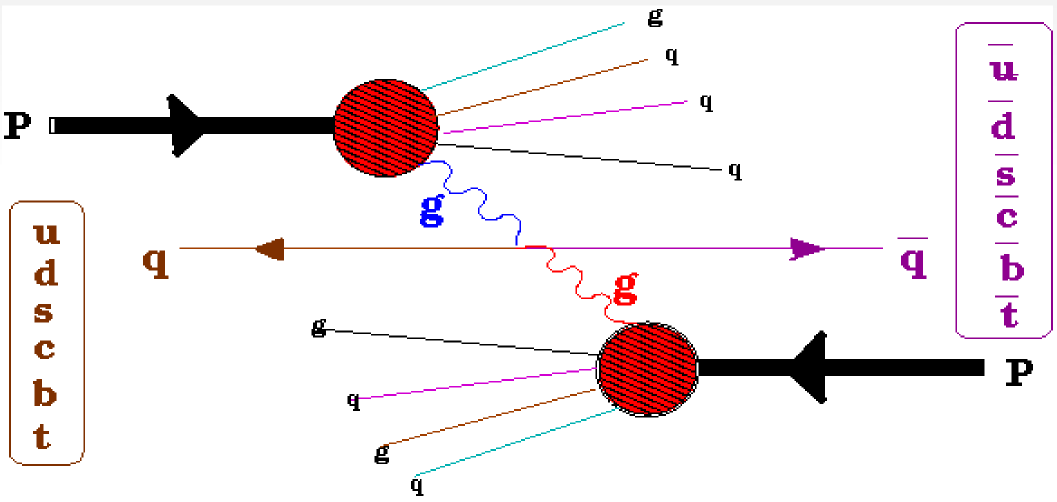
Energia —> Massa

Produção de partículas;
Massivas e instáveis

Energia da colisão
>
Massa da nova partícula

Como se descobre novas partículas?

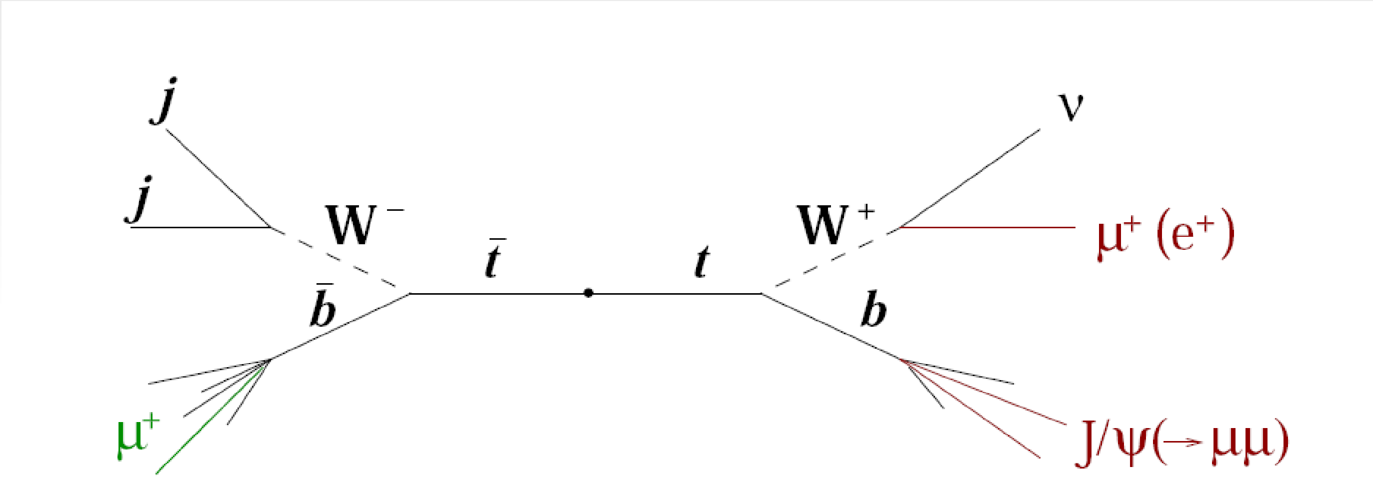
Colisão entre partículas a altas energias



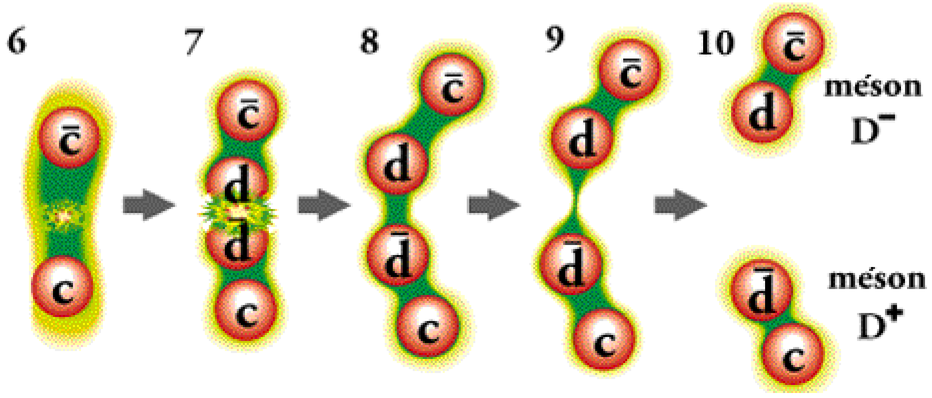
Energia da colisão
>
Massa da nova partícula

Desintegração-criação e hadronização

- **Dezenas de possíveis desintegrações criações**



- Dezenas de possíveis hadronizações

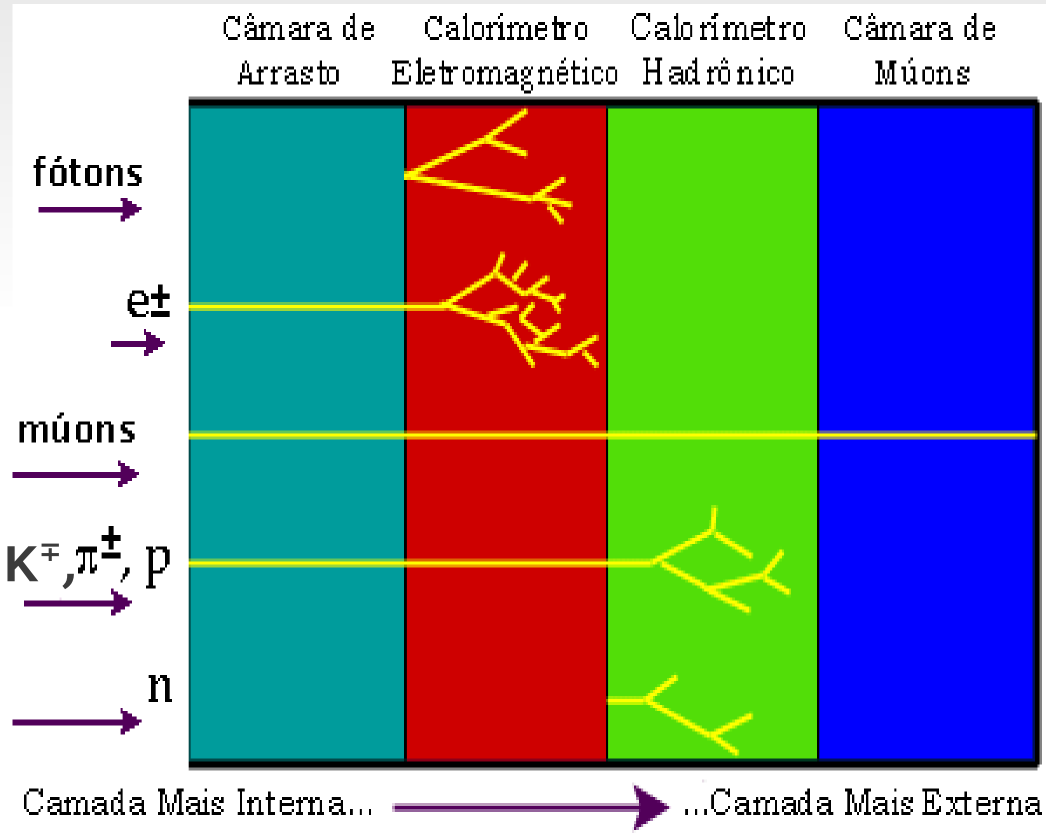


Observáveis

- Observadas diretamente

- Partículas carregadas com vida média menor 10^{-10}s: **próton, elétron, múon, méson π e méson K**

- Partículas neutras: **fóton e nêutron**



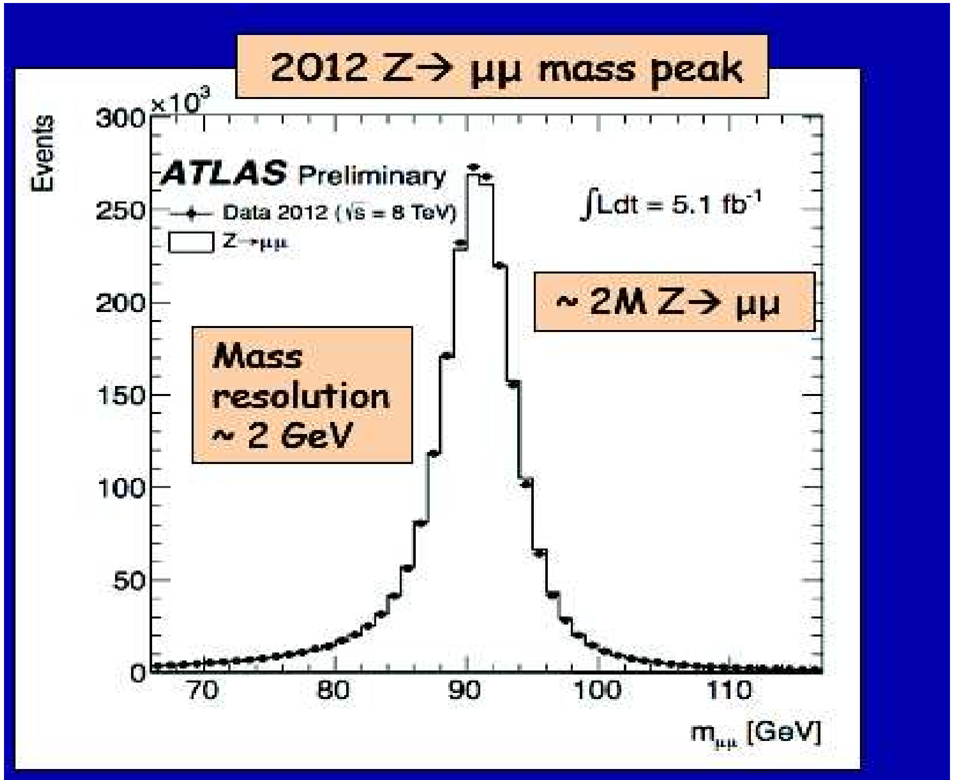
Massa Invariante

- Desintegração do bóson de gauge $Z^0 \rightarrow \mu^+\mu^-$

Conservação do quadri momento $M_z^{\ 2} = (P_{\nu Z})^2 = (P_\nu^{\mu+} + P_\nu^{\mu-})^2$ <u>C=1</u>

$$M^2_{\mu^+\mu^-} = (P^\nu_{\mu^+} + P^\nu_{\mu^-})^2 = m^2_{\mu^+} + m^2_{\mu^-} + 2E_{\mu^+}.E_{\mu^-} + 2\vec{P}_{\mu^-}.\vec{P}_{\mu^+}$$

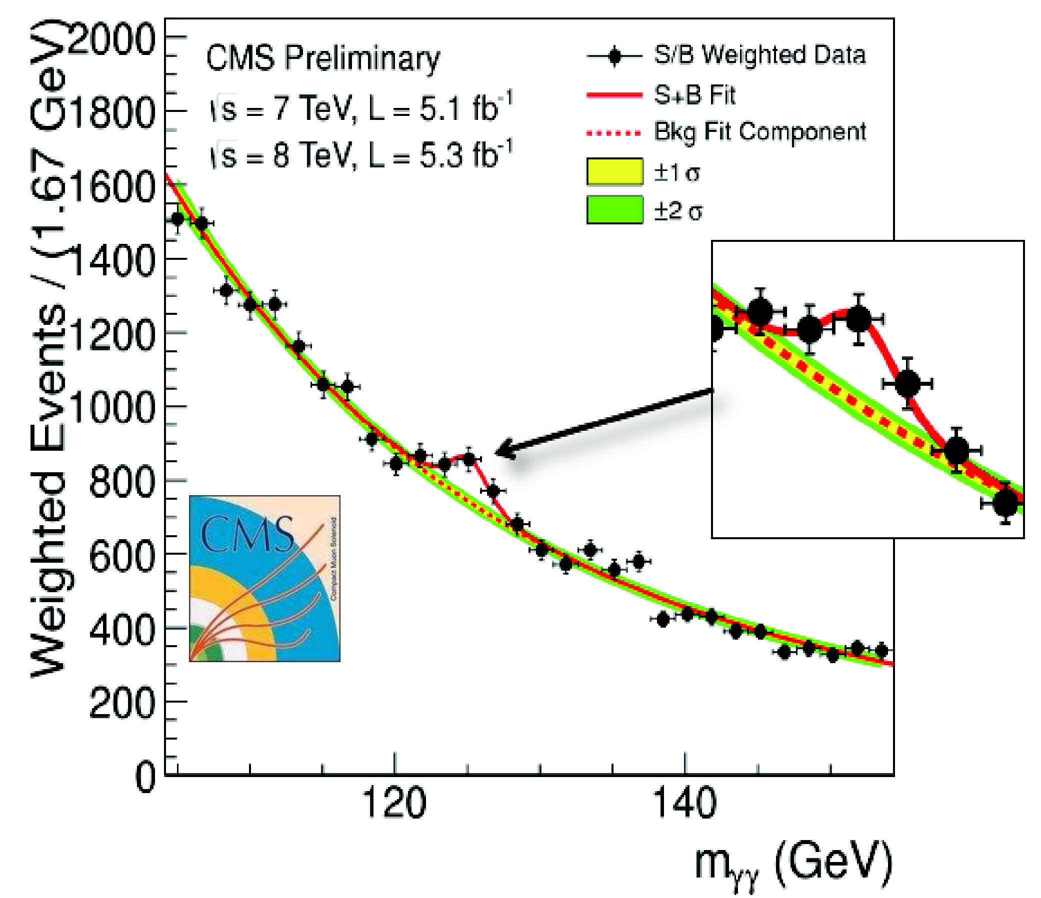
$$= m^2_{\mu^+} + m^2_{\mu^-} + 2\sqrt{|\vec{P}_{\mu^+}|^2 + m^2_{\mu^+}}.\sqrt{|\vec{P}_{\mu^-}|^2 + m^2_{\mu^-}} + 2\vec{P}_{\mu^-}.\vec{P}_{\mu^+}$$

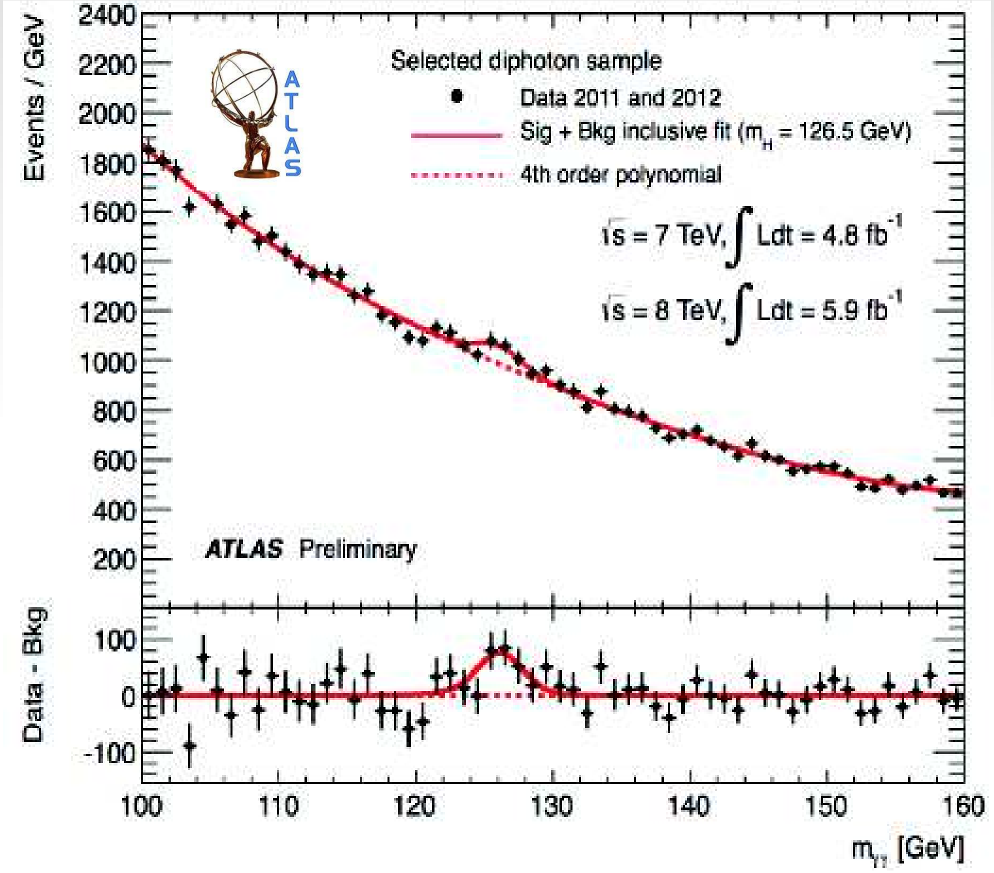


$$BW = |\frac{\sqrt{m_{Z^0}\Gamma}}{m^2_{Z^0} - M^2_{\mu^+\mu^-} - i m_{Z^0}\Gamma}|^2$$

$H \rightarrow \gamma\gamma$

$$M_z^{\ 2} = 2E_1 \ E_2$$





- Minimum local p-value at 125 GeV with a local significance of 4.1 σ

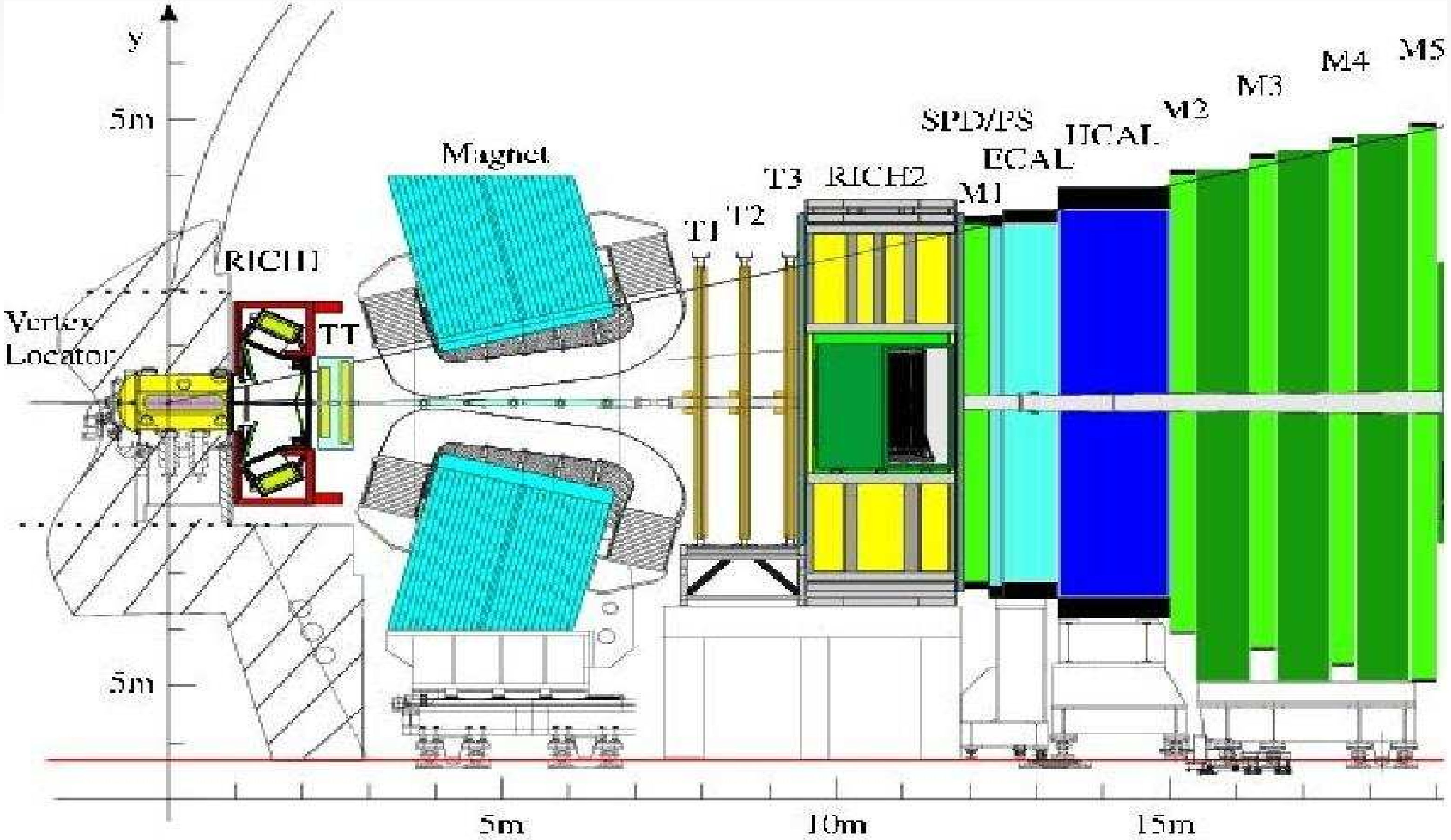
Global 2011+2012 (including LEE over 110-150 GeV range): 3.6 σ

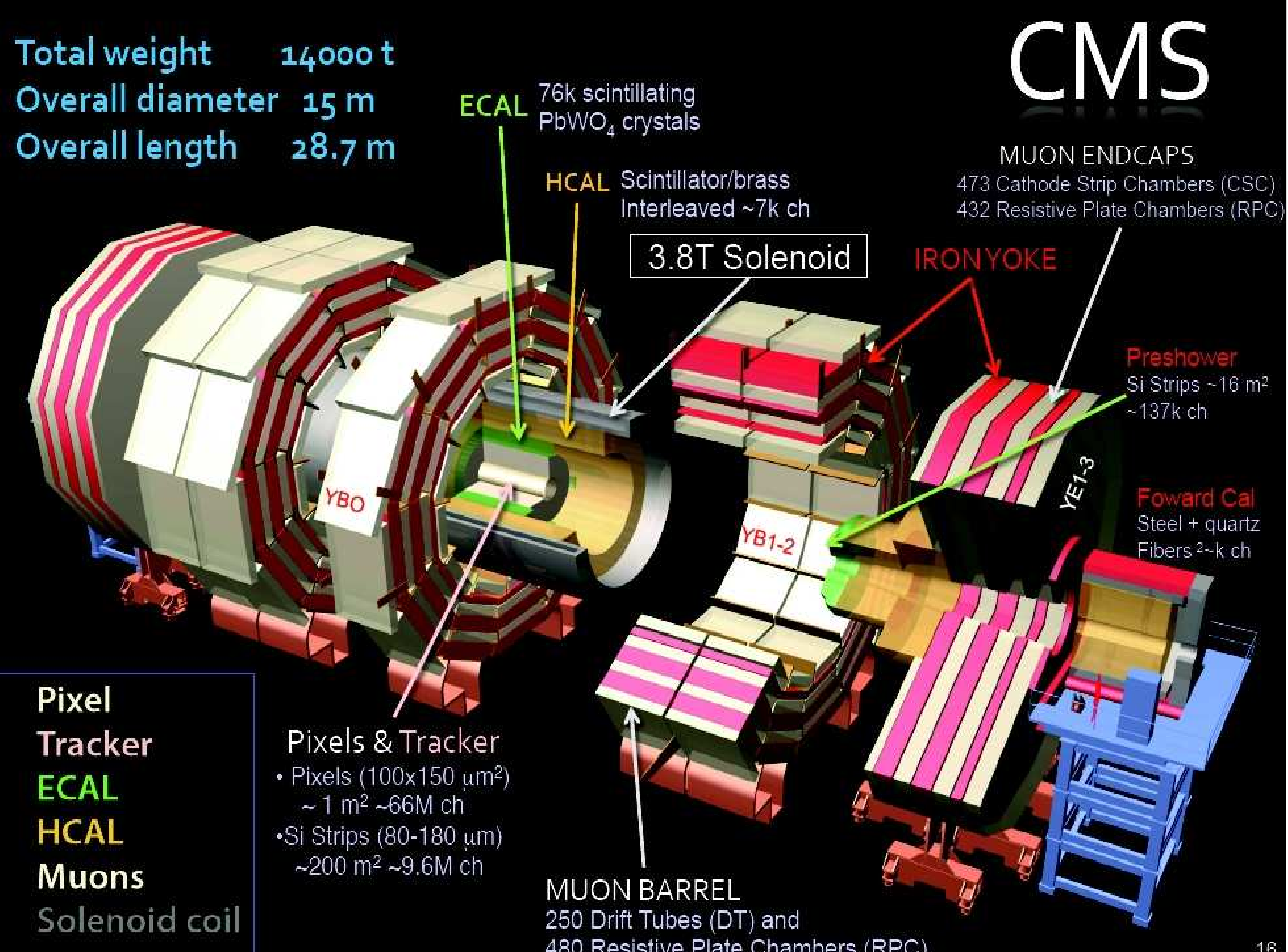
Observação dos eventos

$$M^2_{\mu^+\mu^-} = (P^{\nu}_{\mu^+} + P^{\nu}_{\mu^-})^2 = m^2_{\mu^+} + m^2_{\mu^-} + 2E_{\mu^+}.E_{\mu^-} + 2\vec{P}_{\mu^-}.\vec{P}_{\mu^+}$$

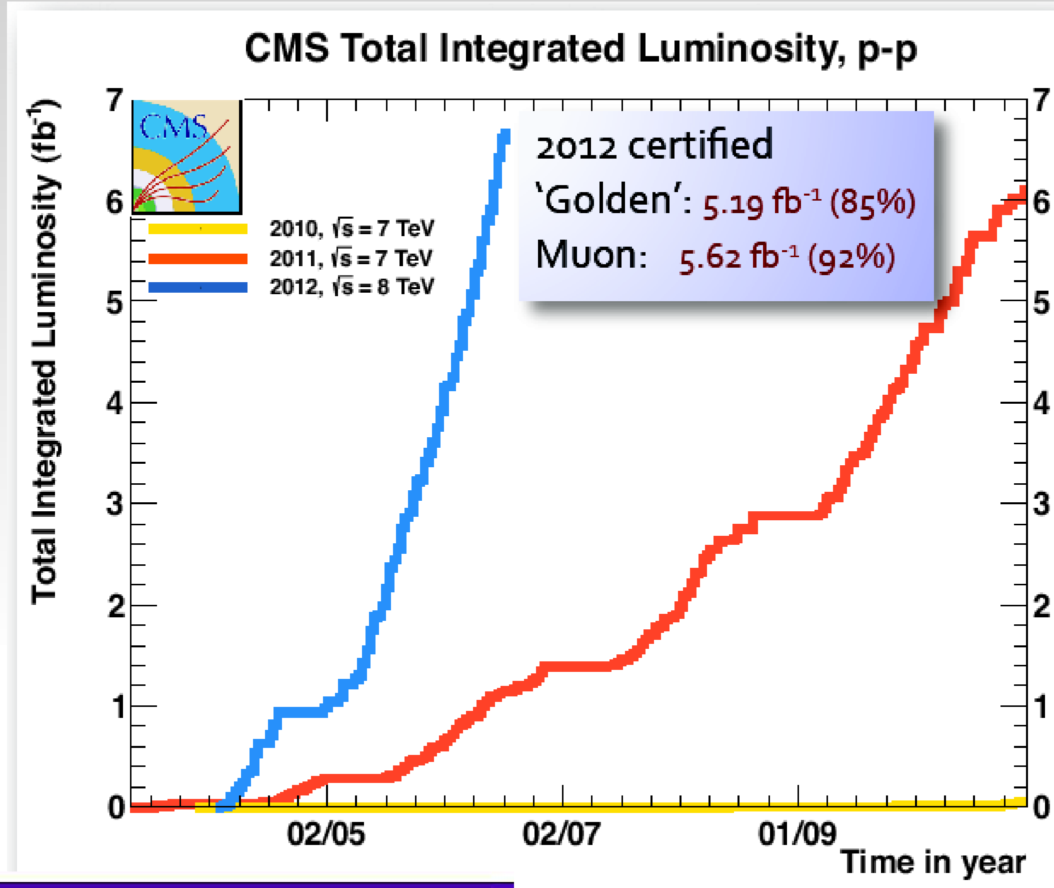
$$= m^2_{\mu^+} + m^2_{\mu^-} + 2\sqrt{|\vec{P}_{\mu^+}|^2 + m^2_{\mu^+}}.\sqrt{|\vec{P}_{\mu^-}|^2 + m^2_{\mu^-}} + 2\vec{P}_{\mu^-}.\vec{P}_{\mu^+}$$

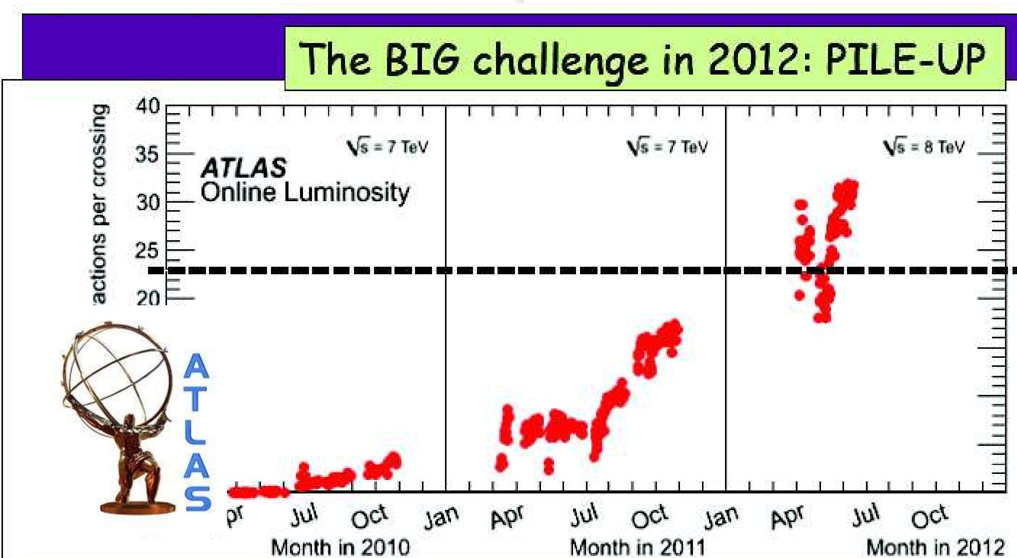
- Determinação da natureza das partículas
- Momento vetorial das partículas carregadas
- Energia das partículas neutras

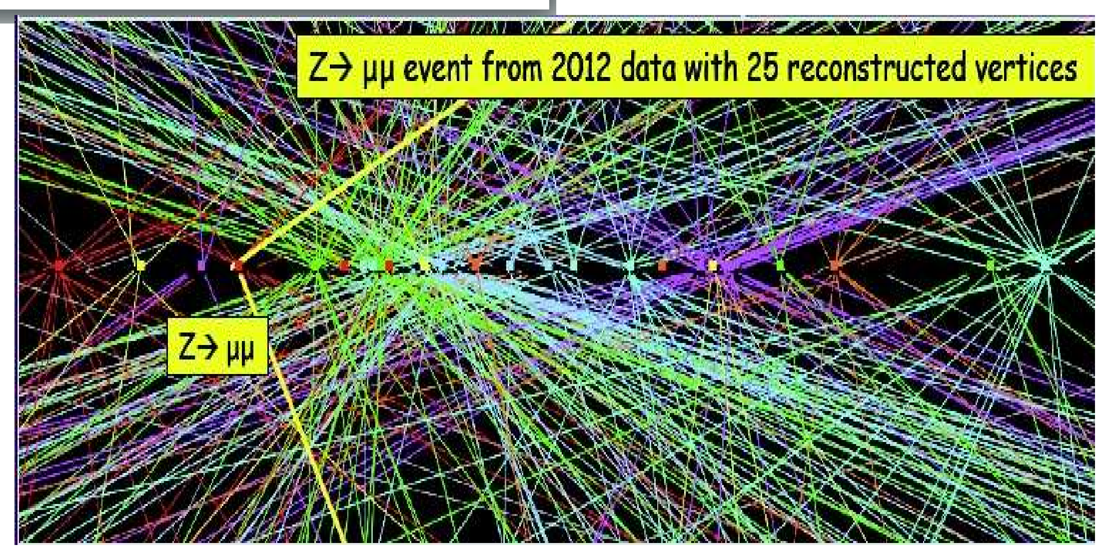



CMS
Total weight 14000 t
Overall diameter 15 m
Overall length 28.7 m
ECAL 76k scintillating PbWO4 crystals
HCAL Scintillator/brass Interleaved ~7k ch
3.8T Solenoid
IRON YOKE
MUON ENDCAPS
473 Cathode Strip Chambers (CSC)
432 Resistive Plate Chambers (RPC)
Preshower
Si Strips ~16 m²
~137k ch
YE1-3
Foward Cal
Steel + quartz
Fibers ²~k ch
YB0
YB1-2
Pixel
Tracker
ECAL
HCAL
Muons
Solenoid coil
Pixels & Tracker
• Pixels (100x150 μm²)
~1 m² ~66M ch
•Si Strips (80-180 μm)
~200 m² ~9.6M ch
MUON BARREL
250 Drift Tubes (DT) and
480 Resistive Plate Chambers (RPC)

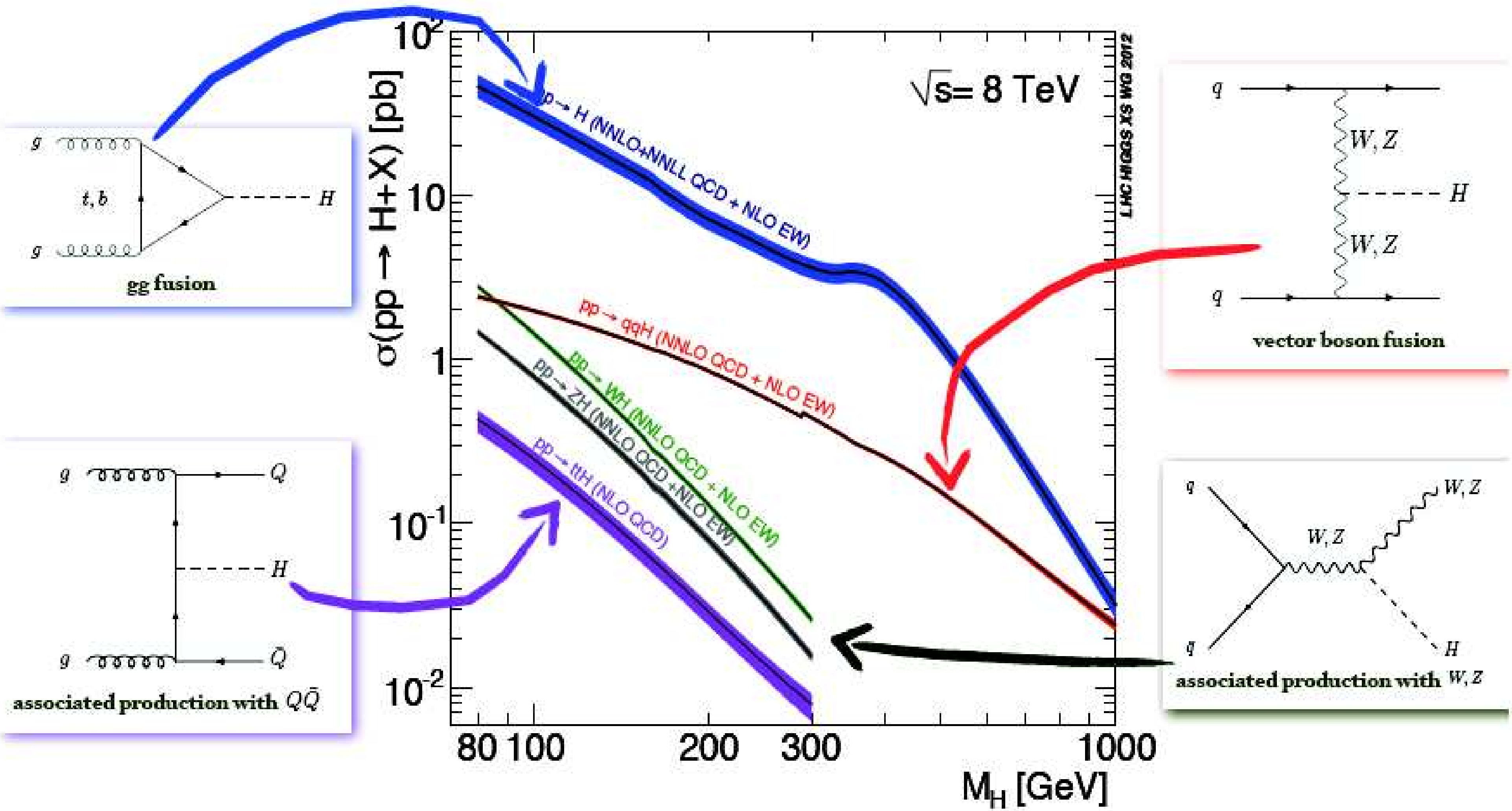
Taxa de colisões 2011 e 2012.







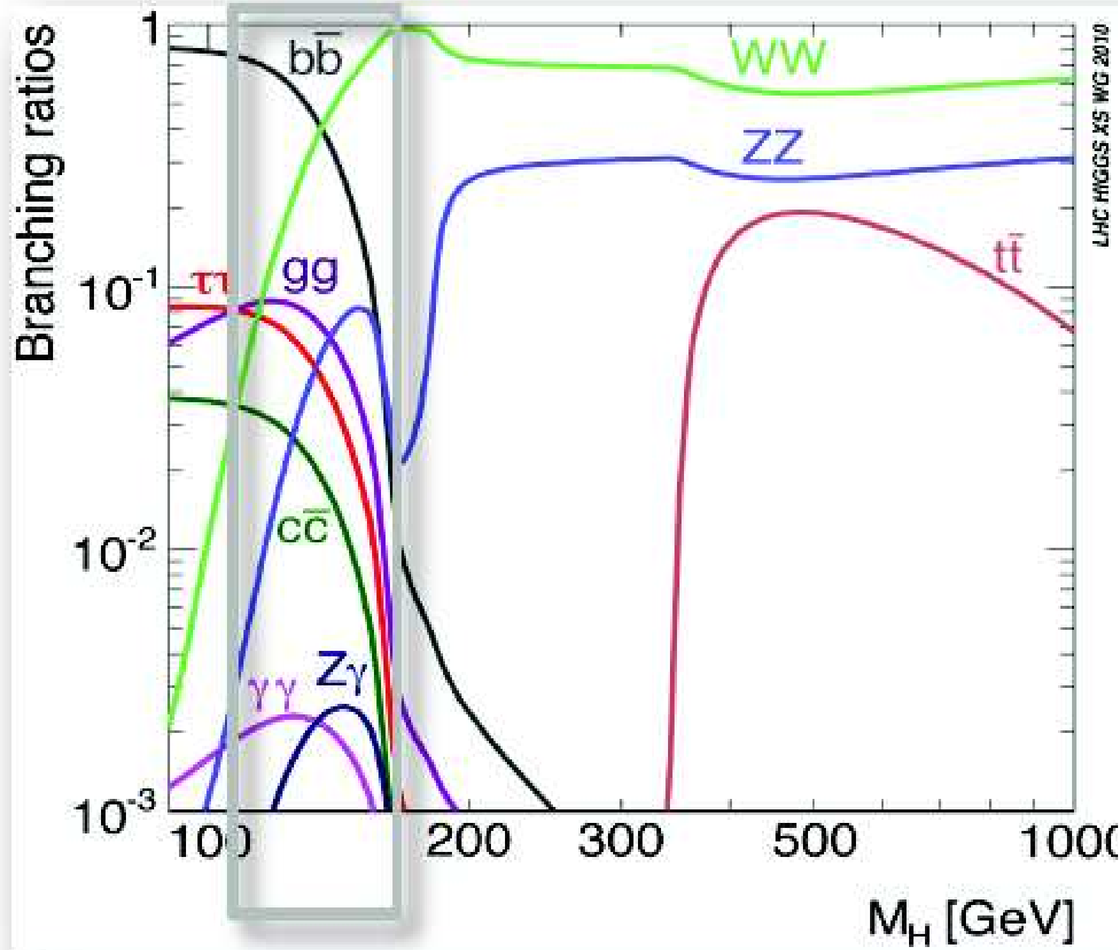
SM Higgs boson production @ LHC



Higgs boson decays

5 decay modes exploited

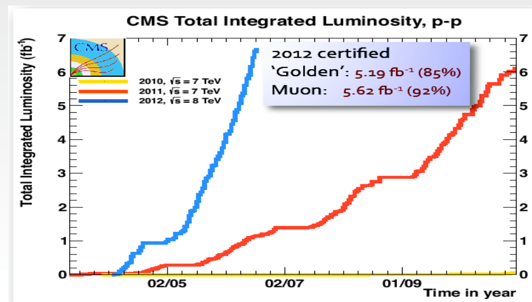
- High mass: WW, ZZ
- Low mass: bb, ττ, WW, ZZ, γγ
- Low mass region is very rich but also very challenging:
  main decay modes (bb, ττ) are hard to identify in the huge background



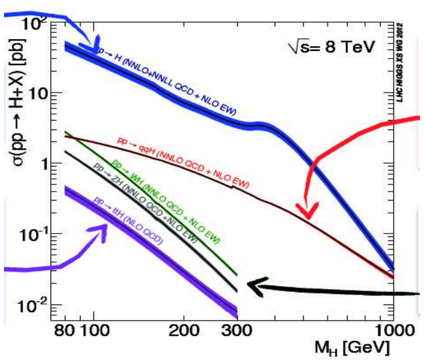
- Very good mass resolution (1%): H→γγ and H→ZZ→4l

Probabilidade de observação do Higgs em função da massa

Dada uma luminosidade ou numero de colisões:

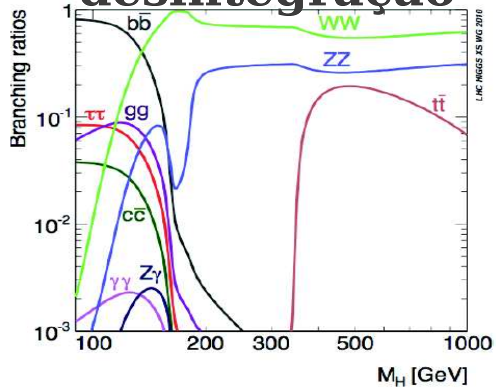


Seção de choque



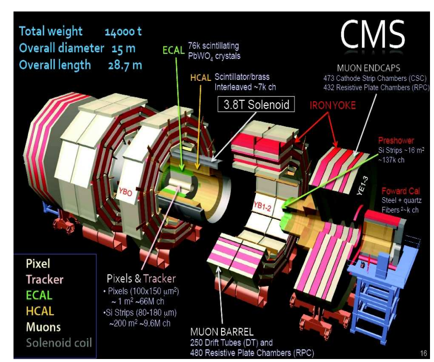
X

Probabilidade de desintegração



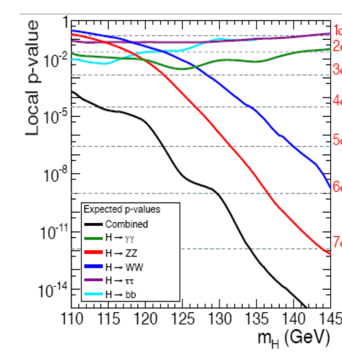
X

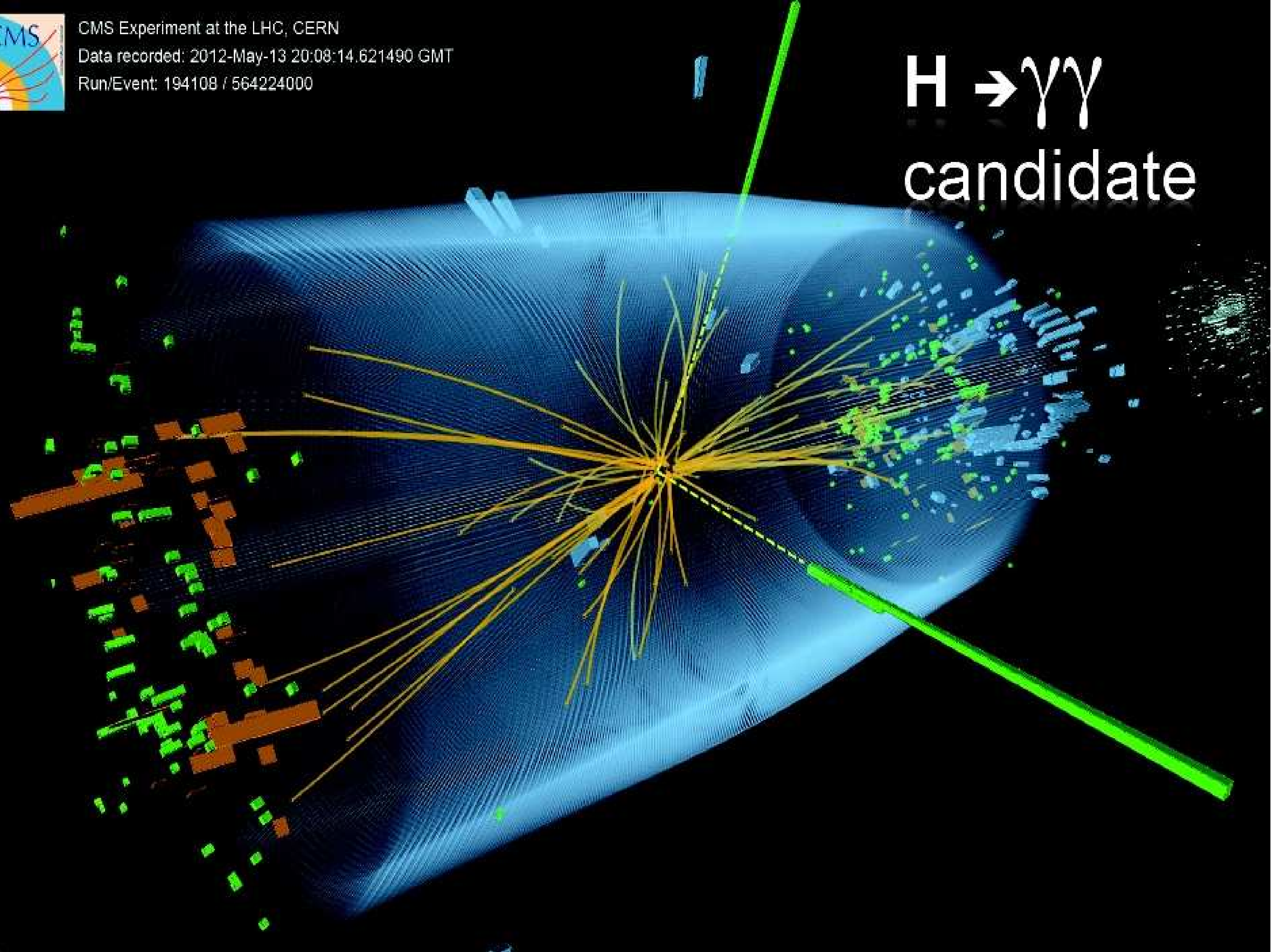
Eficiência de detecção



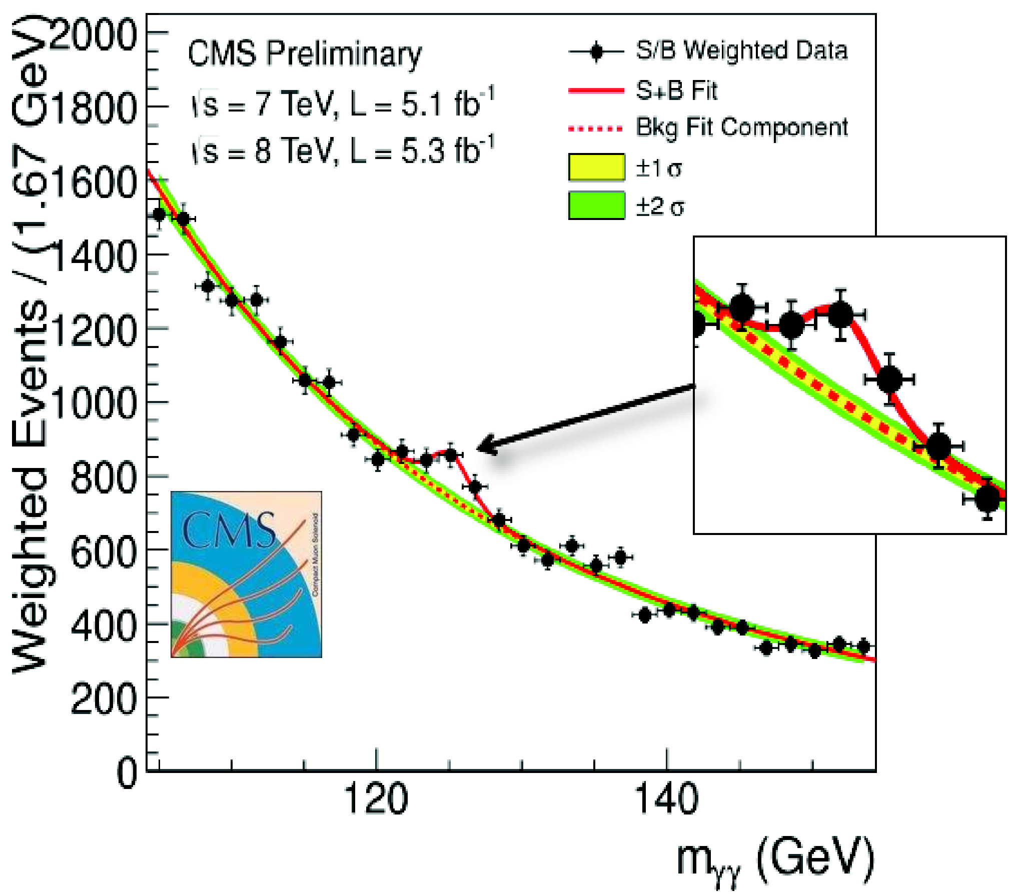
=

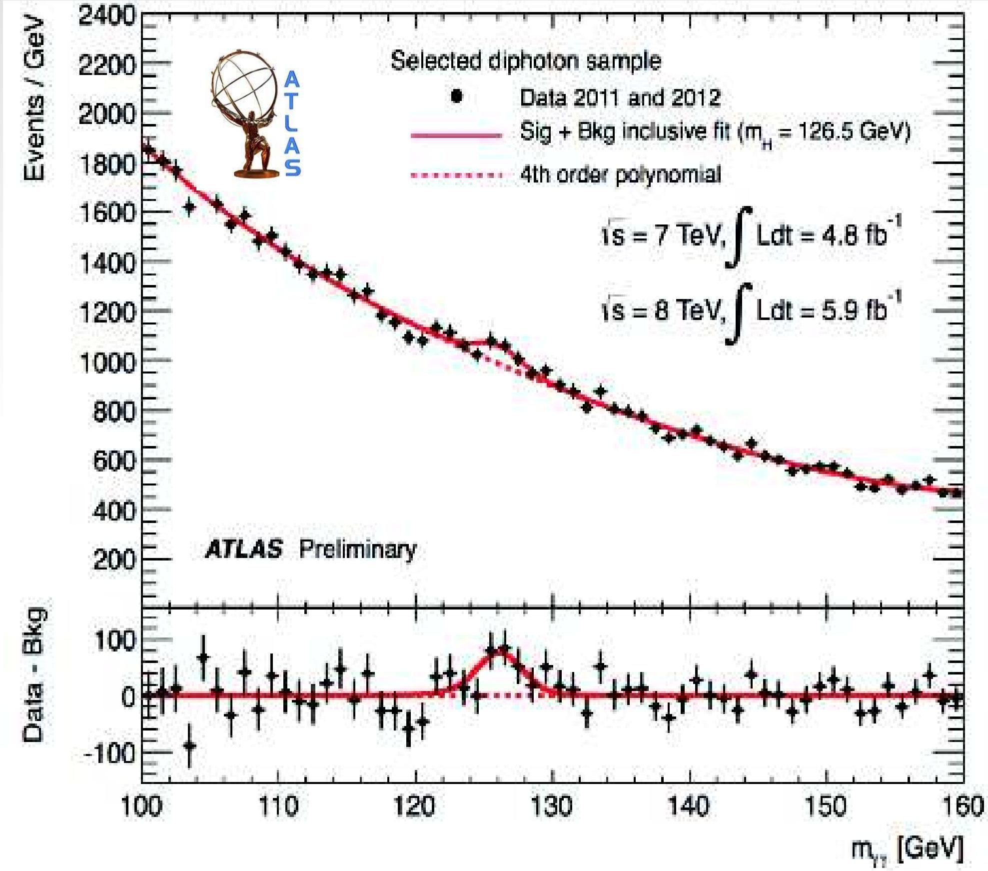
Probabilidade de observação




CMS Experiment at the LHC, CERN
Data recorded: 2012-May-13 20:08:14.621490 GMT
Run/Event: 194108 / 564224000
H →γγ
candidate

$H \to \gamma\gamma$



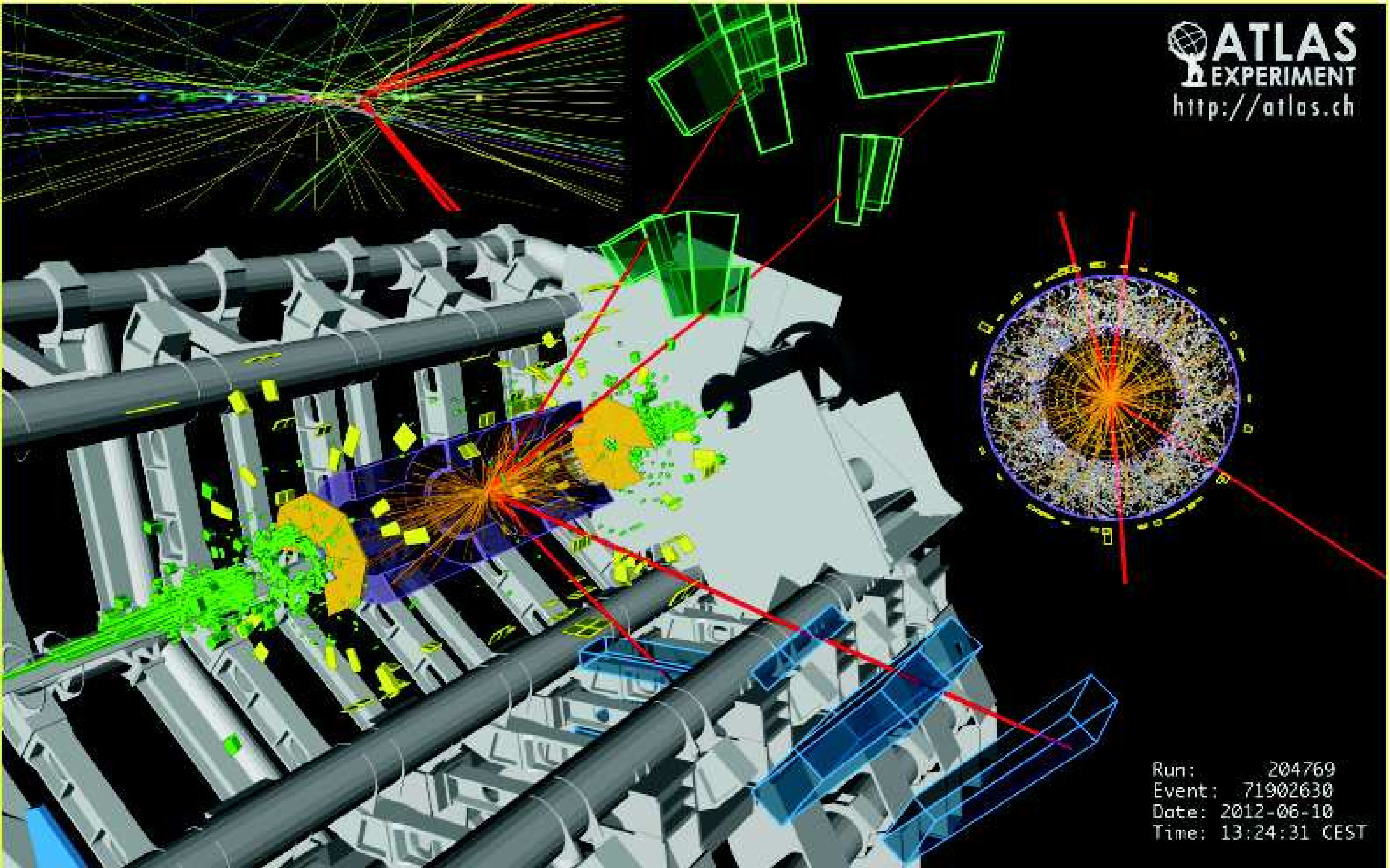


- Minimum local p-value at 125 GeV with a local significance of 4.1 σ

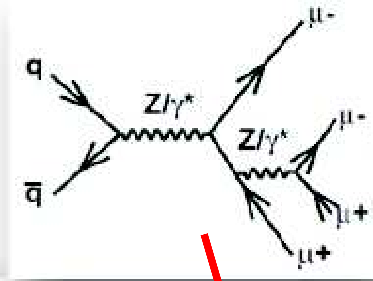
Global 2011+2012 (including LEE over 110-150 GeV range): 3.6 σ

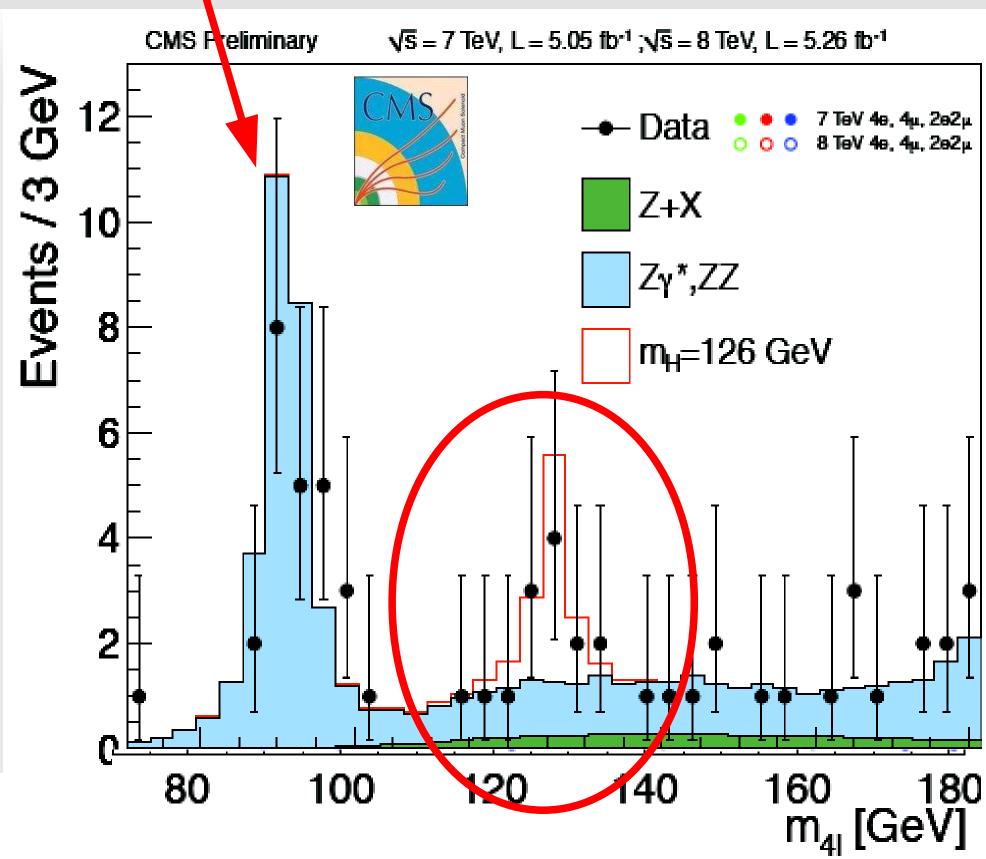
$H \rightarrow ZZ^{(*)} \rightarrow 4l$ ($l = e,\mu$): the golden channel

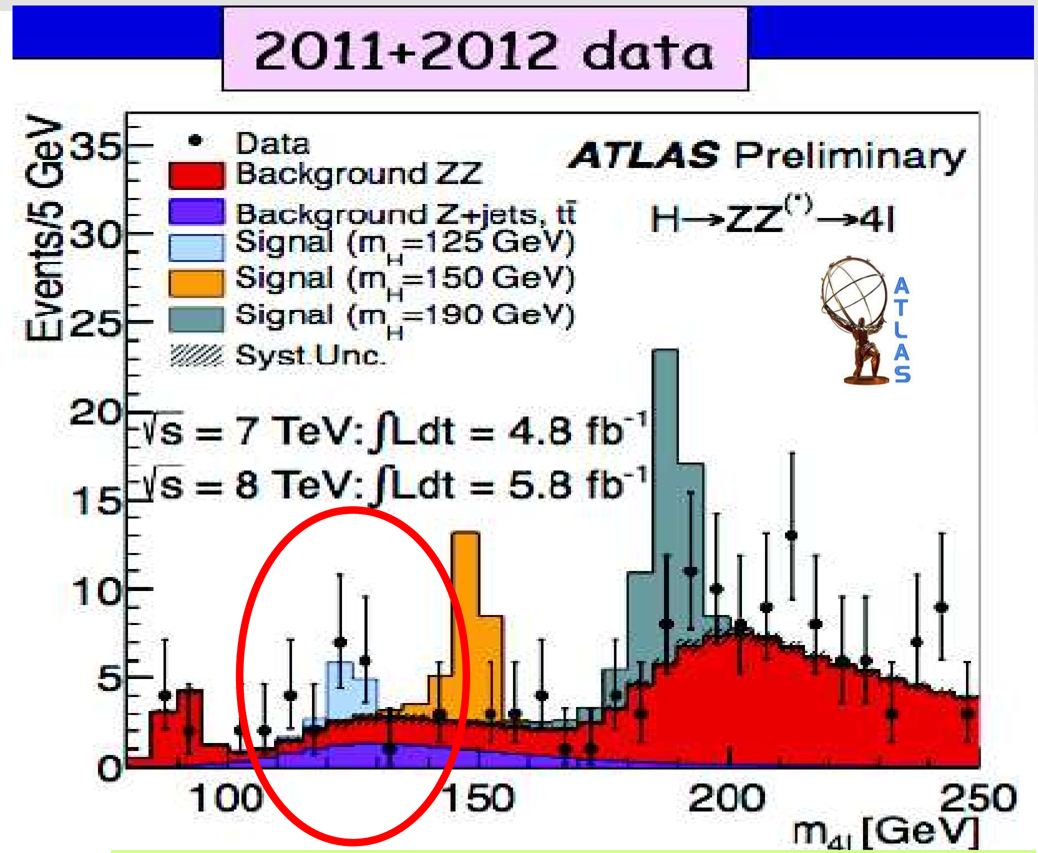
Clean signature: narrow peak, low background



H →ZZ*







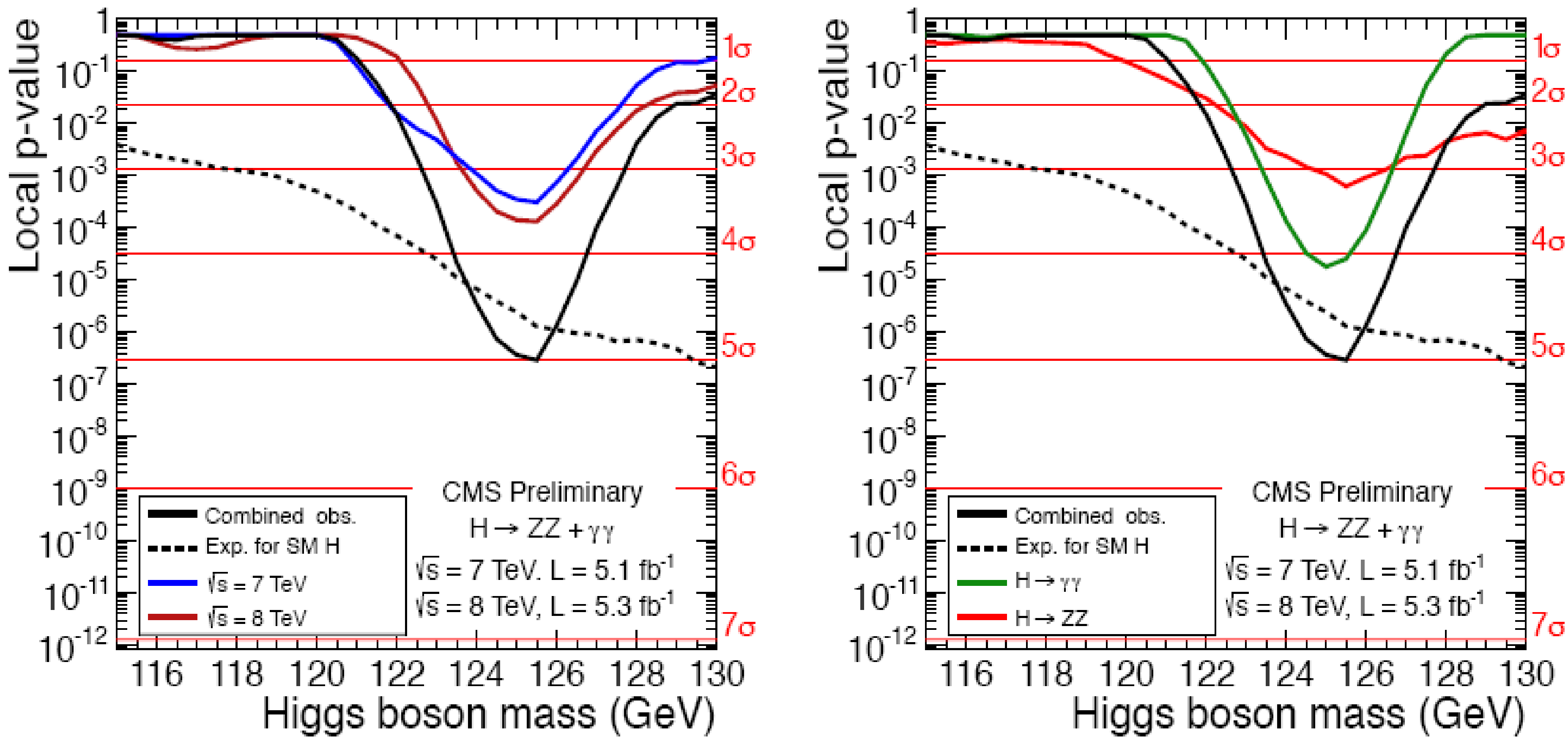
Observed significance at 125.5 GeV:
3.2 σ

Global 2011+2012 (including LEE over full 110-141 GeV range): 2.5σ

Combination: ZZ + γγ

Local significance of excess: **5.0σ**

Expected for SM Higgs signal: 4.7σ

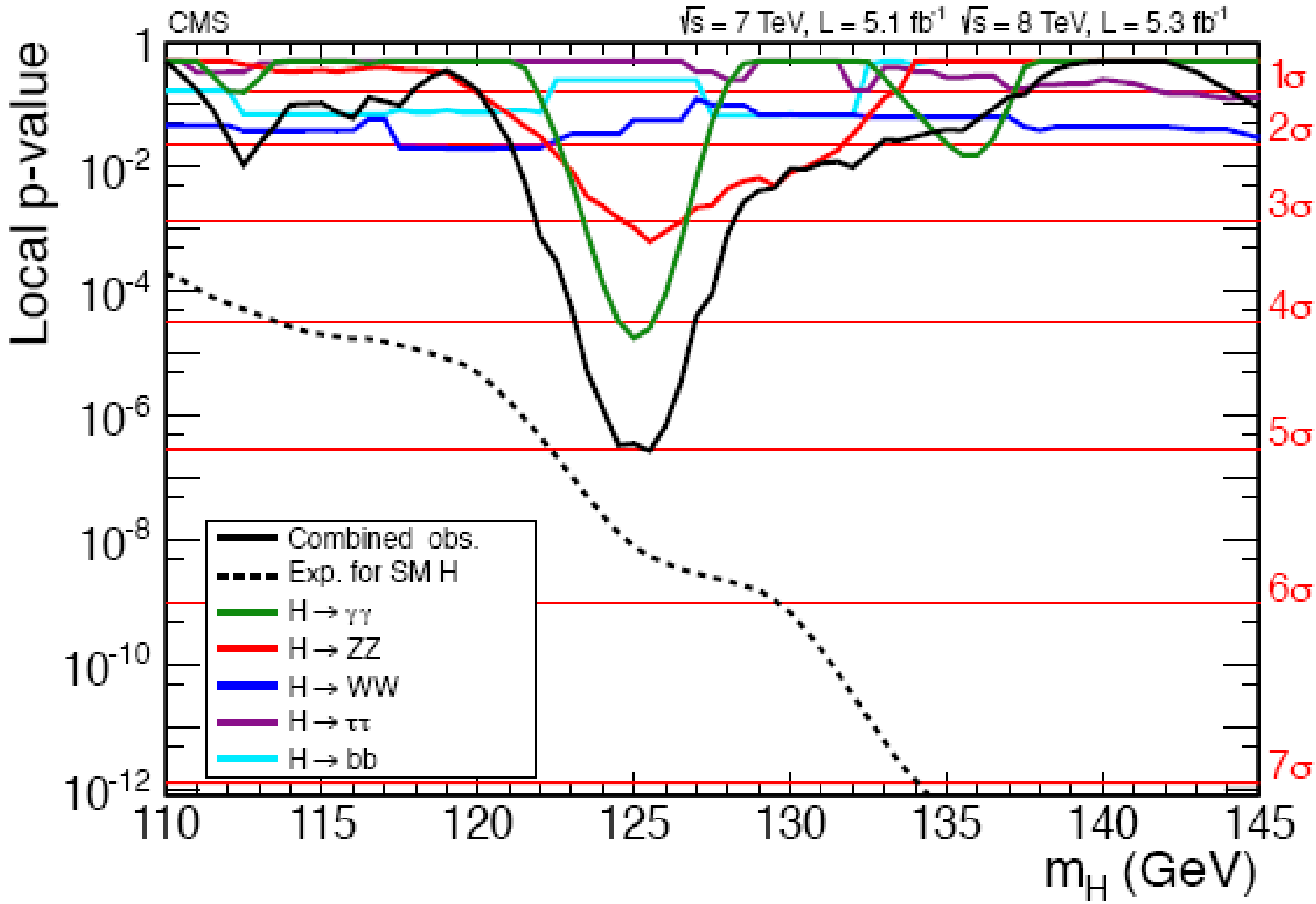


Discovery of a new state

Combination: all the channels

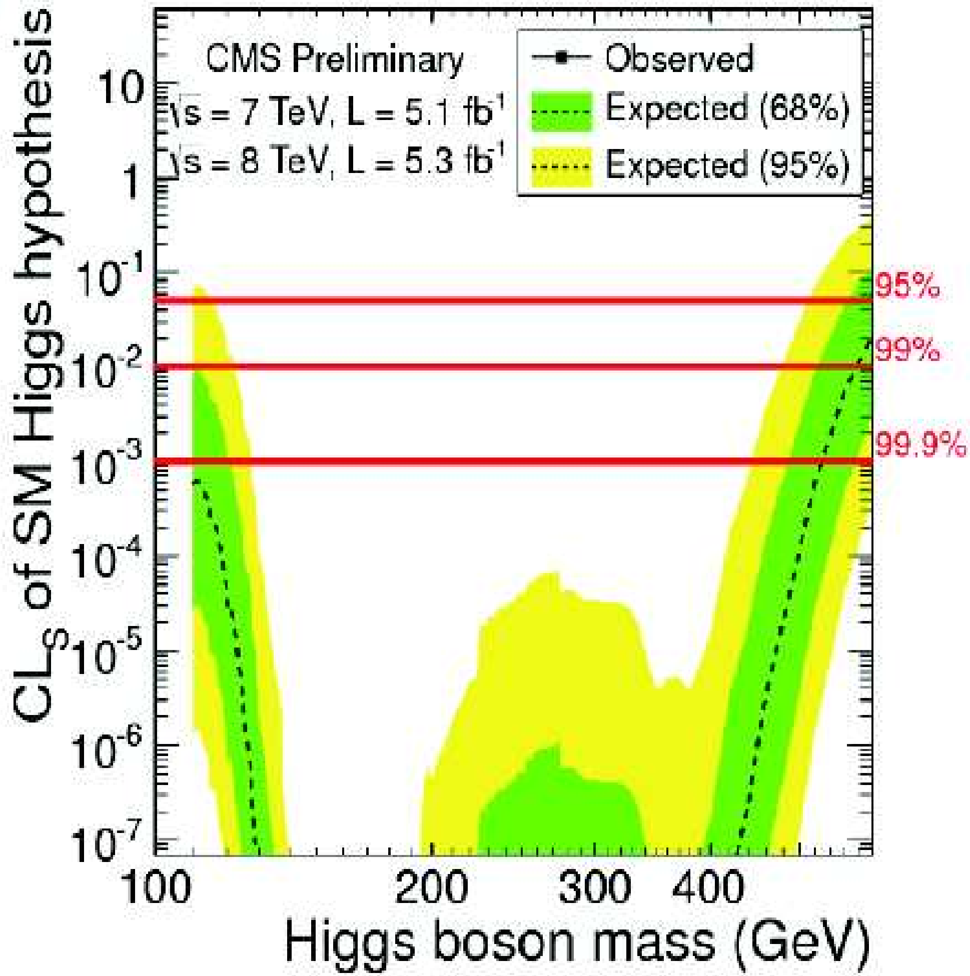
Local significance of excess: 5.0σ

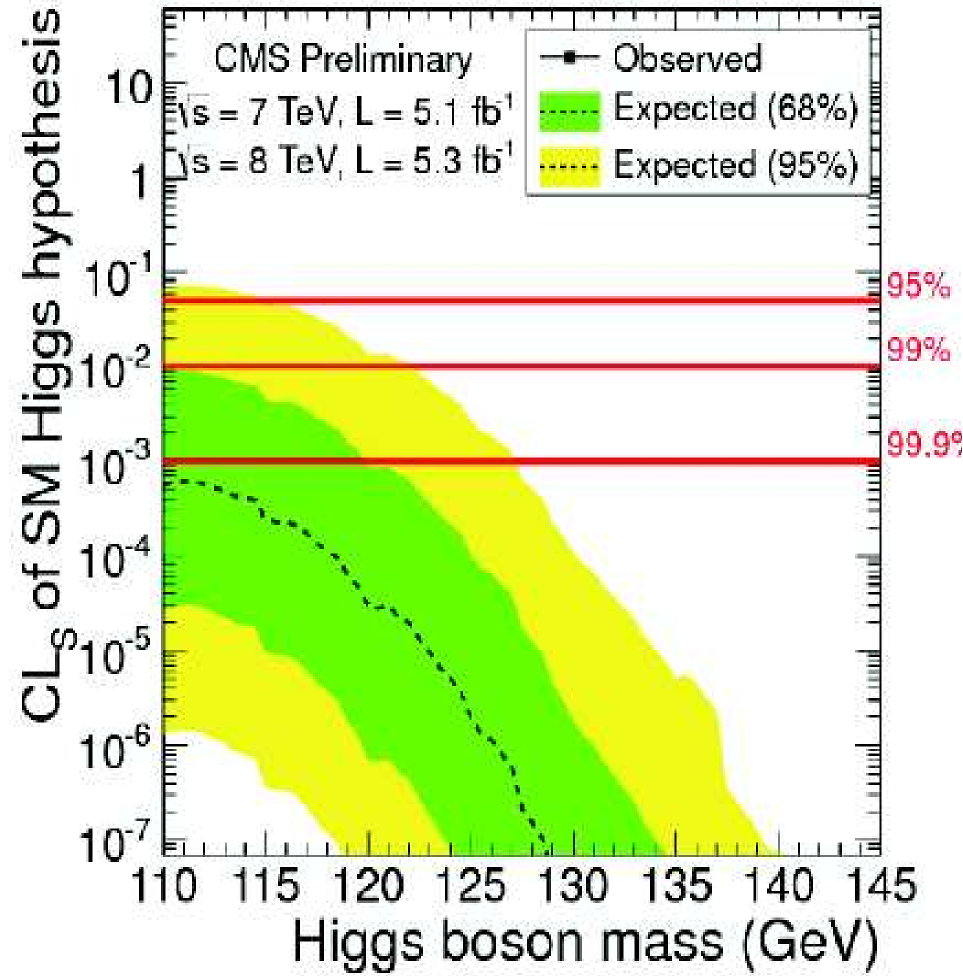
Expected for SM Higgs signal: 6.0σ



Discovery of a new state

SM Higgs exclusion: confidence level



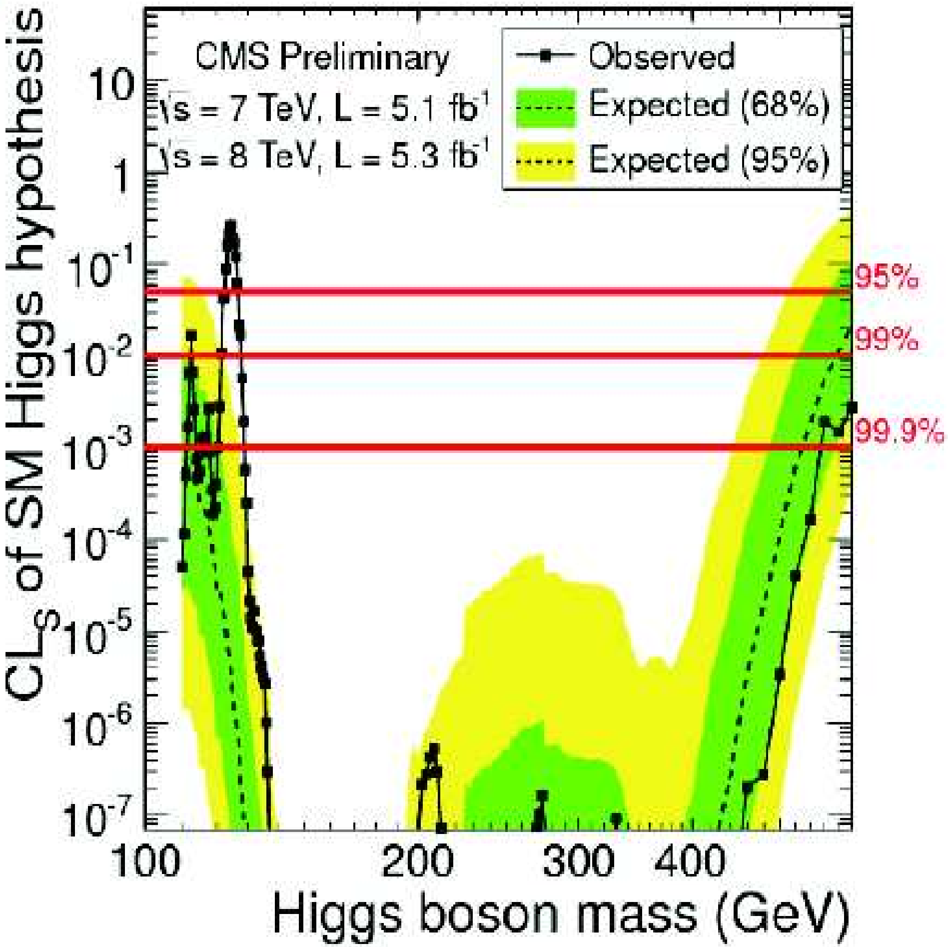


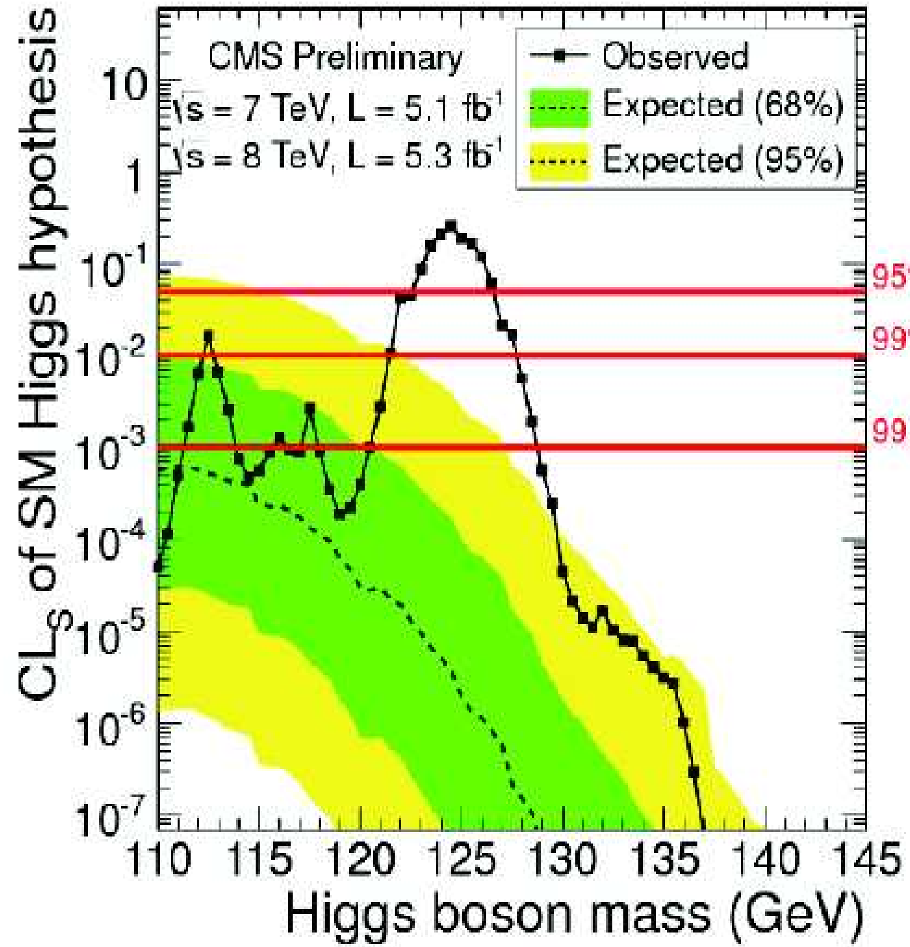
Expected in absence of SM Higgs boson: 110 – 600 GeV at 95% CL

110 – 580 GeV at 99% CL

110 – 520 GeV at 99.9% CL

SM Higgs exclusion: confidence level





Observed: 110 – 122.5 [...] 127 – 600 GeV at 95% CL

110—112 .. 113 – 121.5 [...] 128 – 600 GeV at 99% CL

In summary

We have observed a new boson with a mass of

125.3 ± 0.6 GeV

at

4.9 σ significance !

ATLAS today's main result (preliminary):

5.0 σ excess at m_H~126.5

These accomplishments are the results of more than 20 years of talented work and extreme dedication by the ATLAS Collaboration, with the continuous support of the Funding Agencies

More in general, they are the results of the ingenuity, vision and painstaking work of our community (accelerator, instrumentation, computing, physics)

Argentina
Armenia
Australia
Austria
Azerbaijan
Belarus
Brazil
Canada
Chile
China
Colombia
Czech Republic
Denmark
France
Georgia
Germany
Greece
Israel
Italy
Japan
Morocco
Netherlands
Norway
Poland
Portugal
Romania
Russia
Serbia
Slovakia
Slovenia
South Africa
Spain
Sweden
Switzerland
Taiwan
Turkey
UK
USA
CERN
JINR

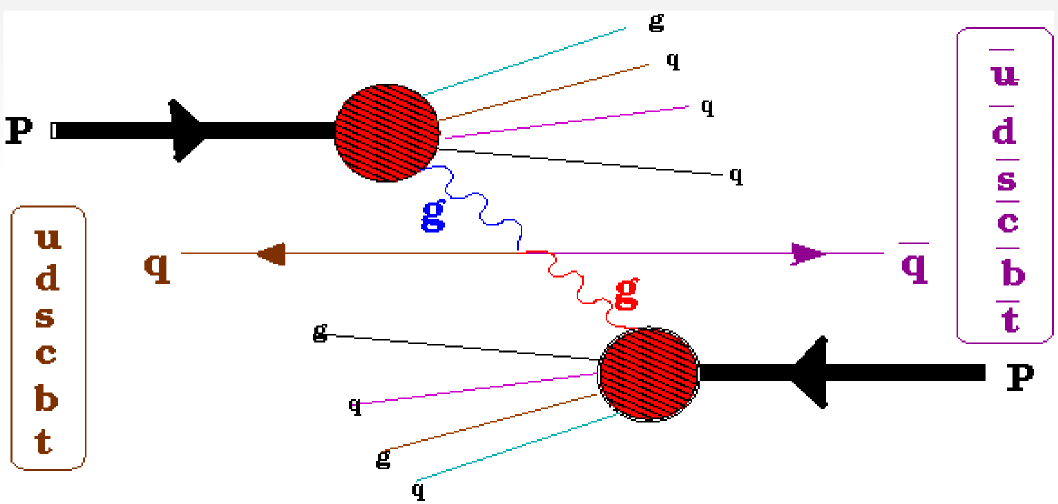
ICHEP Melbourne

ATLAS Collaboration

ATLAS Experiment

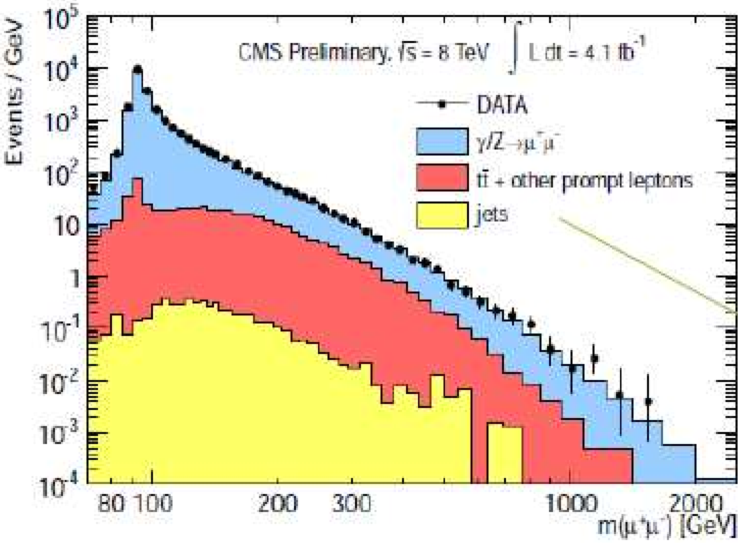
Como se descobre novas partículas?

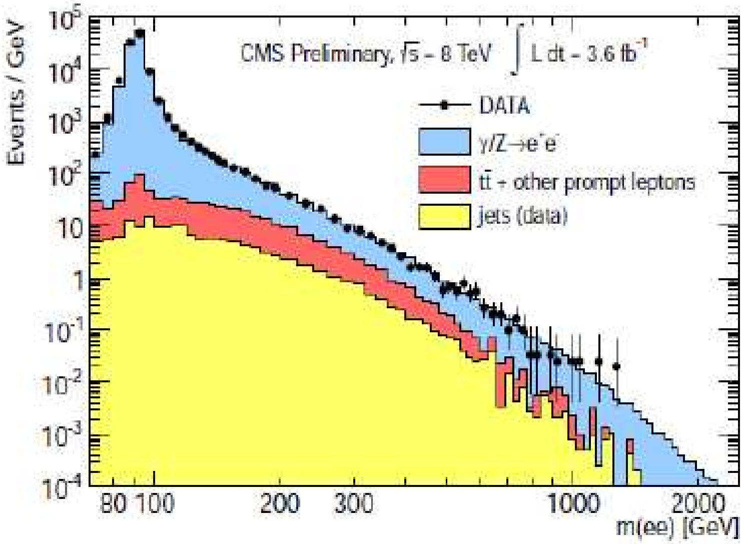
Colisão entre partículas a altas energias



Energia da colisão
\>
Massa da nova partícula

Z' → ee / μμ – analysis strategy

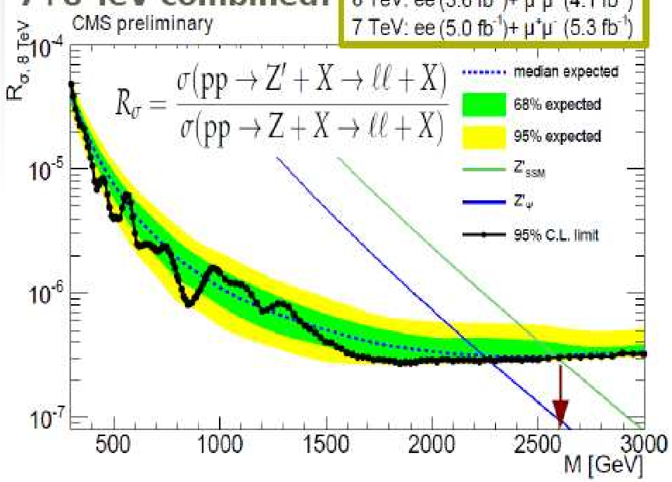




CMS-PAS-EXO-12-015

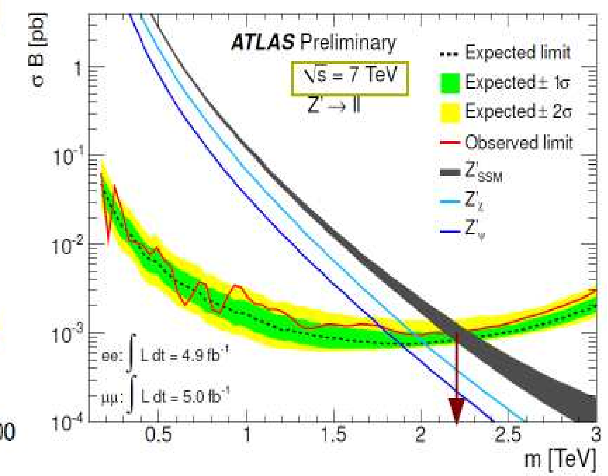
7+8 TeV combined!

8 TeV: ee (3.6 fb^{-1})+ $\mu^+\mu^-$ (4.1 fb^{-1})
7 TeV: ee (5.0 fb^{-1})+ $\mu^+\mu^-$ (5.3 fb^{-1})



$m_{Z'_{SSM}}$>2.59TeV @95% CL

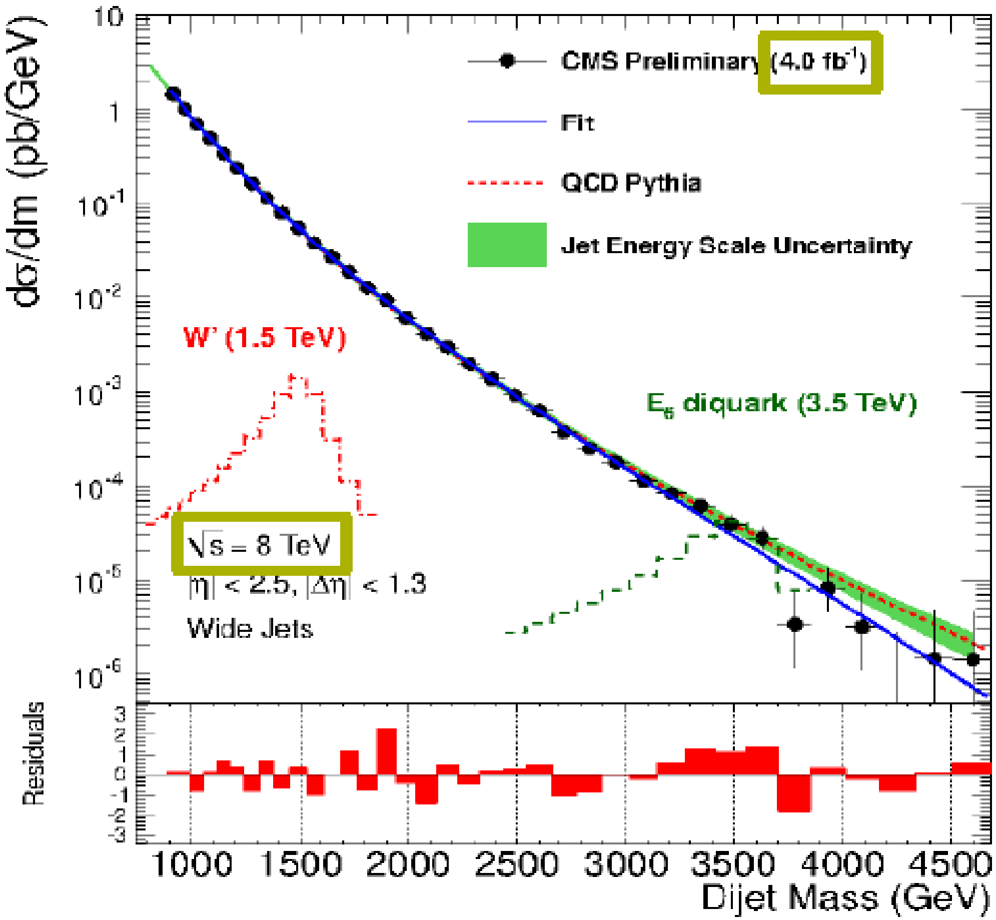
ATLAS-CONF-2012-007



$m_{Z'_{SSM}}$>2.21TeV @95% CL

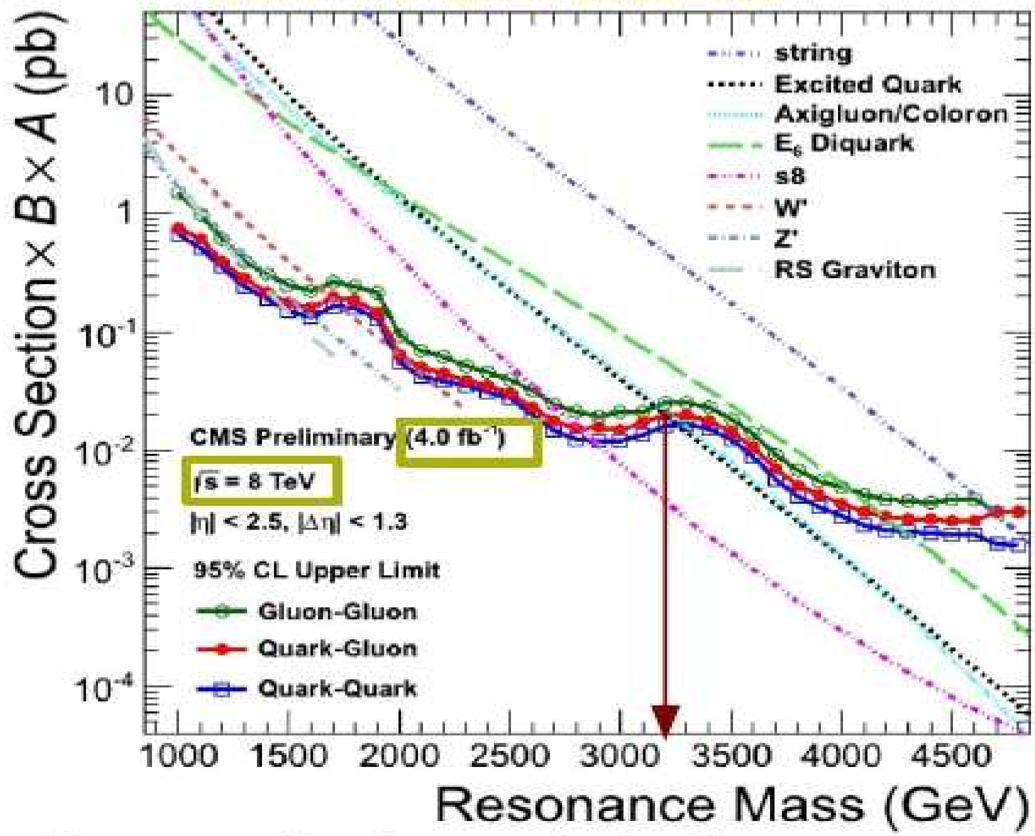
Dijet resonances, e.g. Z' → qq

CMS-PAS-EXO-2012-016



Dijet resonances

CMS-PAS-EXO-2012-016



@ 95% CL using Pythia 6 (8)

CMS: m_{q*} > 3.19 TeV @ 95%CL

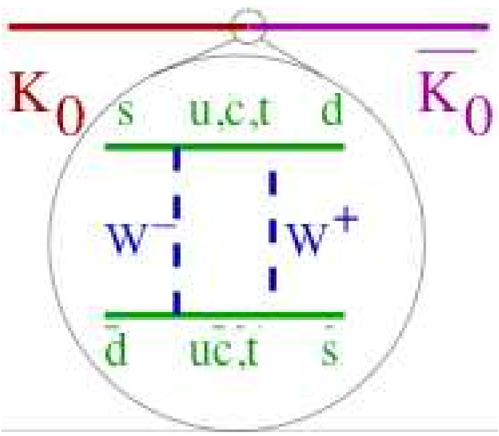
Energia altas Vs alta estatística

Produção em grandes quantidades de partículas conhecidas e observar as suas desintegrações no detalhe

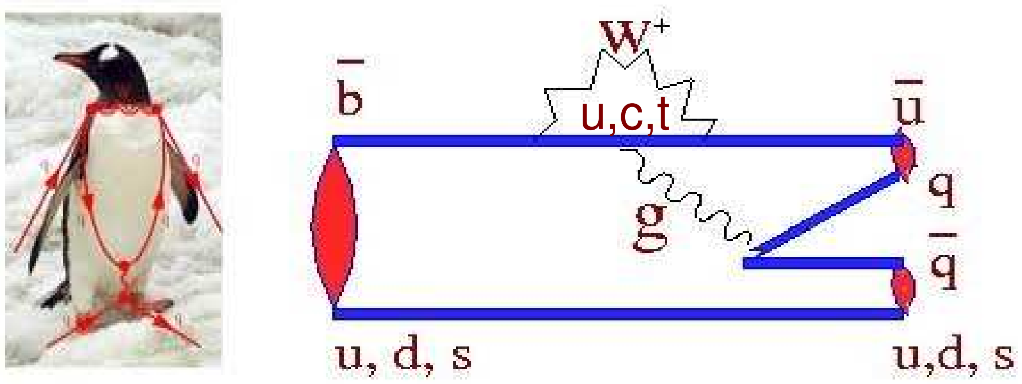
Loops com partículas intermediárias de alta massa.

Maior massa da nova partícula > Maior contribuição

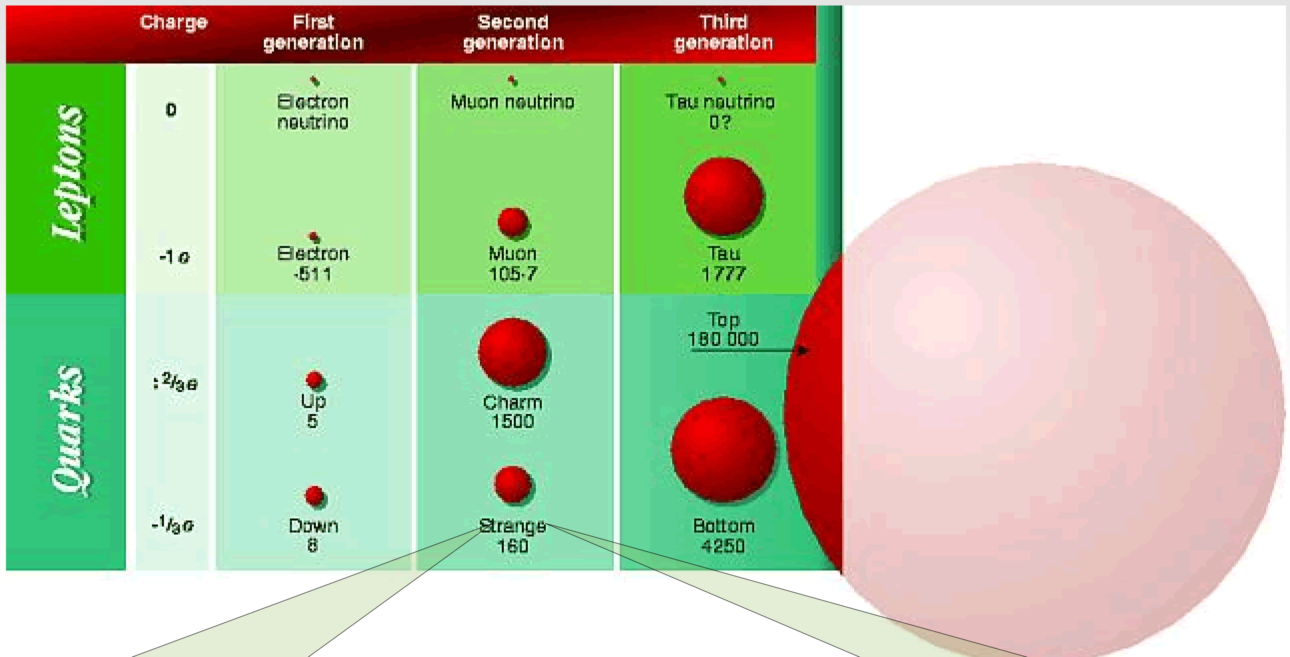
Oscilação de partículas neutras



Contribuição Penguin em desintegração de partículas



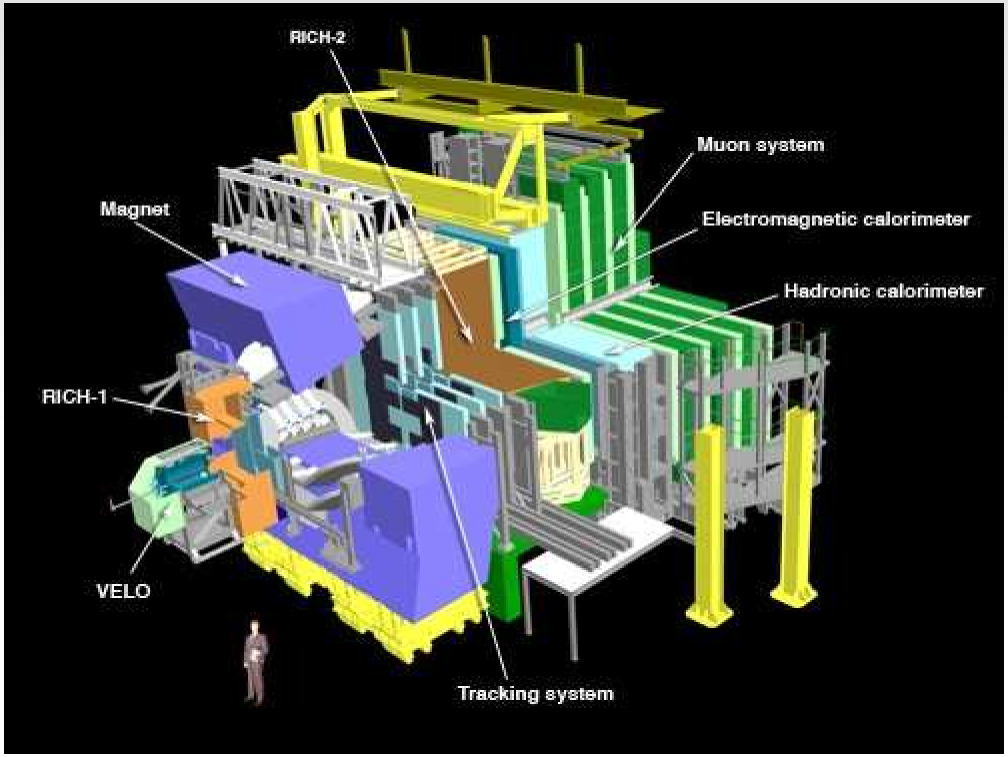
Como se descobrem novos fenômenos envolvendo novas partículas: loops!

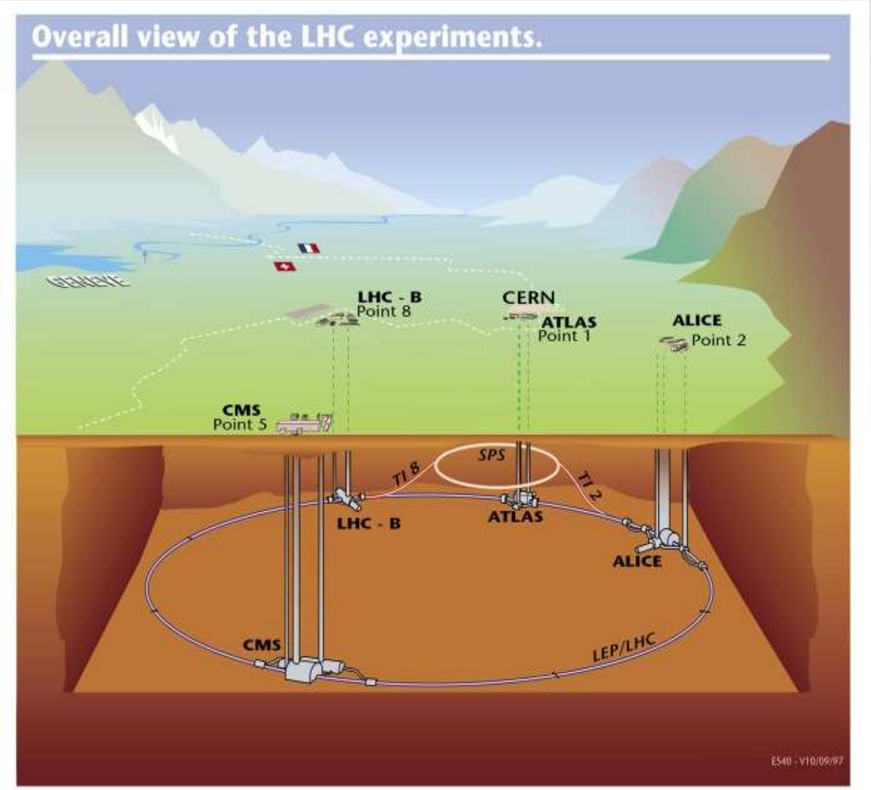


Estudo com partículas estranhas, previram a existência dos quarks c,b e t

Estudo com partículas estranhas, mostraram a existencia de violacao de CP no modelo standard.

Colaboração LHCb no LHC





Produzir de 10 a 100 vezes mais B's e D's, reconstruídos por ano, que o Belle e BaBar produziram nos 10 anos de funcionamento.

800 colaboradores, mais de cinquenta instituições de pesquisa, custo de construção cerca de 100M de CHF.

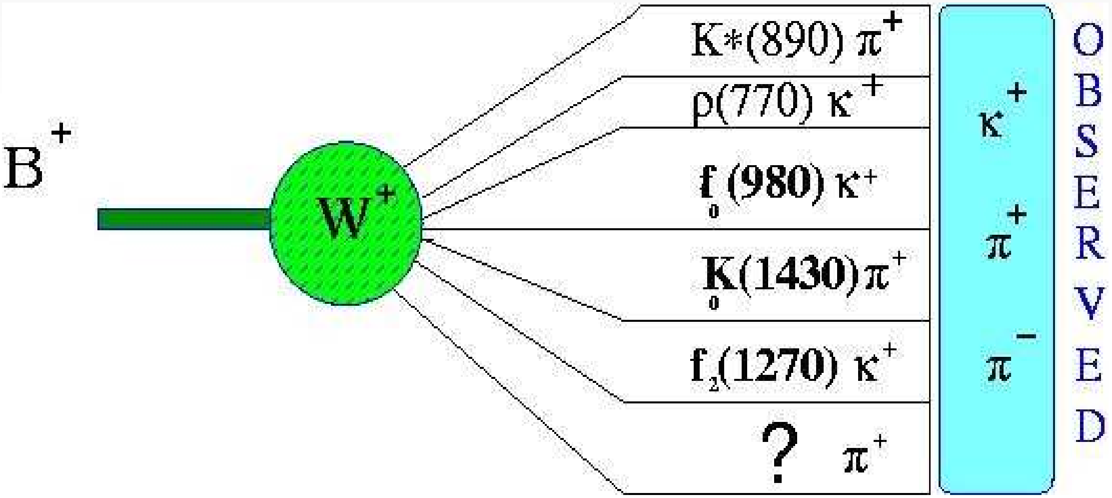
Desintegração de partículas em três corpos e busca por violação de CP.

Busca de violação de CP em desintegrações em três hadrons.

Projeto CBPF e IF/UFRJ

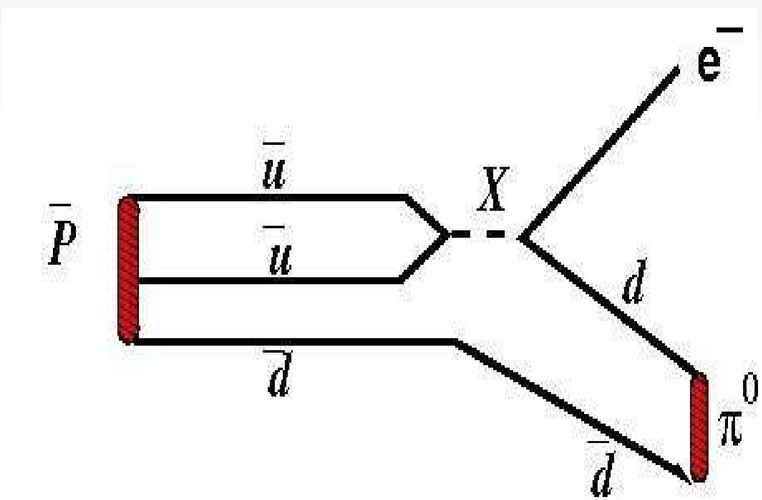
I.B, R.E. Blanco, C. Gobel, R. Mendez-Galain, Phys.Rev.Lett.81:4067-4070,1998.
I.B, Gabriel Guerrer and Jussara Miranda, Phy.Rev D76: 073011 (2007)
I.B., I.I. Bigi, A. Gomes, G. Guerrer, J. Miranda and A.C. Dos Reis .Phys. Rev. D 80, 096006 (2009)
I.B., I.I. Bigi, A. Gomes, J. Miranda, A.C. Dos Reis, J. Otalora and A. Veiga,Phys. Rev. D 86, 036005 (2012)

- *Study the B decays: and intermediary states:*
  - $B^{\pm} \rightarrow \pi^{\pm} \pi^{+} \pi^{-}$
  - $B^{\pm} \rightarrow K^{\pm} \pi^{+} \pi^{-}$
  - $B^{\pm} \rightarrow \pi^{\pm} K^{+} K^{-}$
  - $B^{\pm} \rightarrow K^{\pm} K^{+} K^{-}$
  - $B^{\pm} \rightarrow \pi^{\pm} \bar{p}\, p$
  - $B^{\pm} \rightarrow K^{\pm} \bar{p}\, p$



Violação de CP

Desintegração do próton seria menor que a do antipróton



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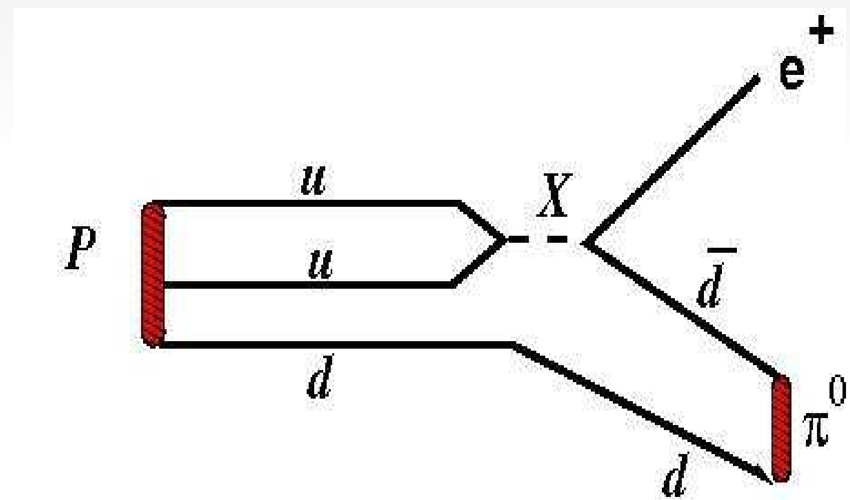
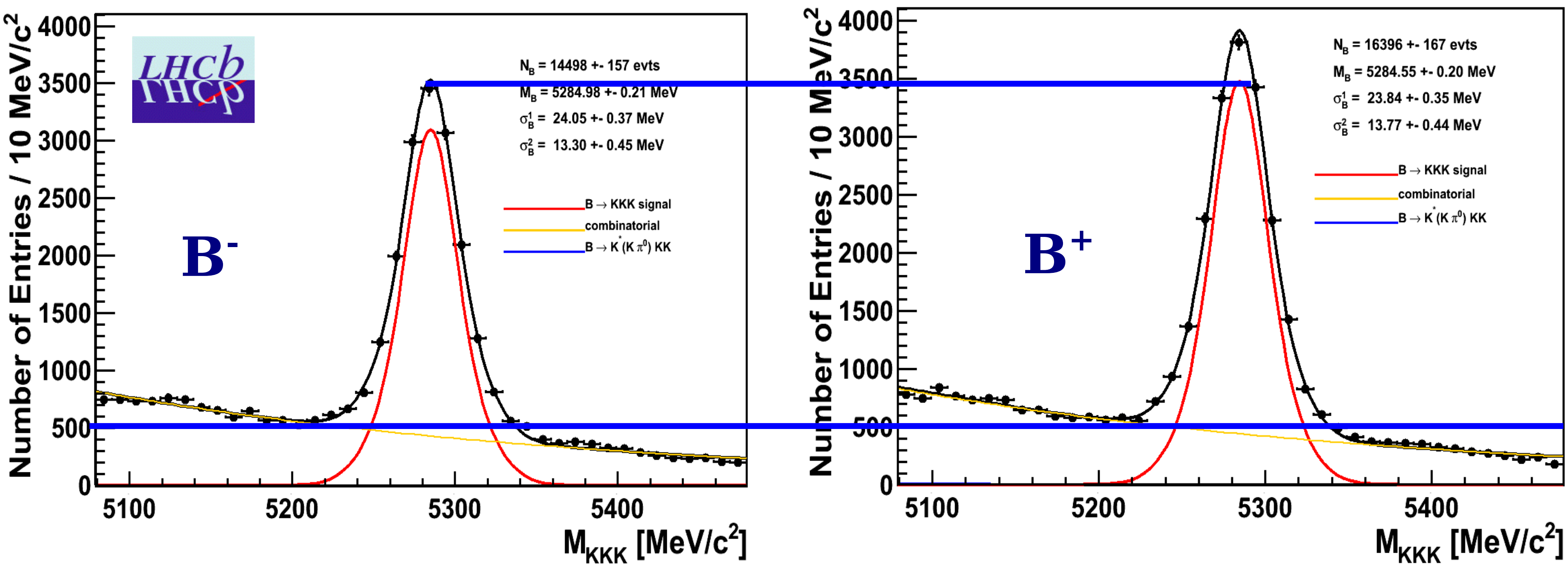


$$B^+ \rightarrow K^+ K^- K^+ \neq B^- \rightarrow K^- K^+ K^-$$

Total charge asymmetry for $B^+ \to K^+ K^- K^+$ ICHEP2012

N(B$^-$) = 14,498 ± 156 N(B$^+$)= 16,396 ± 167

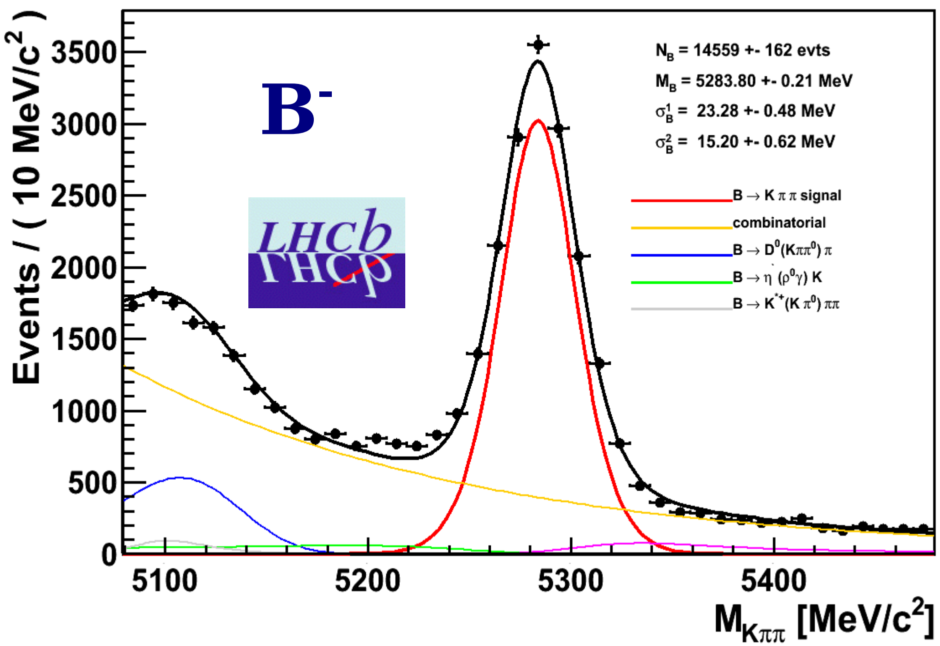


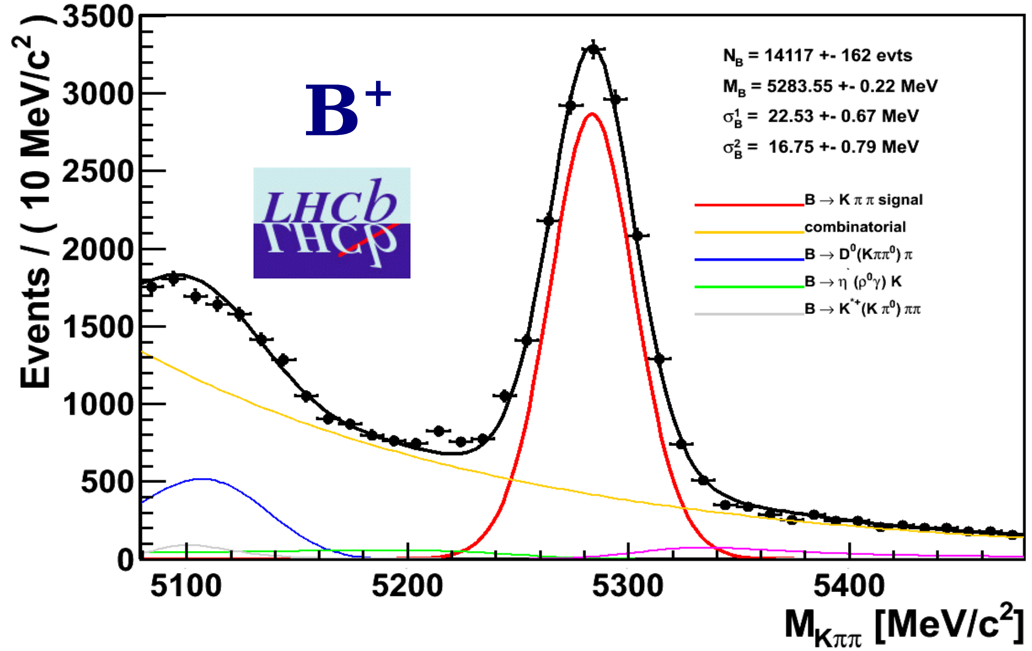
Total charge asymmetry:

$$ACP\_RAW = \frac{N(B^-) - N(B^+)}{N(B^-) + N(B^+)} = -0.061 \pm 0.007$$

Total charge asymmetry for $B^+ \to K^+ \pi^- \pi^+$ ICHEP2012

$N(B^-) = 14{,}559 \pm 162$ $N(B^+) = 14{,}117 \pm 162$



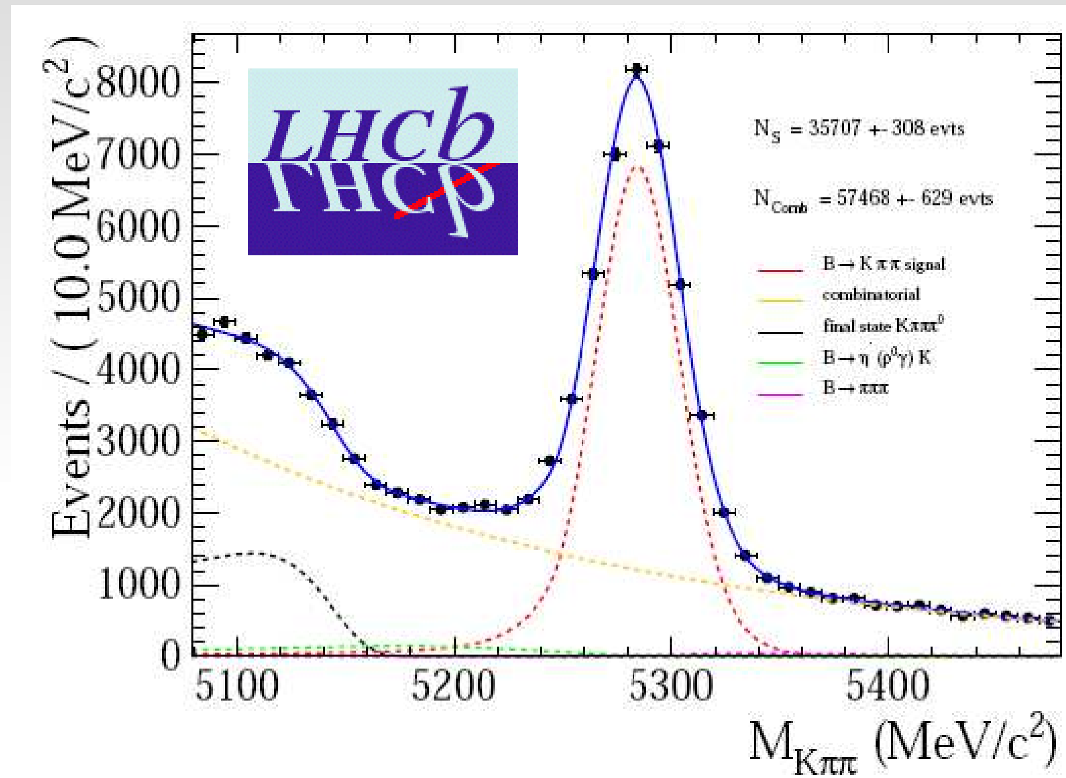


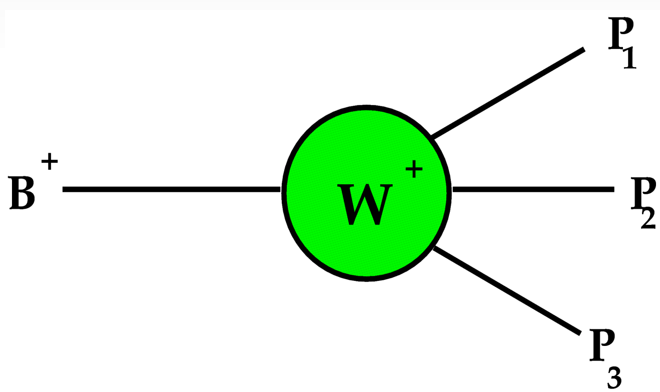
Total charge asymmetry:

$$ACP\_RAW = \frac{N(B^-) - N(B^+)}{N(B^-) + N(B^+)} = 0.015 \pm 0.008$$

Decaimento do B em três mésons

35,707± 308 eventos de sinal $B^{\pm} \rightarrow K^{\pm} \pi^{+} \pi^{-}$
Dados de 2011



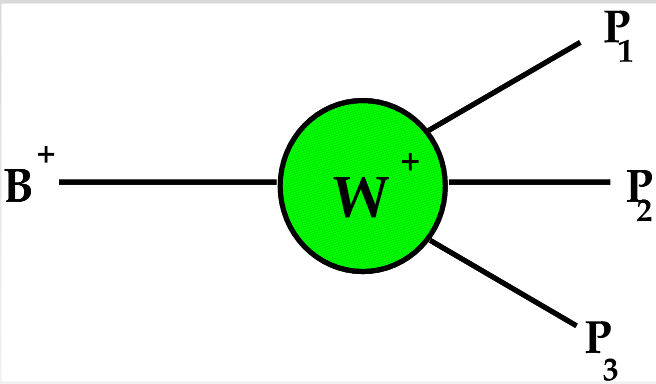


$$M_B^{\ 2} = (P^{\nu}_{\ B})^{\ 2} = (P^{\nu}_{\ 1} + P^{\nu}_{\ 2} + P^{\nu}_{\ 3})^{\ 2}$$

$$s_{12} = M_{12}^2 = (p_1^{\nu} + p_2^{\nu})^2$$
$$s_{13} = M_{13}^2 = (p_1^{\nu} + p_3^{\nu})^2$$
$$s_{23} = M_{23}^2 = (p_2^{\nu} + p_3^{\nu})^2$$

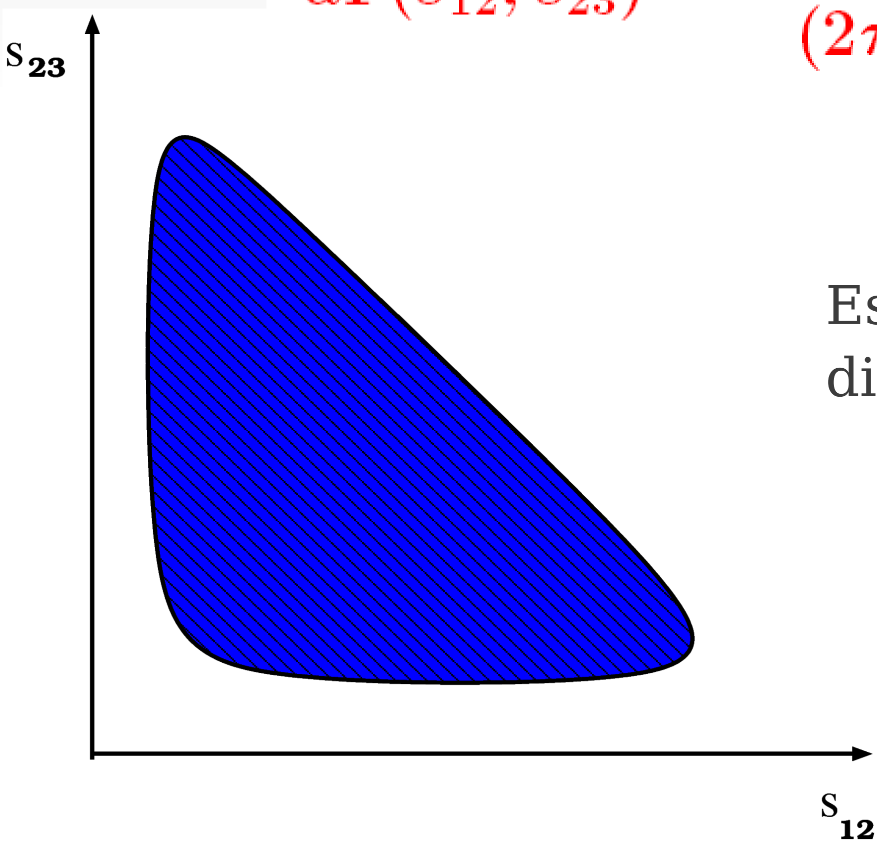
$$M_B^{\ 2} + m_1^{\ 2} + m_2^{\ 2} + m_3^{\ 2} = s_{12} + s_{23} + s_{13}$$

Dalitz Plot-



$$s_{12} = M_{12}^2 = (p_1^\nu + p_2^\nu)^2$$
$$s_{13} = M_{13}^2 = (p_1^\nu + p_3^\nu)^2$$
$$s_{23} = M_{23}^2 = (p_2^\nu + p_3^\nu)^2$$

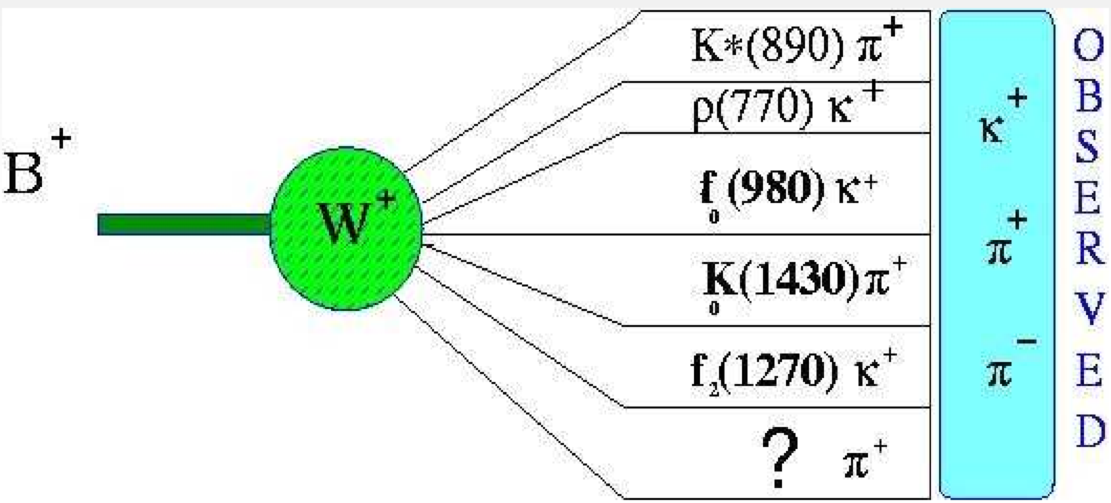
$$d\Gamma(s_{12}, s_{23}) = \frac{1}{(2\pi)^3 32 M_B^3} |\mathcal{M}|^2 \, ds_{12} ds_{23}$$



Espaço de fase onde escrevo a dinâmica dada pelo $| M |^2$

Busca de violação de CP em desintegrações em três hadrons.

$$\mathbf{B}^{+} \rightarrow \mathbf{K}^{+} \pi^{-} \pi^{+}$$



$K^{*}(890)\pi^{+}$, $\rho(770)K^{+}$, $f_0(980)K^{+}$

$$BW = \frac{1}{m^2 - m_0^2 + i m_0 \Gamma(m)},$$

Soma coerente de amplitudes

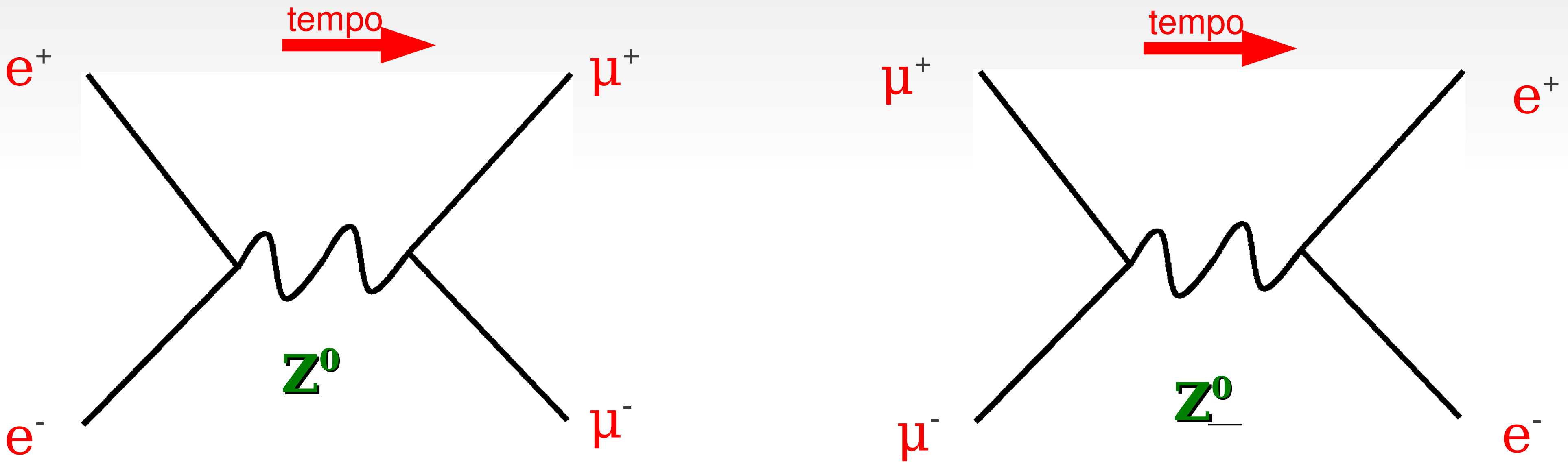
Interferências e fases

Ressonâncias: partículas com vidas médias 10^{-24} s, se desintegram por interações fortes.

Teorema de CPT

Se aplica a qualquer teoria invariante de Lorentz, onde os observáveis são representados por operadores hermitianos.

Violação de CP → Irreversibilidade.

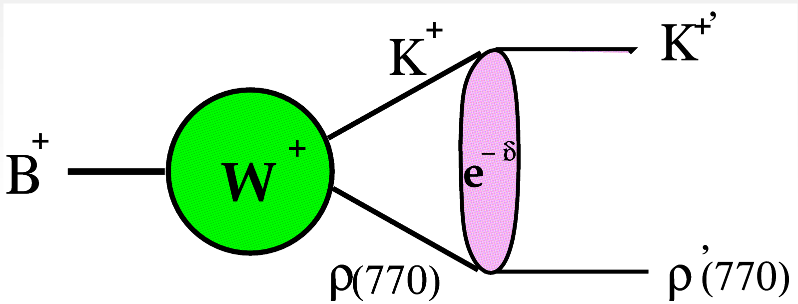


Transformação em tempo deve ser descrita por uma transformação unitária e complexa $e^{-iEt} \rightarrow T \rightarrow e^{iEt}$.

Violação de CP implica na existência de uma fase.

Heavy meson three body decays.
Amplitude analysis

- *Isobaric Model amplitude two body plus one bachelor*
- $M_i = BW_i \times \Theta_i^J$
- *BW - Breit Wigner*
- Θ_i^J *- angular function*
- $M_T = \sum a_i \, e^{i\delta i} \, M_i$
- δ_i *is the re-scattering phase*



Work pretty well for charm three body decays.

- *Approximation 2 + 1 work at least in first order.*

Working group Nabis

Different expertise → formation of working group Nabis

From Theory

I. Bigi, S. Gardner (USA)

C. Hanhart, Th. Mannel, U.-G. Meißner, W. Ochs, A. Sibirtsev (Germany)

J.A. Oller, J.R. Pelaez (Spain)

M.R. Pennington (UK)

From Experiment

I. Bediaga (Brazil)

A.E. Bondar (Russia)

A. Denig, W. Gradl, K. Peters, U. Wiedner (Germany)

T.J. Gershon (UK)

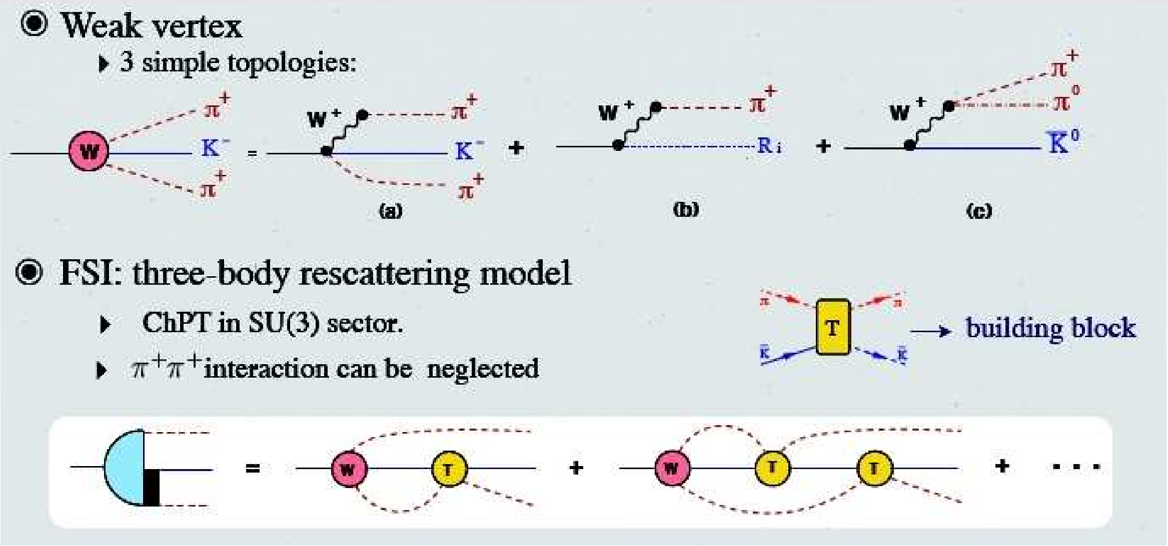
B.T. Meadows (USA)

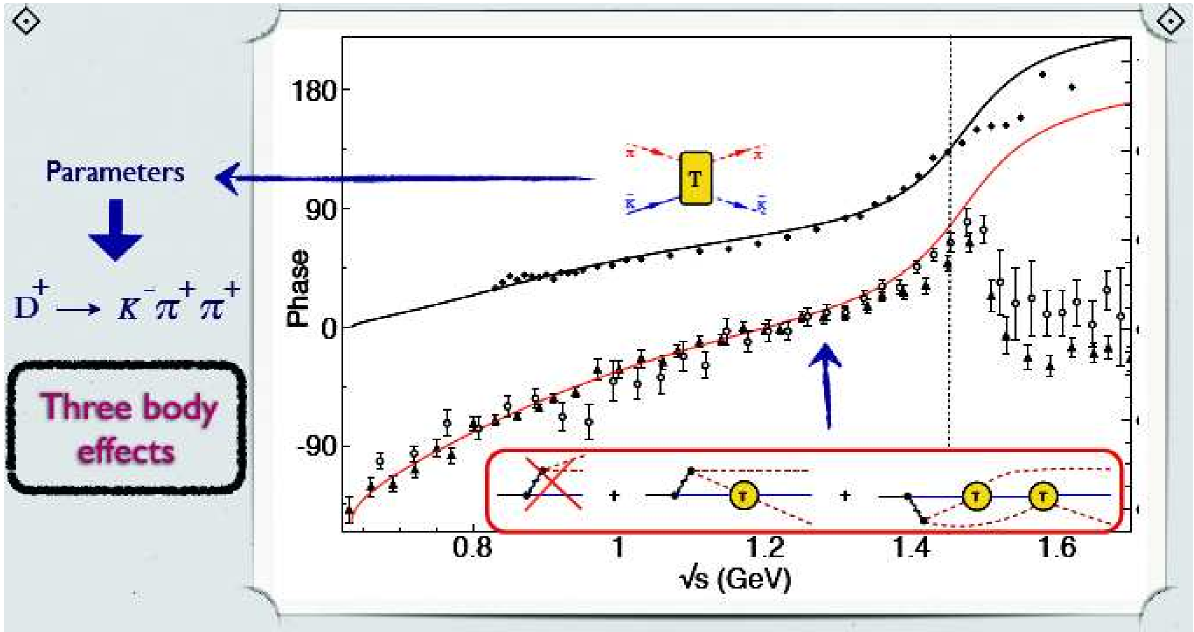
G. Wilkinson (Switzerland)

The talisman Paul Serusier, 1888

Re-scaterring in three body heavy meson decays.

P.C. Magalhaes, M.R. Robilotta, K.S.F.F. Guimaraes, T. Frederico, W. de Paula, I. B., A.C.dos Reis, , C.M. Maekawa, G.R.S. Zarnauskas, Phys.Rev.{ D84}:094001,2011.

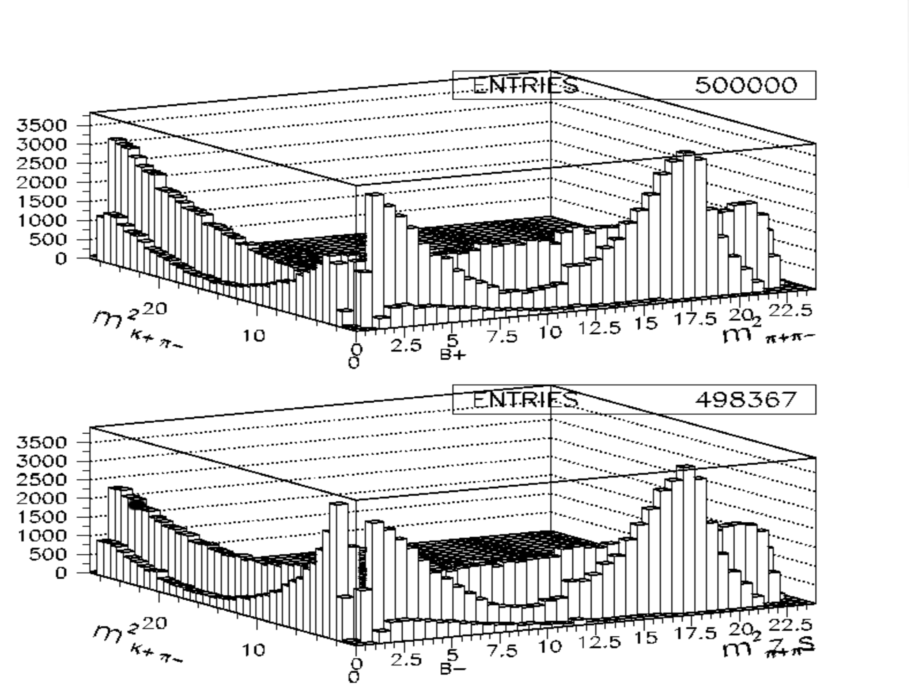




Violação de CP no Dalitz plot:

Subtração entre os planos dos decaimentos

$B^+ \rightarrow K^+ \pi^- \pi^+$ do $B^- \rightarrow K^- \pi^+ \pi^-$



$B^+ \rightarrow K^+ \pi^- \pi^+$

$B^- \rightarrow K^- \pi^+ \pi^-$

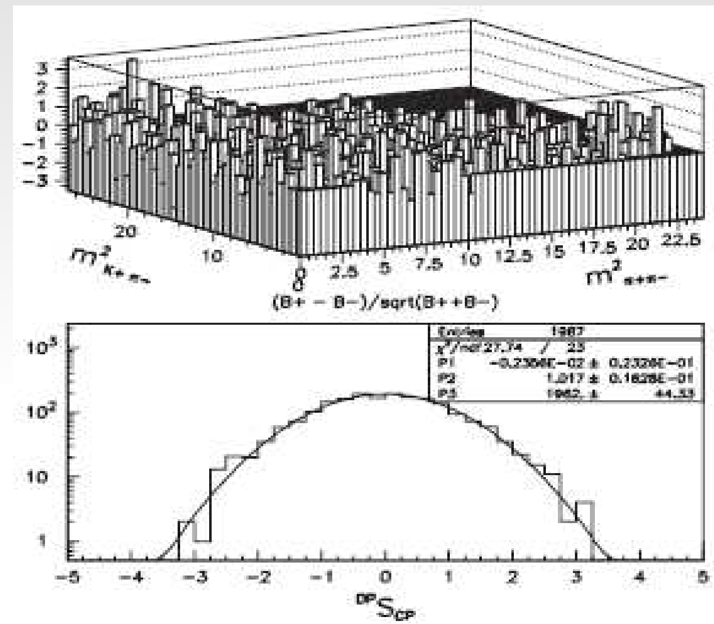
Diferença entre os dois planos ⇒ Violação de CP

Search for sources of $\not{CP}$ in $B^+ \to hhh$: Mirandizing

For $B^+ \equiv B^- \Longrightarrow \boldsymbol{CP}$

Subtract B^+ and B^- Dalitz surface and write the significance of each bin:

$$^{DP}S_{CP}(i) = \frac{(N^+(i) - N^-(i))}{\sqrt{(N^+(i) + N^-(i))}}$$



bins of significance

"imported" from astrophysical community:

Ti-pei Li and Yu-qian Ma, Astr.Jour.272(1983) ,317 by

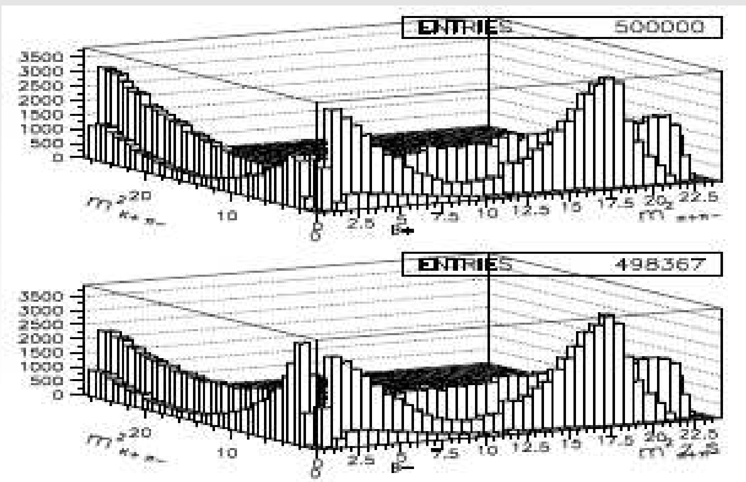
I.B., I.I. Bigi, A. Gomes, G. Guerrer,
J. Miranda and A.C. Dos Reis
-Phys. Rev. D 80, 096006 (2009)

Pure statistical fluctuation:
centred Gaussian of unit width $\mathbf{g_0(0,1)}$.

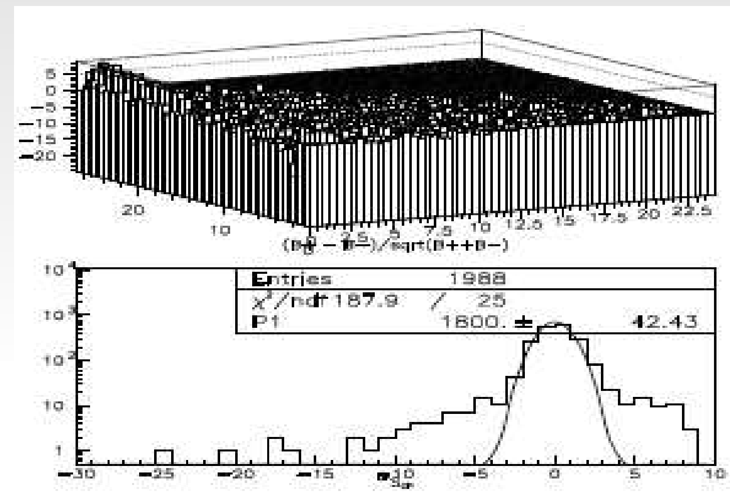
CP invariance => g(0,1)

Search for sources of $\not{C}P$ in $B^+ \to hhh$: Mirandizing

$B^+ \neq B^- \Longrightarrow \not{C}P$



$^{DP}\mathcal{S}_{CP}$ →



bins of significance

$\not{C}P \Rightarrow g(0,1)$ (with "(0" struck through)

Possibility of <u>probing regions</u> of the Dalitz plot looking at interference with $\not{C}P$:

1- resonant intermediary asymmetries like: $A_{cp}(B^+ \to K^+ \rho^0)$

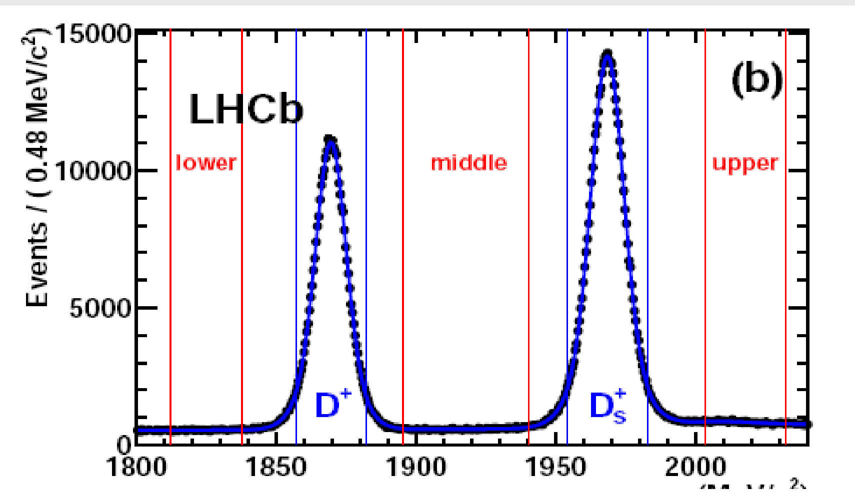
2- $\not{C}P$ in interferences between intermediary resonant states with CP

model independent method

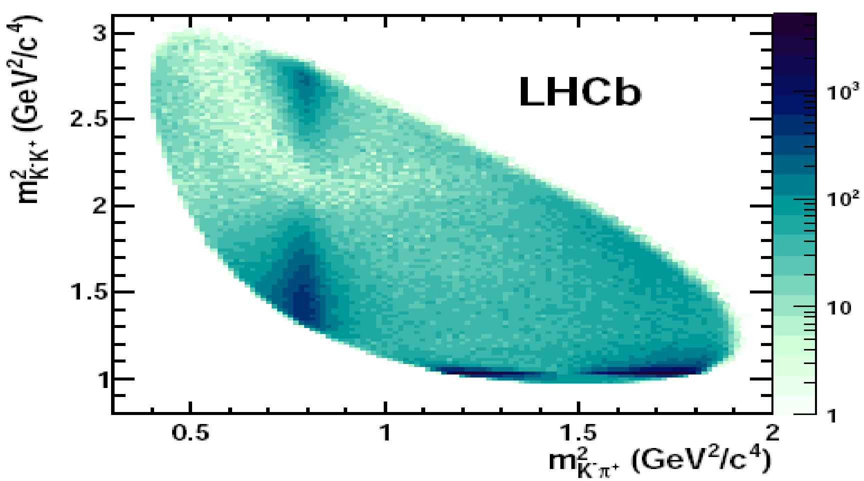
Application of the method Mirandizing in date: $D^+ \rightarrow K^+ K^- \pi^+$

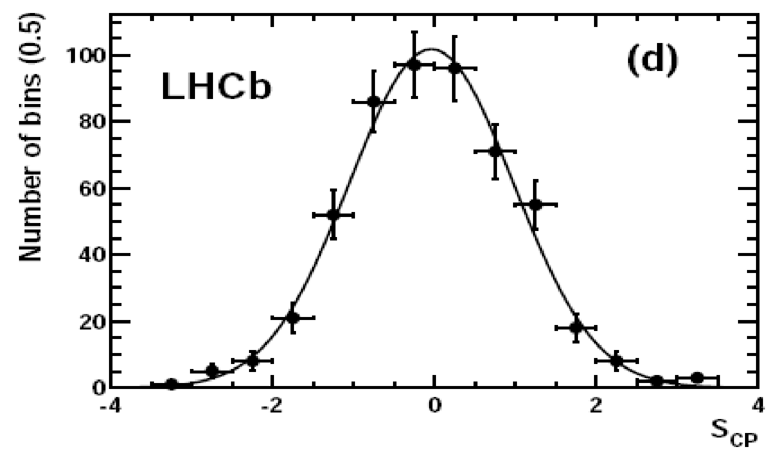
LHCb Collaboration, Phys.Rev.D84:112008,2011.

370.000 eventos
0.035ft-1



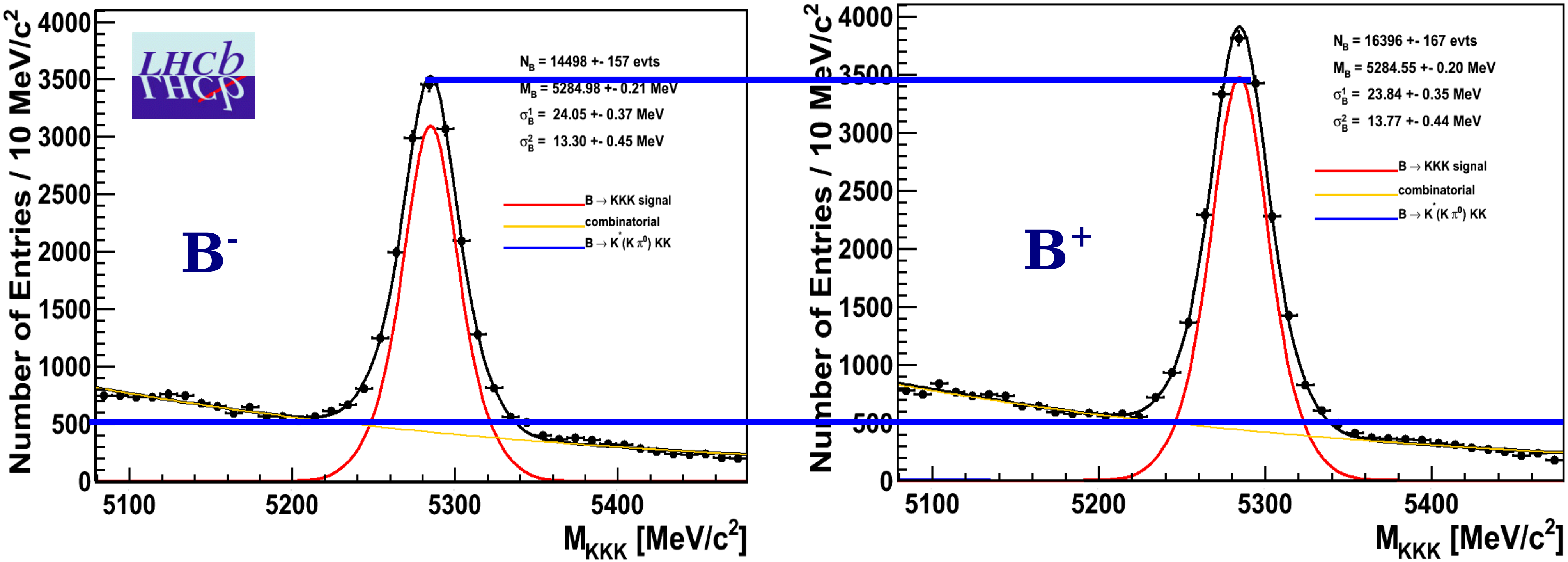
CP => g(0,1)





Total charge asymmetry for $B^+ \to K^+ K^- K^+$

N(B^-) = 14,498 ± 156 **N(B^+)= 16,396 ± 167**

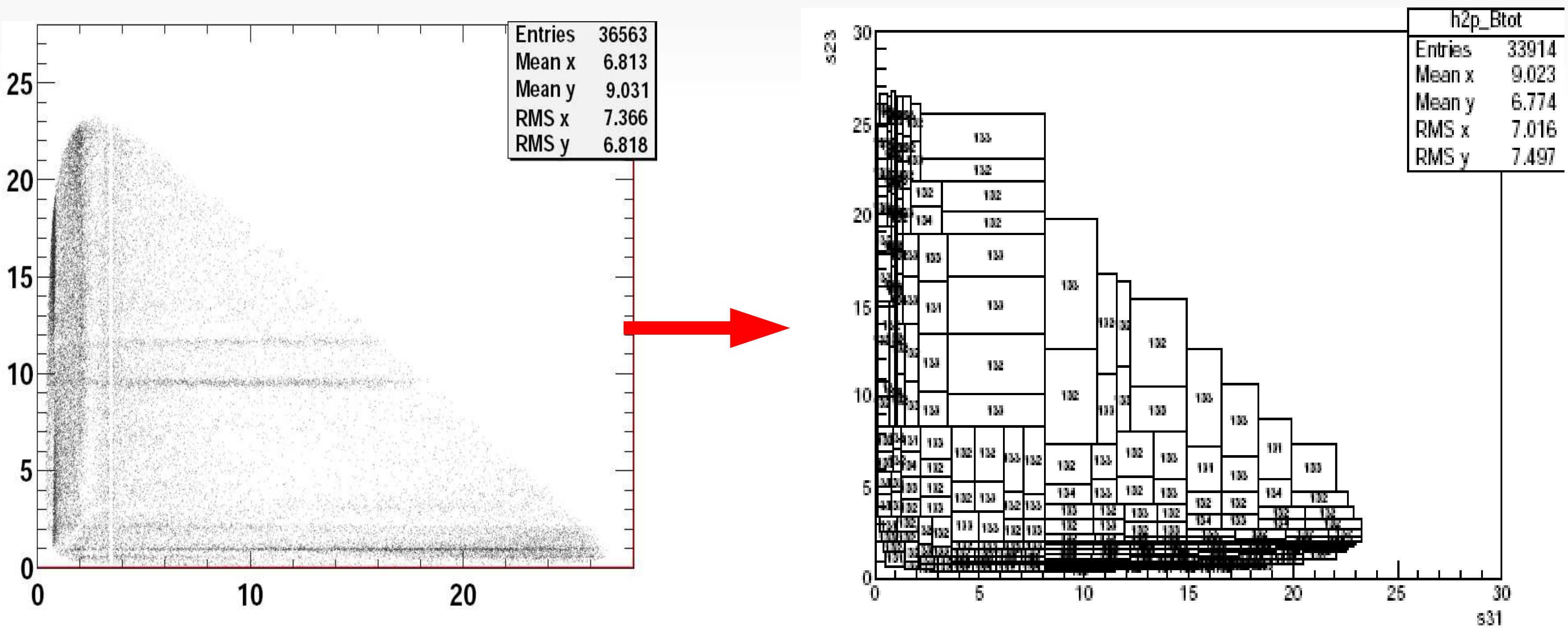


Total charge asymmetry:

$$\text{ACP\_RAW} = \frac{N(B^-) - N(B^+)}{N(B^-) + N(B^+)} = -0.061 \pm 0.007$$

Dalitz bins with the same number of events

- Producing a Dalitz surface for the sum of B^+ plus B^- with equal number of events per bin (+-1).
- Algorithm divided recursively step-by-step into two with the same number of events, alternating in ***x*** and ***y*** .



A_{CP} Mirandizing

New quantitative model independent method.

I.B, I.I. Bigi, A. Gomes, J. Miranda, A.C. Dos Reis, J. Otalara and A. Veiga, Phys. Rev. DD 86, 036005 (2012)

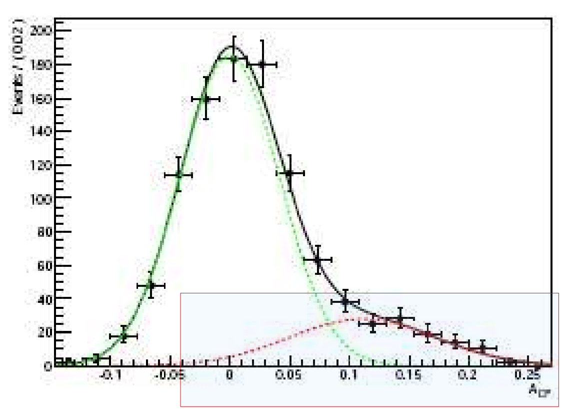
- *Since $N^{+}(i) + N^{-}(i) = N(i)$ = constant and the same for all bins, we can redefine:*

$$S_{CP}(i) = \frac{N^{+}(i) - N^{-}(i)}{\sqrt{(N^{+}(i) + N^{-}(i))}} \rightarrow A_{CP}(i) = \frac{N^{+}(i) - N^{-}(i)}{N^{+}(i) + N^{-}(i)}$$

changing the width from 1 to $1/\sqrt{N(i)}$

S_{CP} Mirandizing → A_{CP} Mirandizing

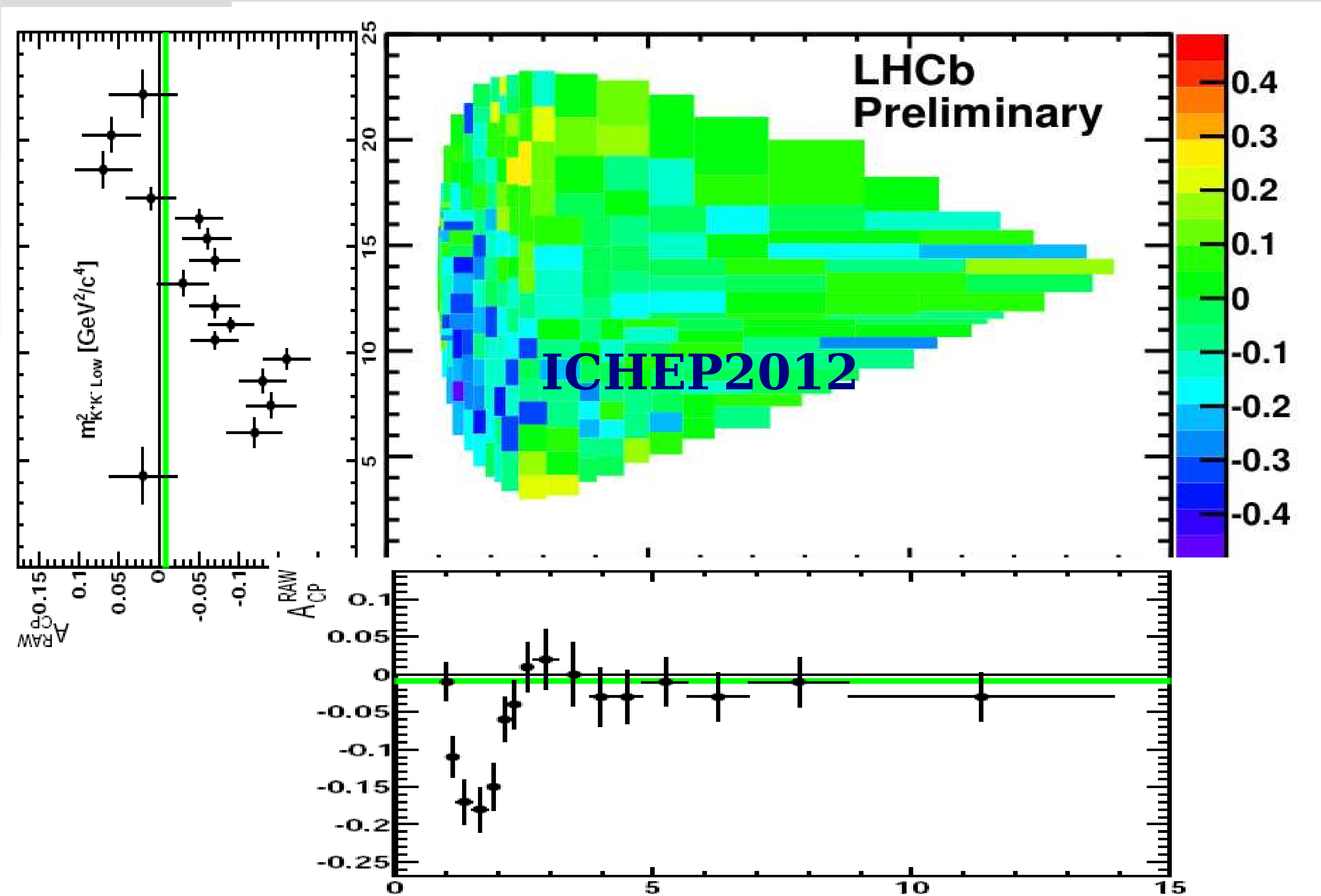
CP => g(0,1) → CP => g(0,1/√N(i))



B^+ - B^- Dalitz differences

Low M^2_{KK} and High M^2_{KK} phase space distribution

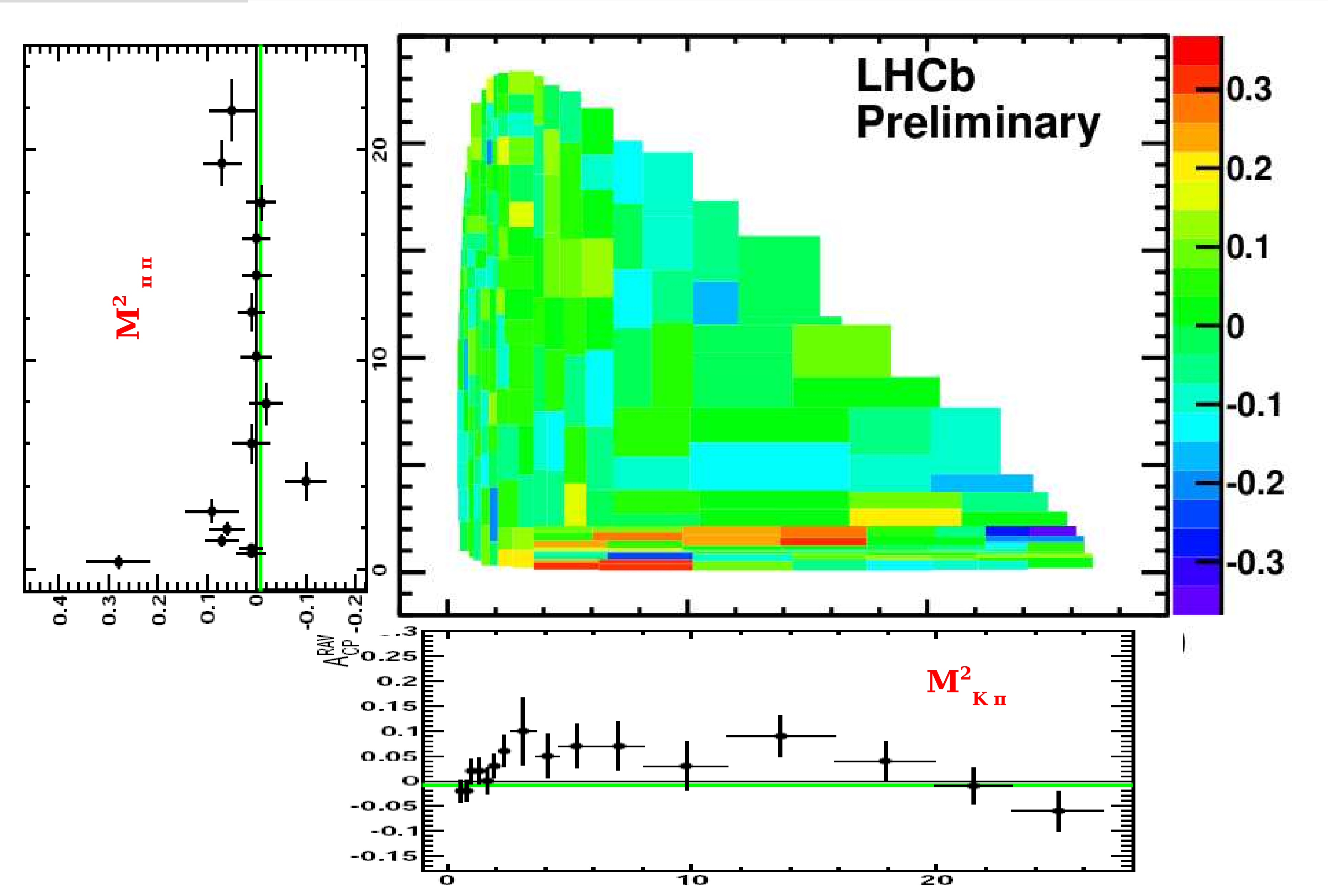
ICHEP2012



B^+ - B^- Dalitz differences

$M^2_{K+\pi-}$ Vs $M^2_{\pi+\pi-}$ phase space distribution

ICHEP2012



CP asymmetry and CPT

Directly CP violation in a heavy meson decay:
Number of final state coming from a particle is different from anti-particle.

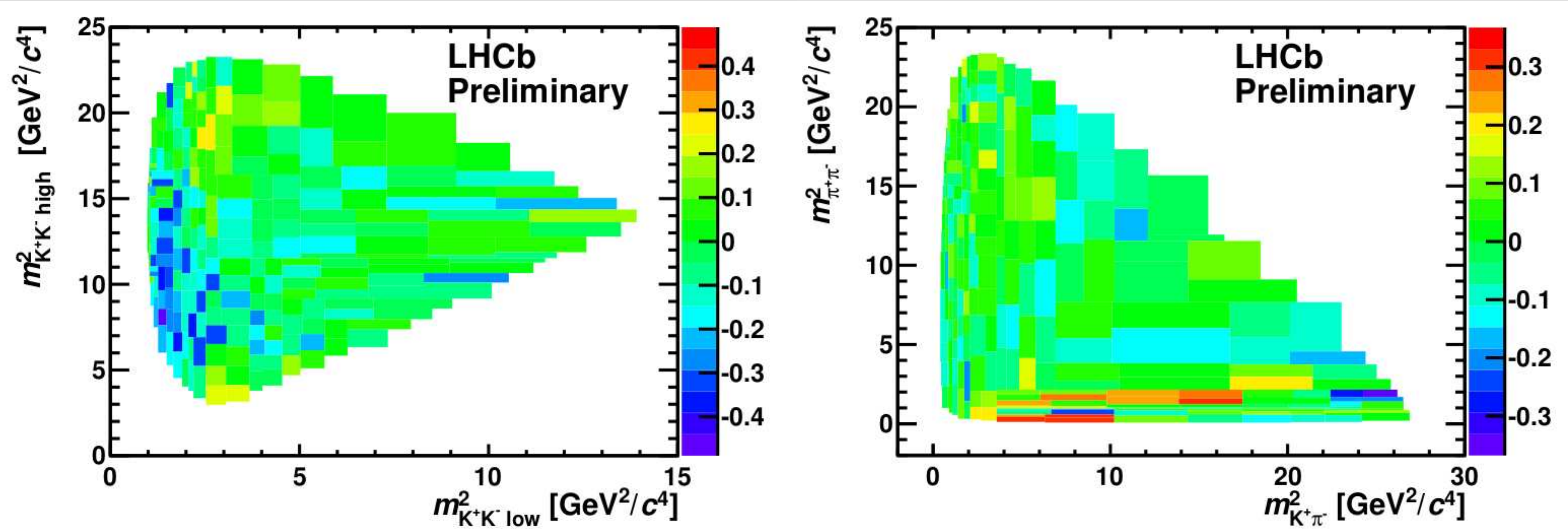
Basic question: Decay of particles produced with same amount: when CP asymmetry is violated, that is $N(M^+ \rightarrow f^+) > N(M^- \rightarrow f^-)$, **where the surplus $M^- \nrightarrow f^-$ events go?**

CPT imposes that these M^- events go to another *hadronic final state,* ***connected to f^- via S matrix.*** Bigi and Sanda or Marshak et al. Books.

Other than weak phases at quarks scale, directly CP violation needs the existence of re-scattering amplitudes different from zero.

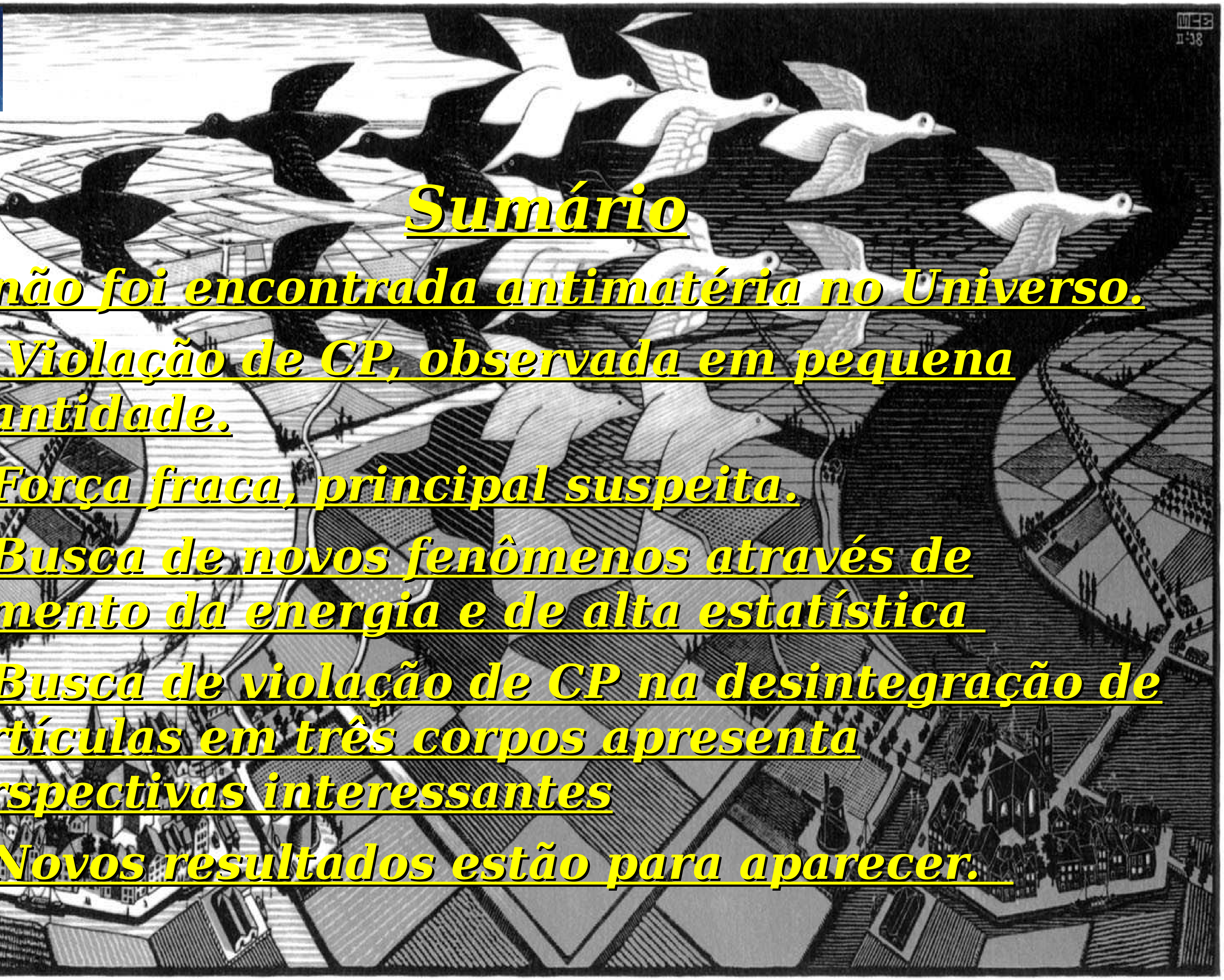
$$\mathbf{CPT} \Rightarrow \Delta|A|^2 \rightarrow \Delta|A|^2 \times P(K^+\pi^-\pi^+ \rightarrow \text{hadrons})$$

What we learned with the first preliminary results from LHCb data?



- Seems *CP* violation in $B^+ \rightarrow K^+ \pi^- \pi^+$ decay is positive and the $B^+ \rightarrow K^+ K^+ K^-$ negative.
- The number of events involved in CP Violation is basic the same.
- Both have CP Violation in similar low $K^+ K^-$ and $\pi^- \pi^+$ mass kinematic regions.
- There is a non Dalitz symmetrical CP Violation distribution in both decays.
- **Are the sources of CP violation for these two channels, correlated by CPT constraint?**

Sumário



Sumário

1- não foi encontrada antimatéria no Universo.

2- Violação de CP, observada em pequena quantidade.

3- Força fraca, principal suspeita.

4- Busca de novos fenômenos através de aumento da energia e de alta estatística

5- Busca de violação de CP na desintegração de partículas em três corpos apresenta perspectivas interessantes

6- Novos resultados estão para aparecer.

Searches for new fermions and bosons

Petra Van Mulders

On behalf of the CMS and ATLAS collaborations

Physics In Collision 2012 – September, 12 – 15

We are not there yet!

Only the latest-greatest results presented, there is much more!

Searches are ongoing, we are starting to exclude some models

We are not there yet!

Only the latest-greatest results presented, there is much more!

Searches are ongoing, we are starting to exclude some models

But we are not done yet, theorists tend to reanimate their favorite models...