# FPCP 2012
# Summary Talk on Experiments

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# Before Summarizing, Some Context

Particle Physics – The Study of Matter, Energy, Space, and Time

What do we really want to know?

# Matter

- Why is the universe so dominantly matter; why is there so little antimatter around?
- Why is matter made of quarks and leptons, antiquarks and antileptons?
- Why are these constituents spin ½ particles?
- Why do quarks and leptons come in three generations? (and are there only three?)
- Why do the quark generations have such different masses?
- Why are neutrino masses so small; and why different by generation? Dirac or Majorana?
- Why do quarks come in three colors?

# Energy

- Why is so little of the energy density in the universe composed of the mass that I just listed?
- What is the dark matter we claim is the rest of the matter?
- Why are the force carriers spin 1; not spin 0 for example? Why gravitons spin 2?
- Why are the strong and EW forces flavor independent?
- Why aren't all interactions flavor diagonal?

# Space and Time

- Why are there three obvious dimensions? Are there more?
- Why is the universe expansion accelerating? Or, do we not understand gravity/space?

# 3x3 - Not the CKM or PNMS Matrices

Note the 3 threes in my list of questions.

In fact, a 3x3 matrix:

3 dimensions

3 generations

3 colors

Are all these trinities related?

Are any of them related?

# Ideas About the Keys to Answering Some of These Questions

- Structure of quarks and leptons and generations from substructructure?
- Higgs mechanism for EWS breaking – mass of W, Z – the same for quarks?
- Neutrino masses from a seesaw mechanism involving very massive right-handed partners?
- Matter/antimatter asymmetry – not the CKM matrix (inadequate by 8-10 orders of magnitude)? Seesaw mechanism in the neutrino sector?

Not all these ideas are directly testable. Those that are, we are working hard to test. We are doing it by going to higher energies at the LHC and by making more and more precise measurements in the flavor sector. The latter is the focus of our FPCP conferences, of course.

# The Drunk and the Lamp Post

- I am reminded of the story of the drunk and the lamp post. Maybe this is only well known in the West, so indulge me if I tell it here.
- A drunk has lost his keys and is spending a long time looking for them under a lamp post. When asked why he is still looking there, he says that that is where there is enough light to see them!


"I'm searching for my keys."

# The Drunk and the Lamp Post

- We need to be careful not to make the same mistake by only looking where theorists have suggested we look.
- Certainly, look where we think we may find the answers since we have good models to test.
- However, in parallel, probe as deeply as we can where we don’t have such light to guide us.

# Vast Data Sets – An Opportunity

- We have vast new data sets to use in testing our ideas
- But, also, we need to check for the unexpected.
- An example we have seen here: when looking for B, D decays to $h^{-,+}$ $l^{+}$ $l^{-}$, looked for $h^{+,-}$ $l^{-,+}$ $l^{-,+}$; etc.
- No matter what our theorist friends tell us about where the answer lies, we have already seen the preferred space of minimal SUSY disappear.
- The space for the Higgs to hide is also closing down.

Sorry, I am supposed to say that we are closing in on the Higgs at 125. GeV/c2!

# Postcards from FPCP 2012

- This brings us to the beautiful results shown here at FPCP 2012 – very many of the results new since the last meeting, some shown here for the first time.
- As you look over the slides from the meeting, you will each have your favorites to use as souvenir post cards from this trip.
- Choosing post cards when you are on travel is a personal matter.
- I will show you some of my favorite postcards from FPCP 2012, those I have found especially pretty or revealing.
- I won’t repeat all the excellent explanations of the results. I could not do as well as you have already heard from all the presenters themselves.

# FPCP 2012 Picture Postcards

# FPCP 2012 Picture Postcards

Chinese Opera Masks

Bao Gong Memorial Park

# FPCP 2012 Physics Picture Postcards

There were lots of pretty plots with content.

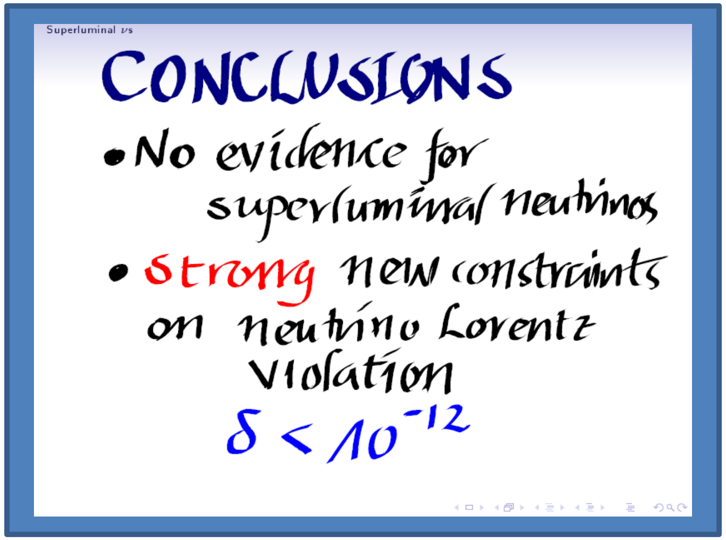
Let me organize my souvenir postcards around some themes:

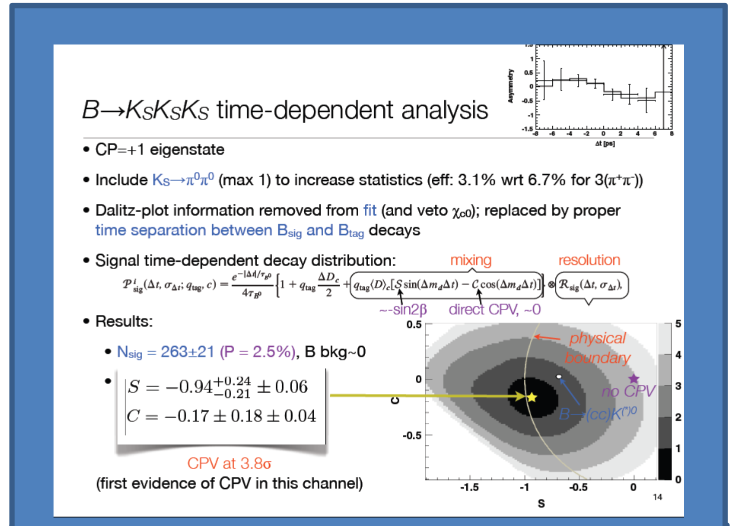
- Standard model confirmations
- Significant reductions in uncertainty
- New physics space ruled out
- New signals and structures
- Hints of new physics
- Tension with the standard model
- Looking beyond the lamp post
- Postcards of the future

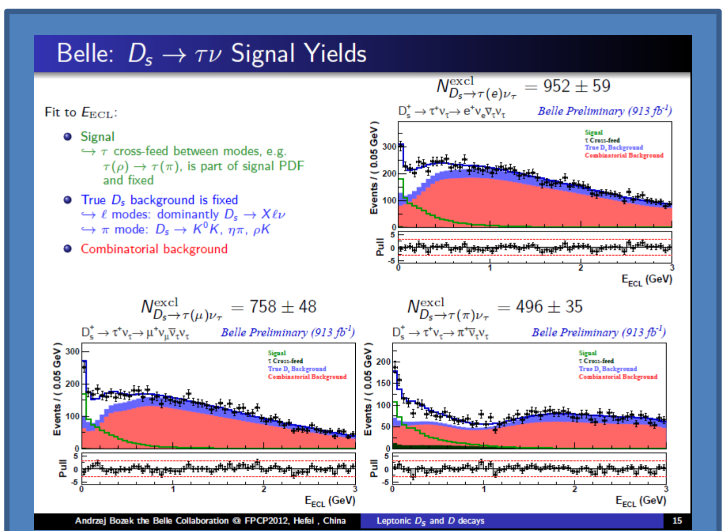
Remember, these are just souvenirs, not a guide book.

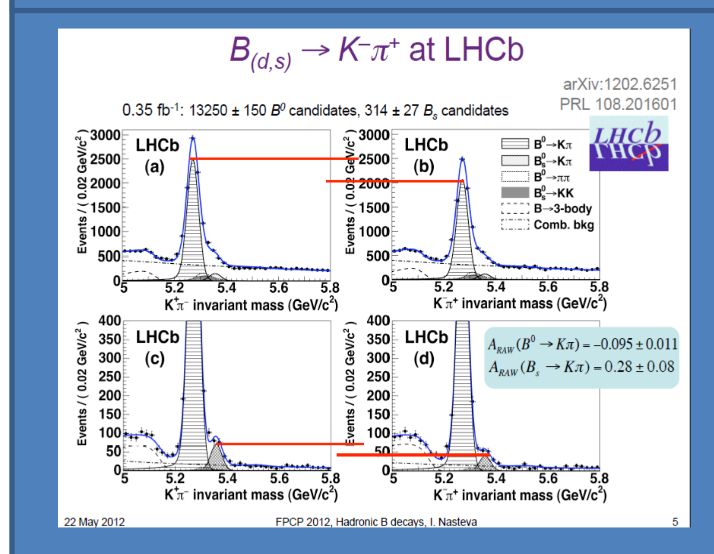
# FPCP 2012 Picture Postcards

## Standard Model Confirmations - I



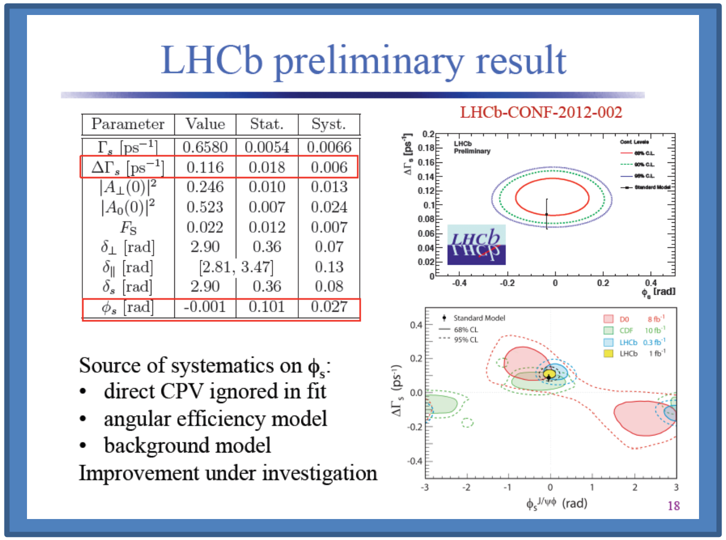




1st 3 sigma evidence of CPV in Bs

# FPCP 2012 Picture Postcards

## Standard Model Confirmations - II



LHCb preliminary result

LHCb-CONF-2012-002

| Parameter | Value | Stat. | Syst. |
|---|---|---|---|
| $\Gamma_s$ [ps$^{-1}$] | 0.6580 | 0.0054 | 0.0066 |
| $\Delta\Gamma_s$ [ps$^{-1}$] | 0.116 | 0.018 | 0.006 |
| $\lvert A_\perp(0)\rvert^2$ | 0.246 | 0.010 | 0.013 |
| $\lvert A_0(0)\rvert^2$ | 0.523 | 0.007 | 0.024 |
| $F_S$ | 0.022 | 0.012 | 0.007 |
| $\delta_\perp$ [rad] | 2.90 | 0.36 | 0.07 |
| $\delta_\parallel$ [rad] | [2.81, 3.47] | | 0.13 |
| $\delta_s$ [rad] | 2.90 | 0.36 | 0.08 |
| $\phi_s$ [rad] | -0.001 | 0.101 | 0.027 |

Source of systematics on $\phi_s$:

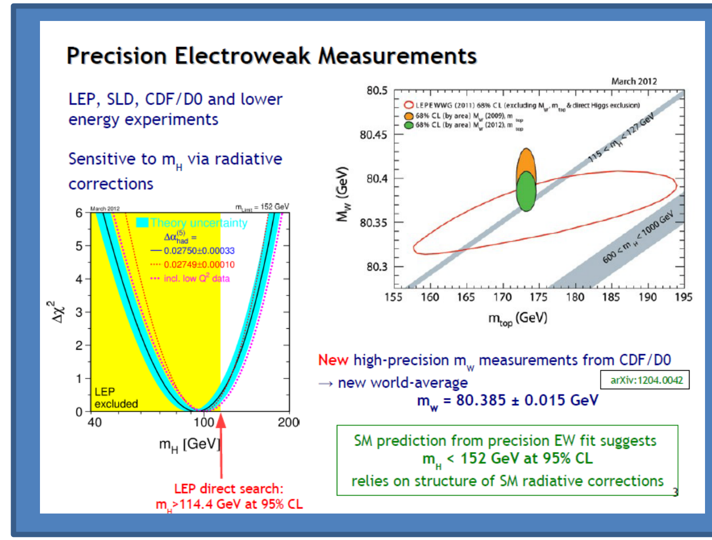
- direct CPV ignored in fit
- angular efficiency model
- background model

Improvement under investigation



Heavier Bs lives longer.

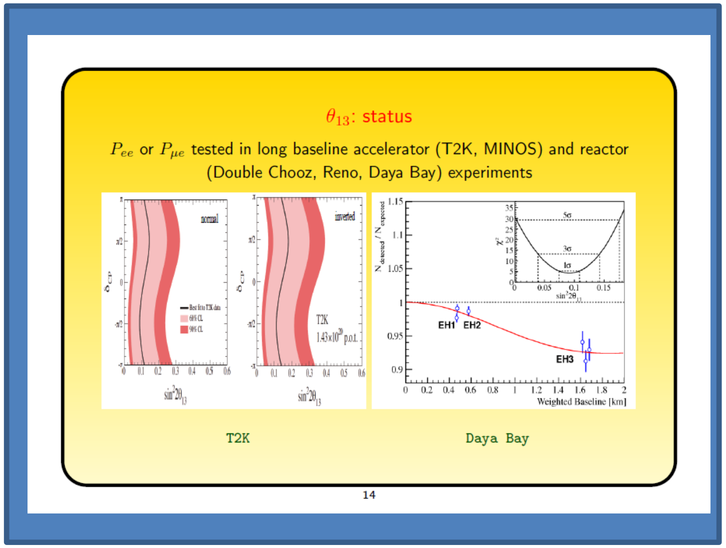
Higgs?

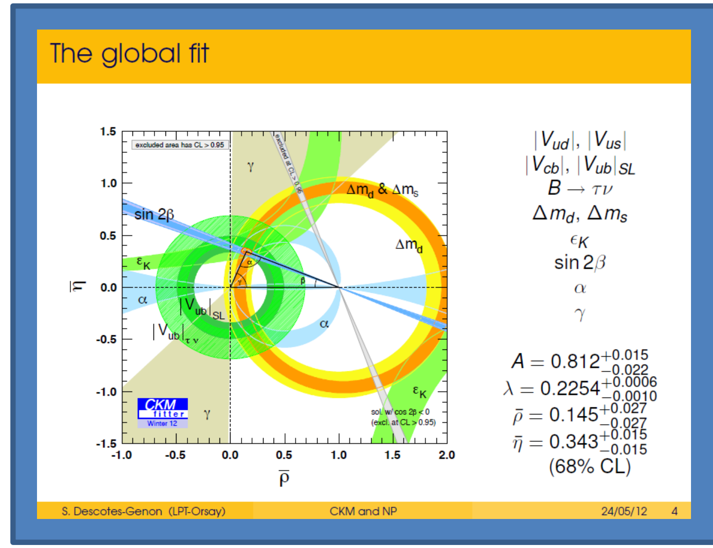


# FPCP 2012 Picture Postcards

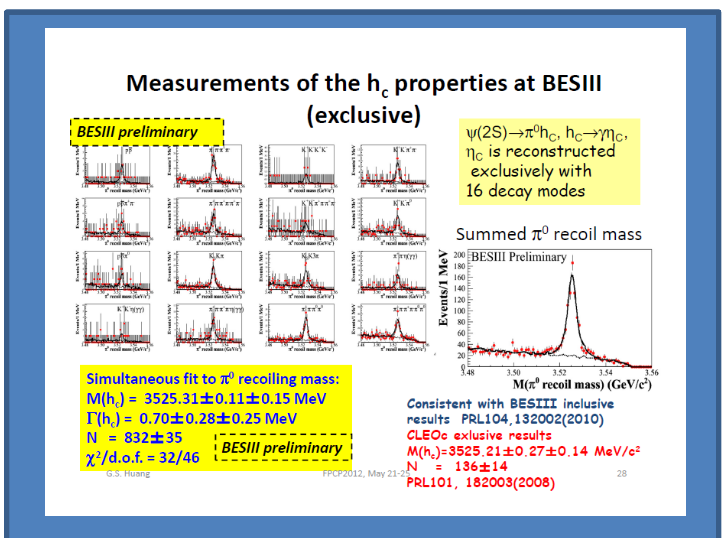
## Significant Reductions in Uncertainty - I

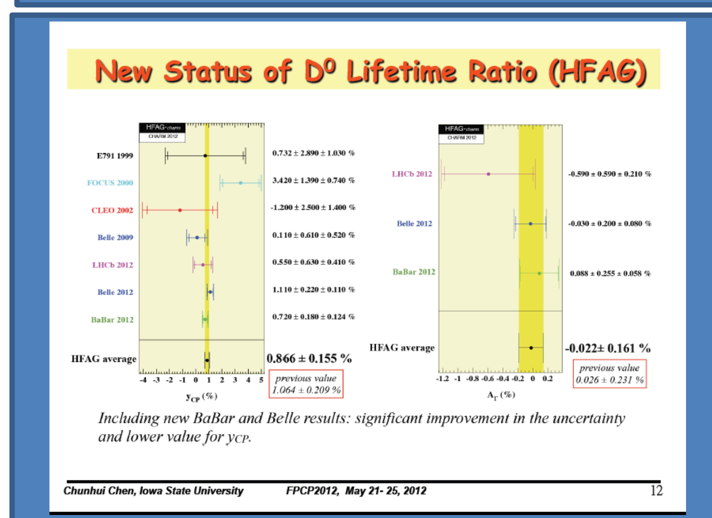
$\theta_{13}$




CKM



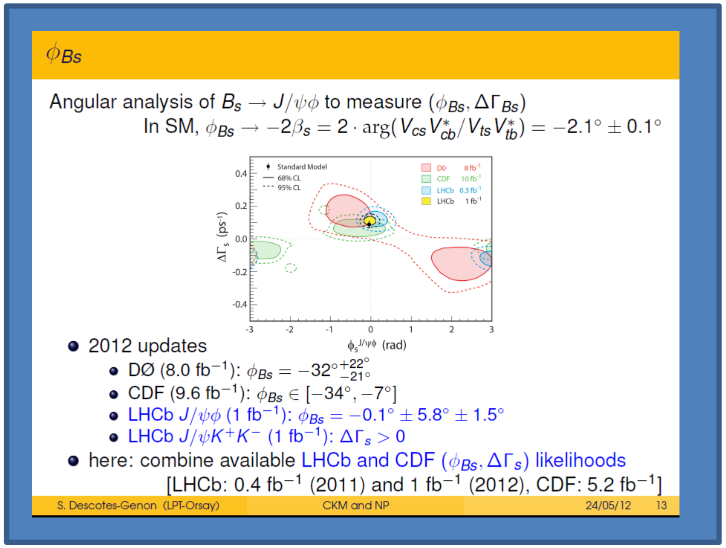



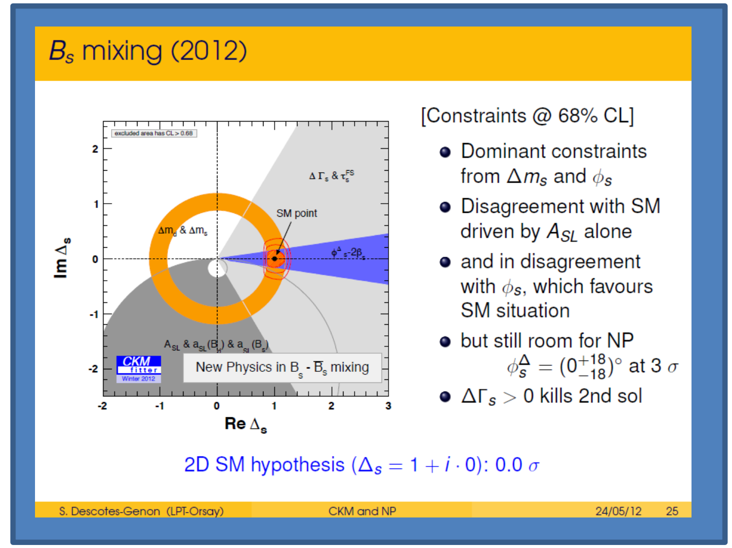

1st 3 sigma evidence of CPV in Bs

# FPCP 2012 Picture Postcards

## Significant Reductions in Uncertainty -II

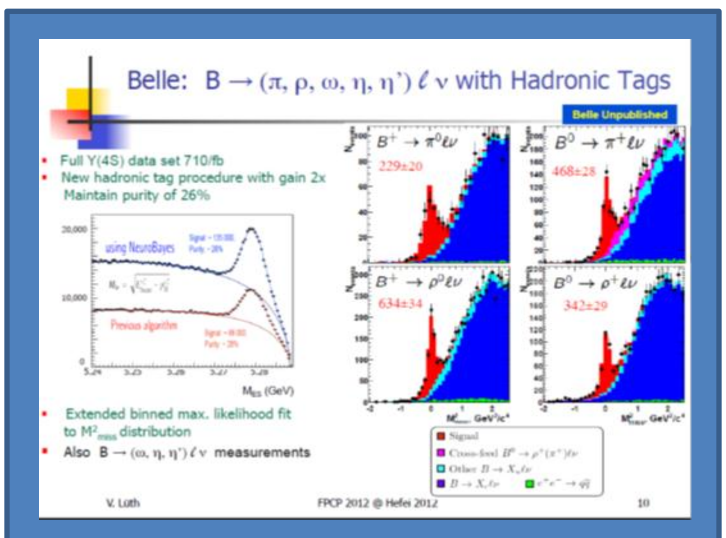
$\phi_{Bs}$

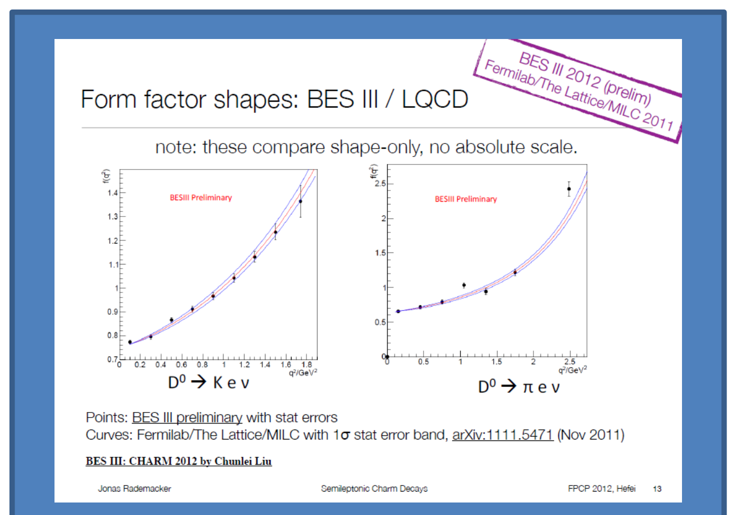



Bs Mixing

Incl/Ex SL B decays



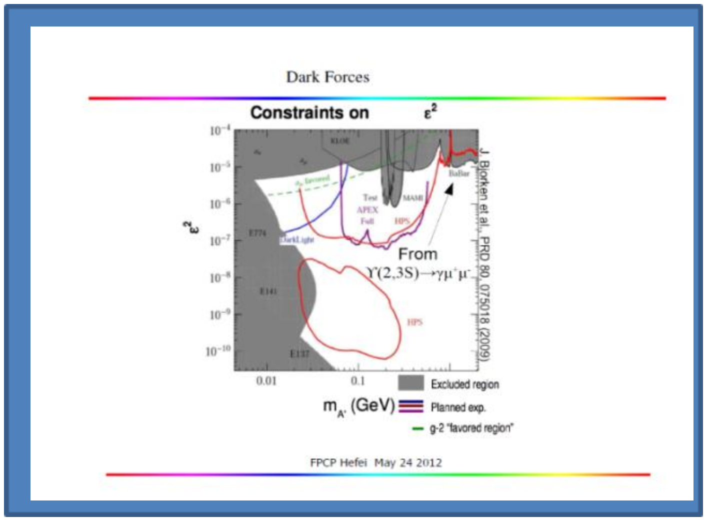



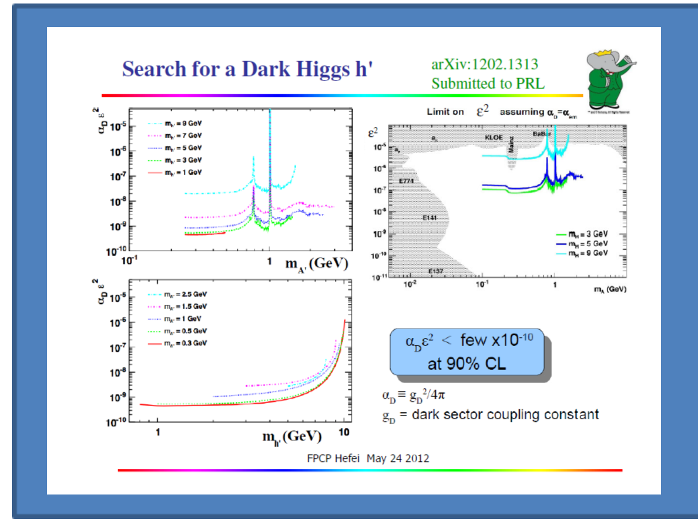

D SL FF

# FPCP 2012 Picture Postcards

## New Physics Space Ruled Out - I

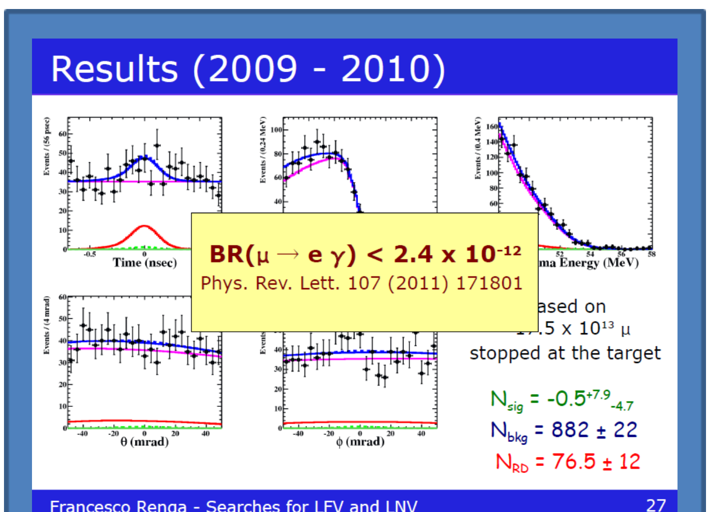
Dark Matter

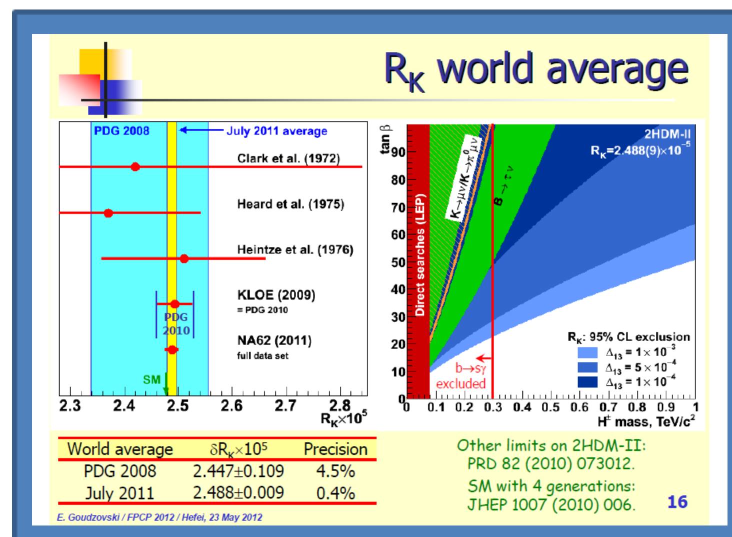



Dark Higgs

$\mu$ to e $\gamma$

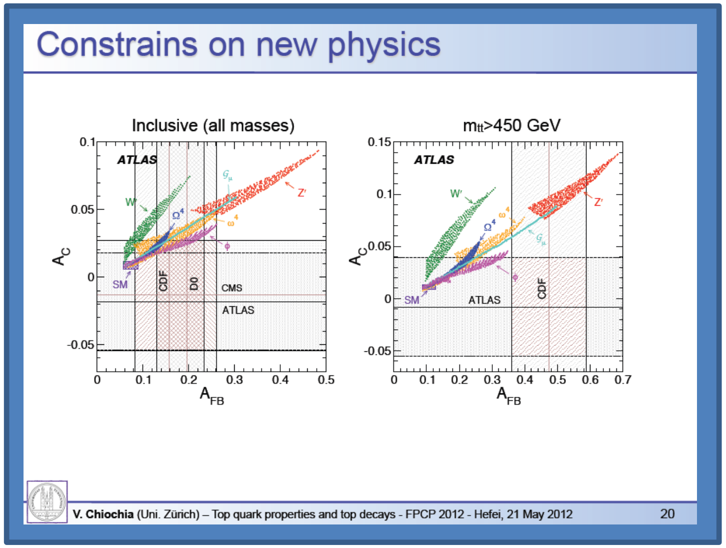


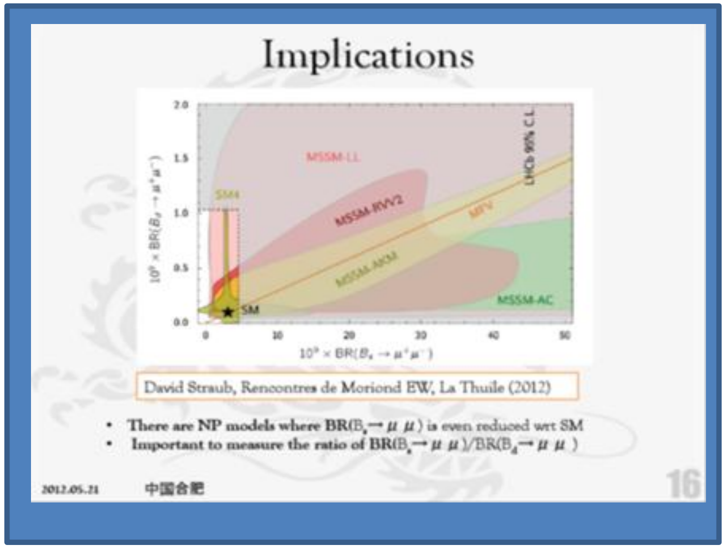



# FPCP 2012 Picture Postcards

## New Physics Space Ruled Out - II

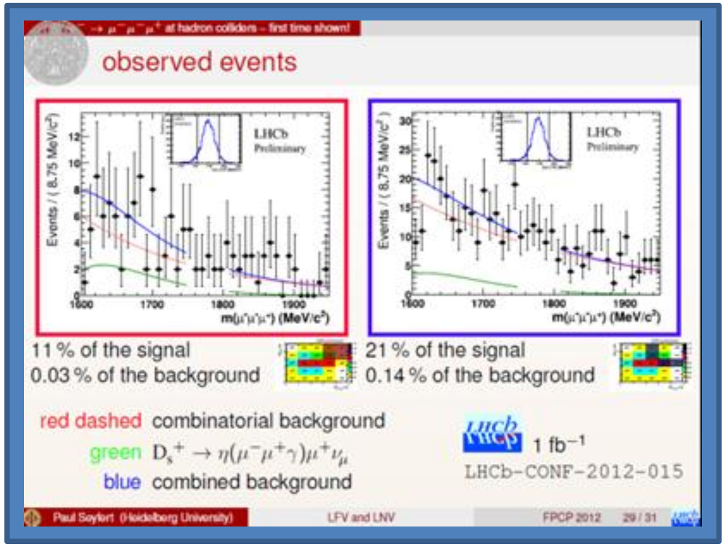
top quark



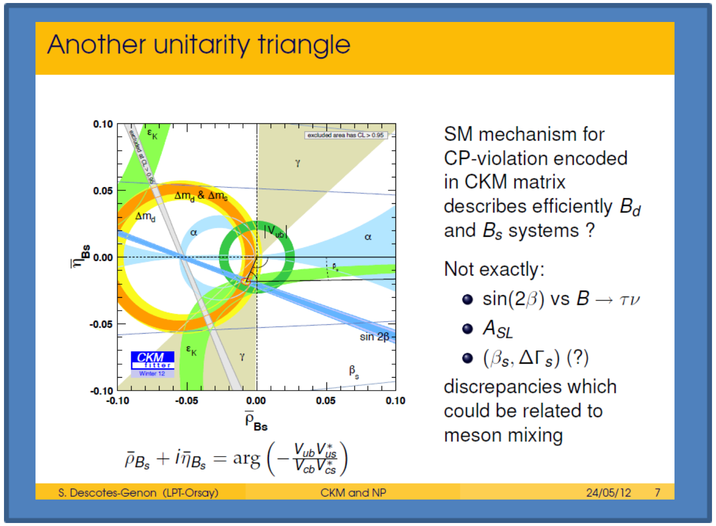

$B_s$ to $\mu\mu$

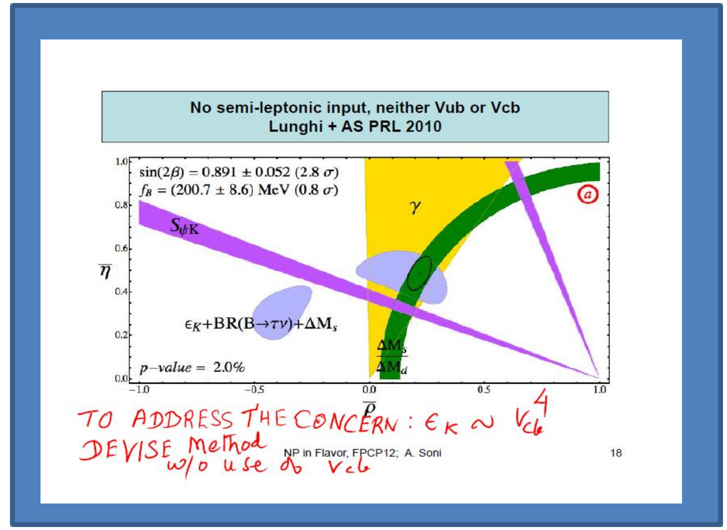
$\tau$ to 3 $\mu$



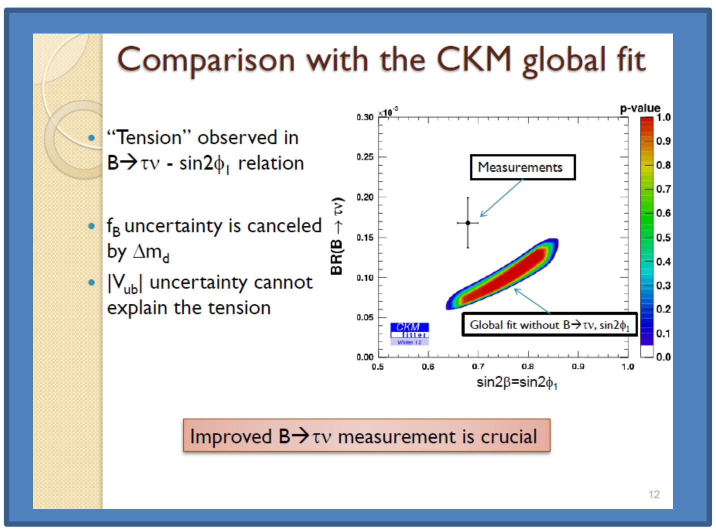
# FPCP 2012 Picture Postcards

## Tension with the Standard Model - I

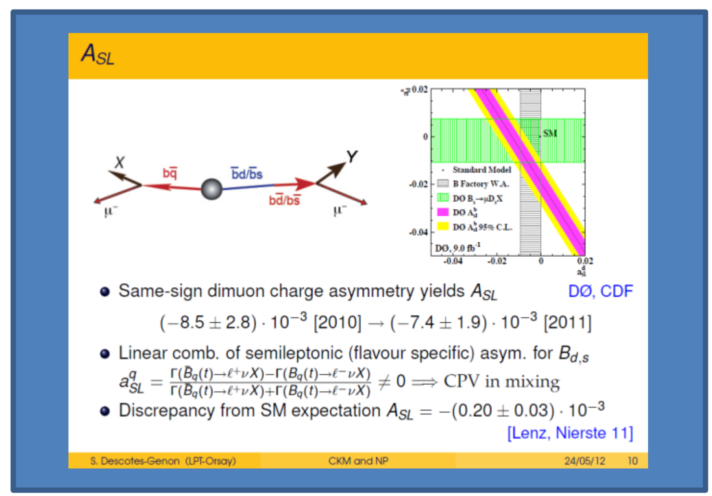



CKM w Selected Inputs




B to τ ν and sin(2β)

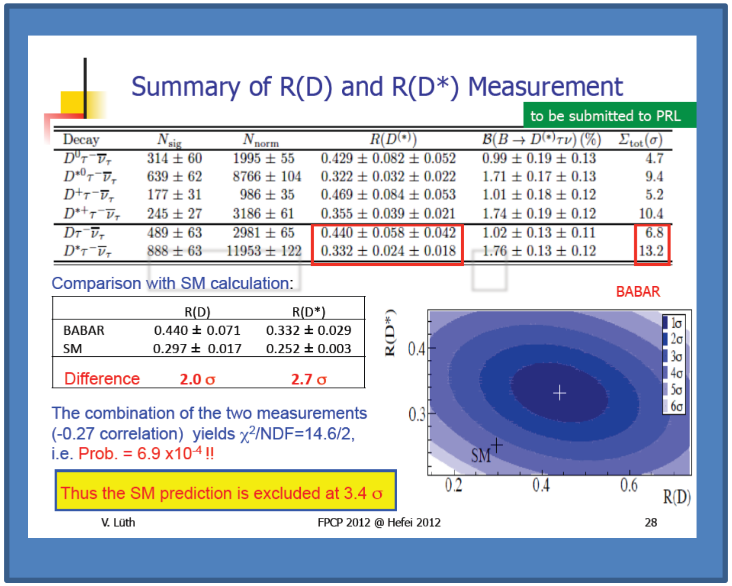



$A_{SL}$

Aμμ and $\phi_s$

# FPCP 2012 Picture Postcards

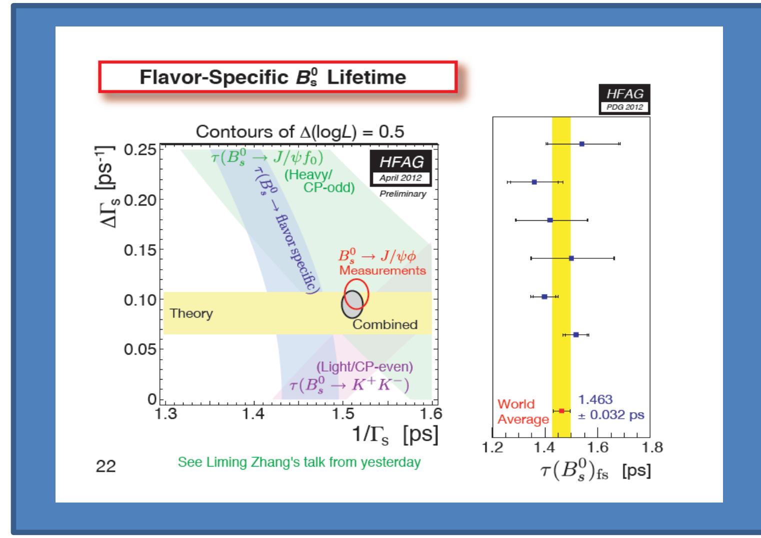
## Tension with the Standard Mode - II



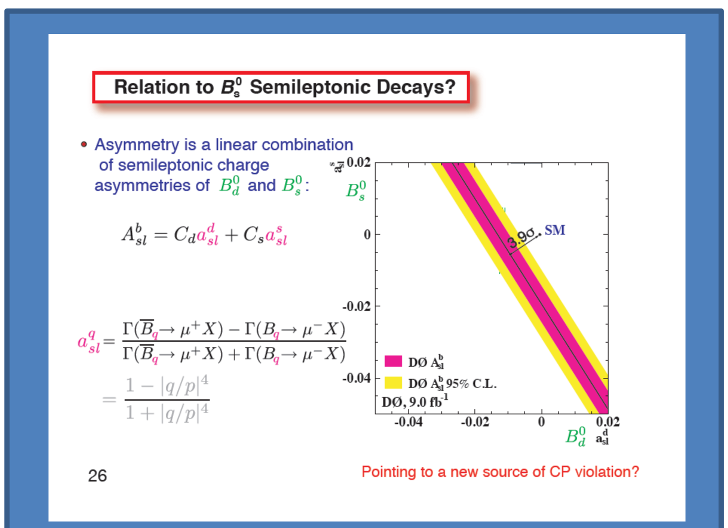

| Decay | $N_{sig}$ | $N_{norm}$ | $R(D^{(*)})$ | $\mathcal{B}(B \to D^{(*)}\tau\nu)$ (%) | $\Sigma_{tot}(\sigma)$ |
|---|---|---|---|---|---|
| $D^0\tau^-\overline{\nu}_\tau$ | 314 ± 60 | 1995 ± 55 | 0.429 ± 0.082 ± 0.052 | 0.99 ± 0.19 ± 0.13 | 4.7 |
| $D^{*0}\tau^-\overline{\nu}_\tau$ | 639 ± 62 | 8766 ± 104 | 0.322 ± 0.032 ± 0.022 | 1.71 ± 0.17 ± 0.13 | 9.4 |
| $D^+\tau^-\overline{\nu}_\tau$ | 177 ± 31 | 986 ± 35 | 0.469 ± 0.084 ± 0.053 | 1.01 ± 0.18 ± 0.12 | 5.2 |
| $D^{*+}\tau^-\overline{\nu}_\tau$ | 245 ± 27 | 3186 ± 61 | 0.355 ± 0.039 ± 0.021 | 1.74 ± 0.19 ± 0.12 | 10.4 |
| $D\tau^-\overline{\nu}_\tau$ | 489 ± 63 | 2981 ± 65 | 0.440 ± 0.058 ± 0.042 | 1.02 ± 0.13 ± 0.11 | 6.8 |
| $D^*\tau^-\overline{\nu}_\tau$ | 888 ± 63 | 11953 ± 122 | 0.332 ± 0.024 ± 0.018 | 1.76 ± 0.13 ± 0.12 | 13.2 |

| | R(D) | R(D*) |
|---|---|---|
| BABAR | 0.440 ± 0.071 | 0.332 ± 0.029 |
| SM | 0.297 ± 0.017 | 0.252 ± 0.003 |
| Difference | 2.0 σ | 2.7 σ |

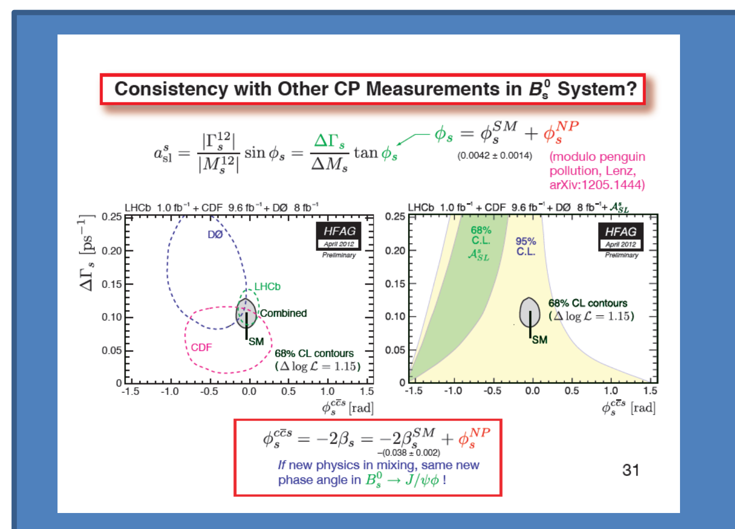
B to Dτν
B to D*τν
3.4 σ




Flavor Specific Bs Lifetime

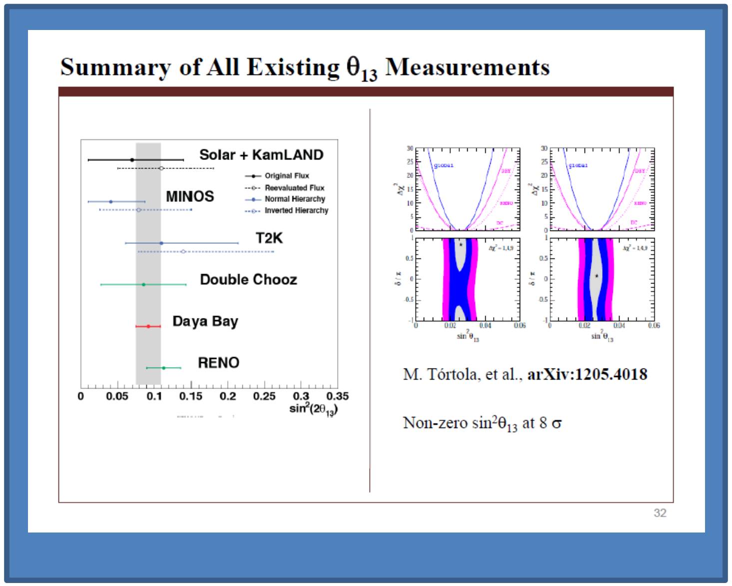


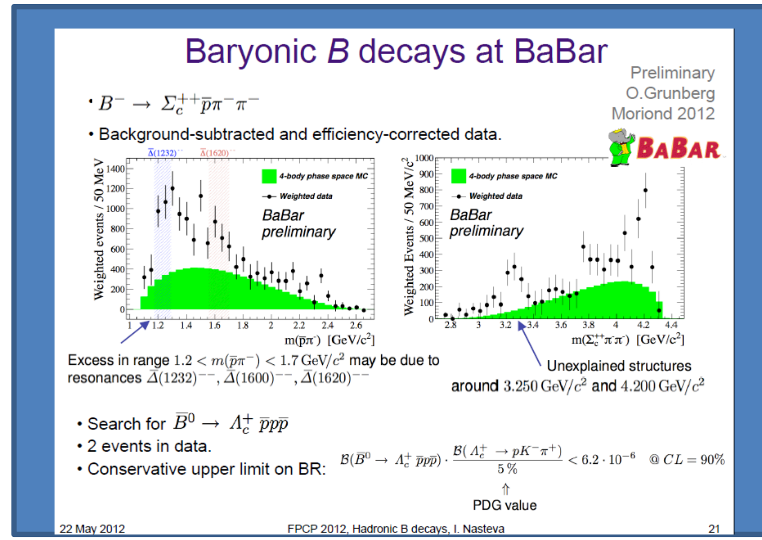

$B_s$ $a_{SL}$

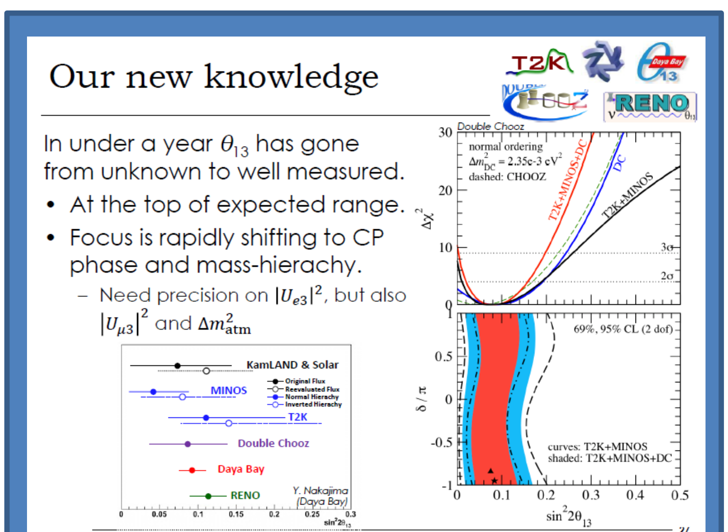


# FPCP 2012 Picture Postcards

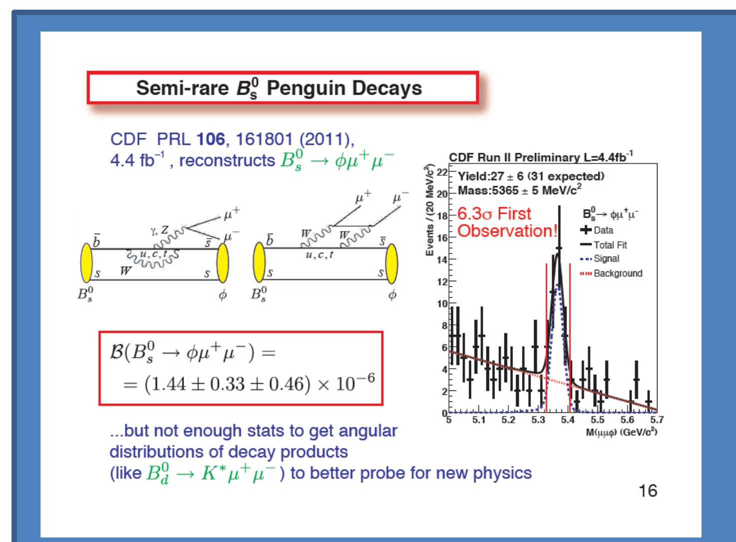
## New Signals and Structures - I



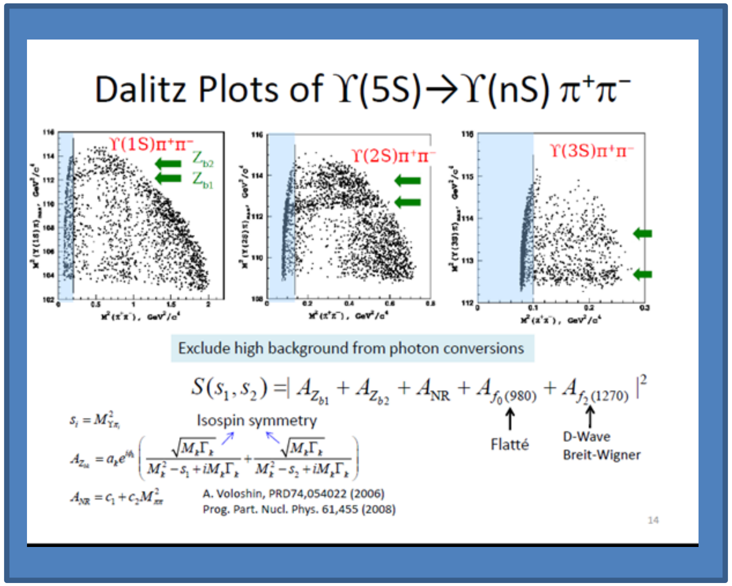




Bs to φμμ

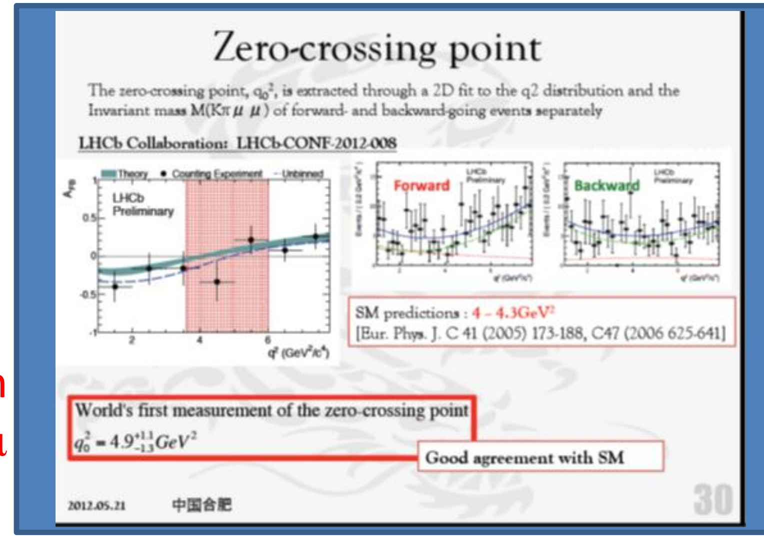


# FPCP 2012 Picture Postcards

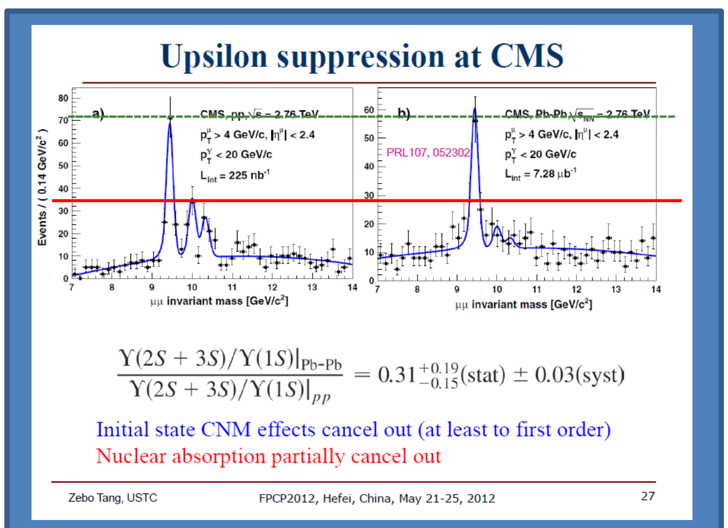
## New Signals and Structures - II



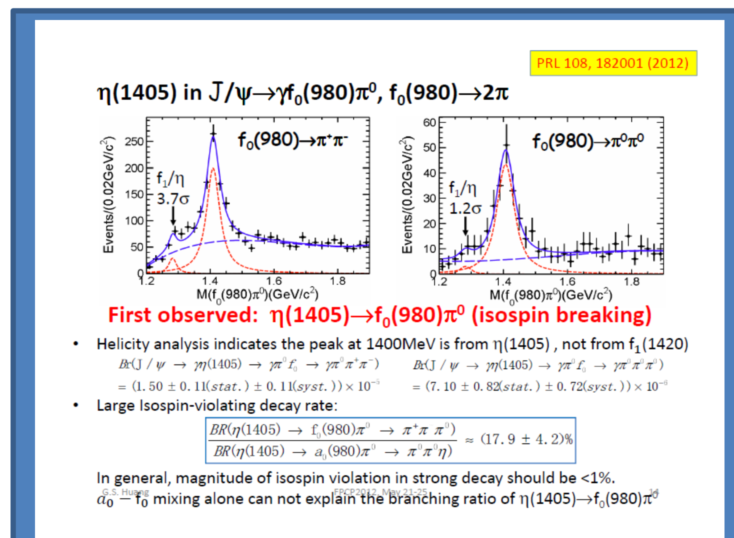

$Z_{1,2}$ to $h_b(1,2)\ \pi$




$A_{FB}$ in B to K* μμ

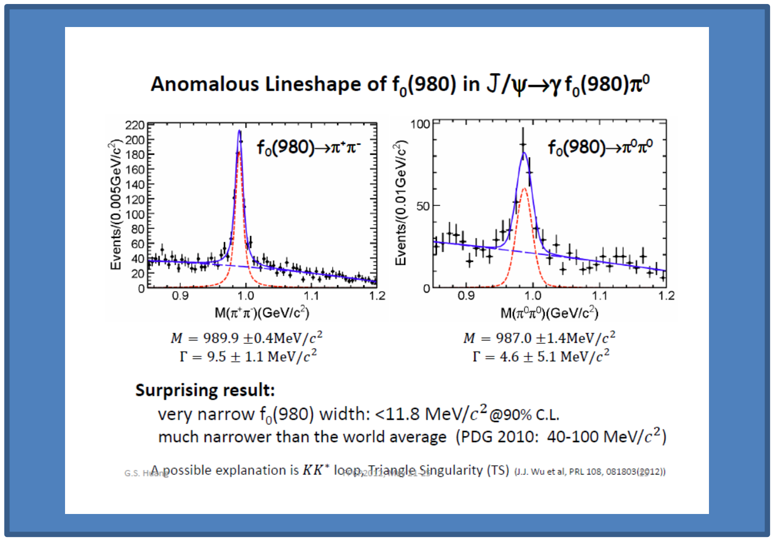


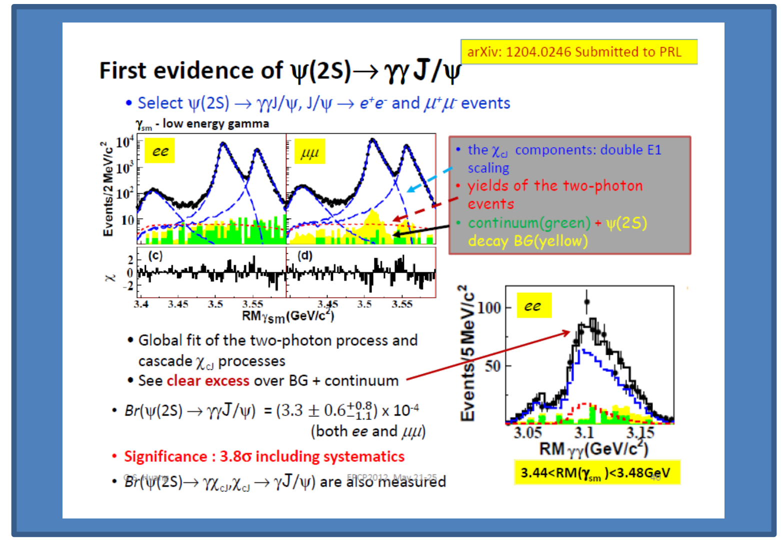

ϒ suppression in HI col

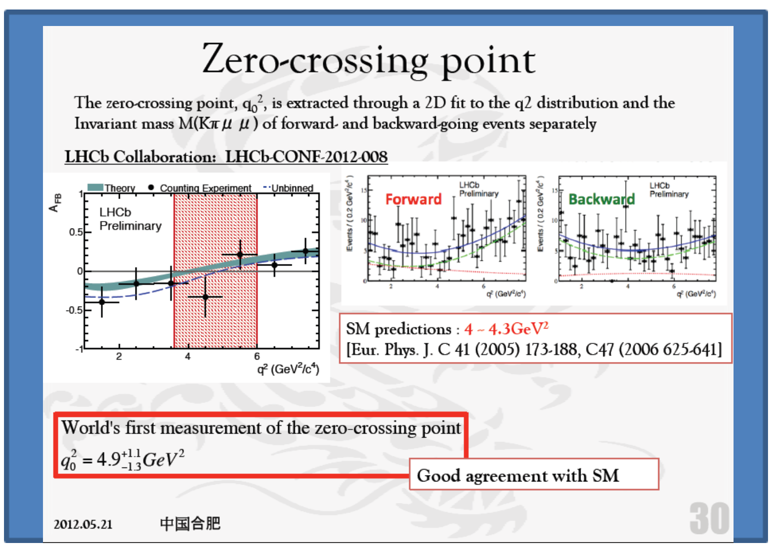


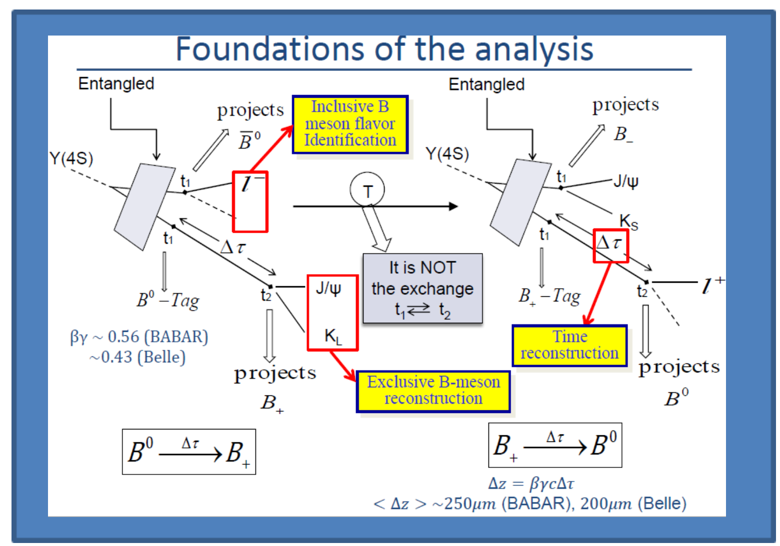
# FPCP 2012 Picture Postcards

## New Signals and Structures - III

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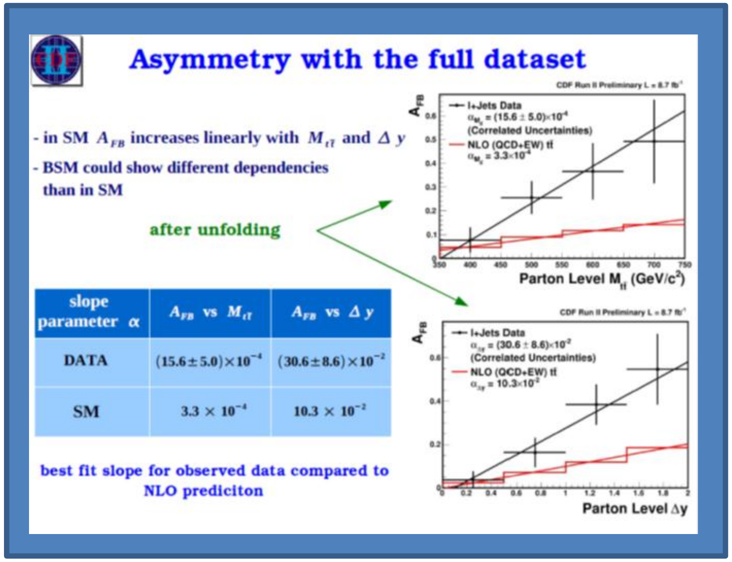
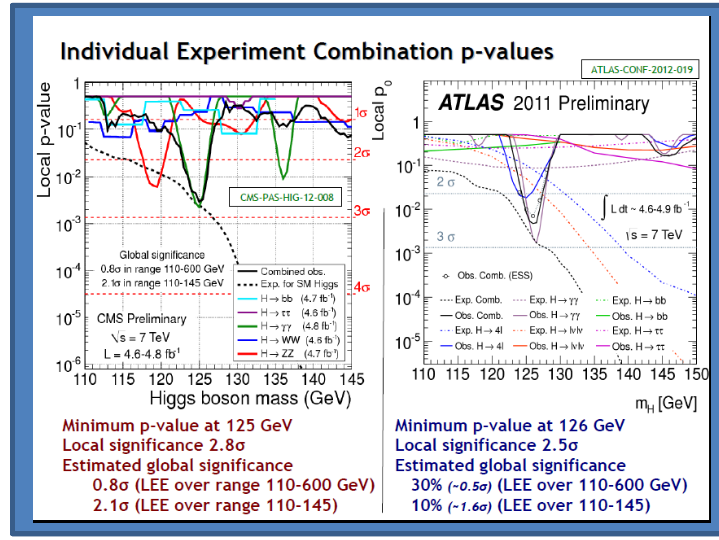
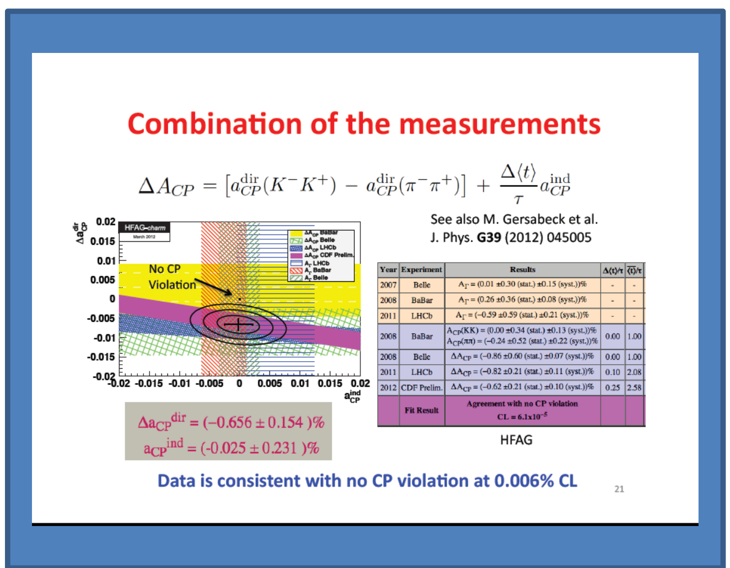
# FPCP 2012 Picture Postcards

## Hints of New Physics



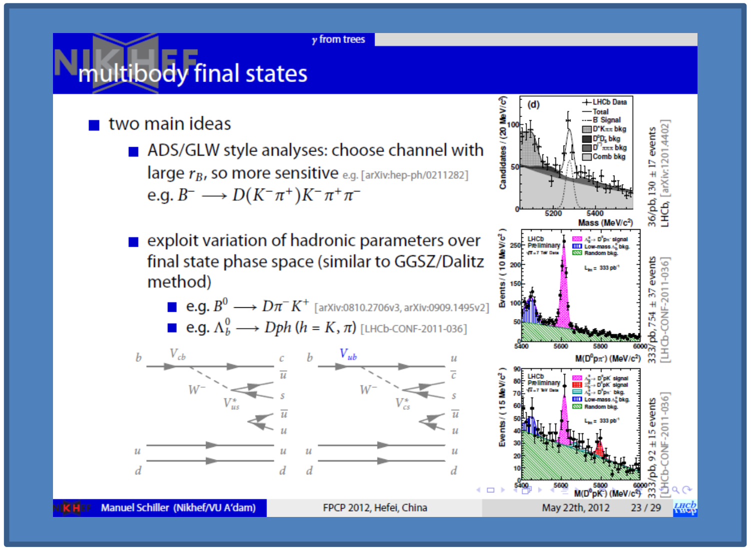



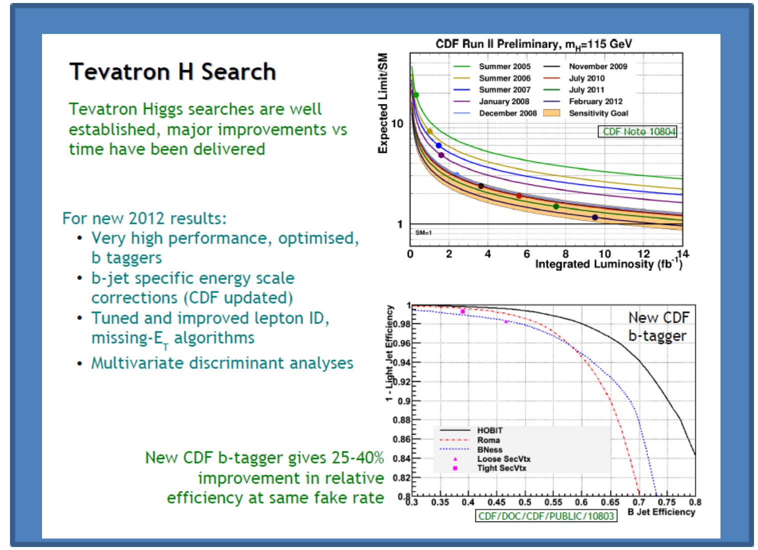

125/126 GeV Higgs?



# FPCP 2012 Picture Postcards

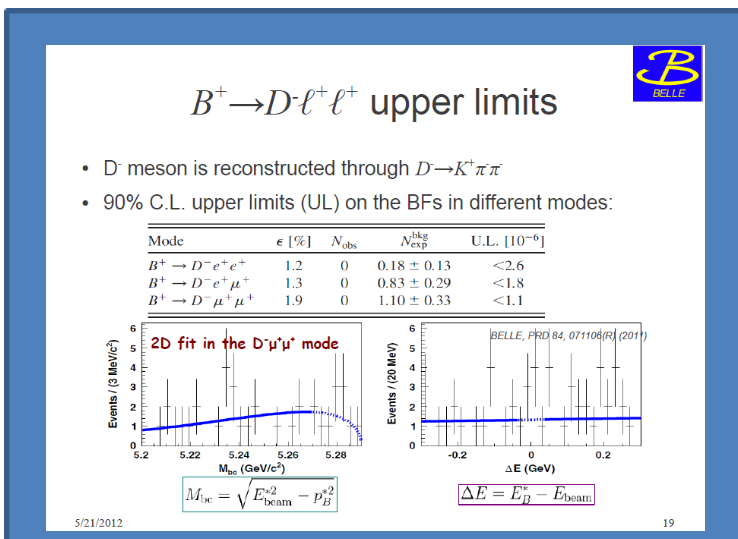
## New Techniques &Looking Beyond the Lamp Post




New Methods

Analysis Improvements




The Unexpected

# FPCP 2012 Picture Postcards

## Postcards of the Future

# The Previous Slide

I was going to reserve the last slide for postcard images of the morning's new facilities.

However, I decided to focus on the physics we expect most.

The fact is, I am less certain what to expect than for many years.

# FPCP 2012 Experiment Summary

As we flipped through the picture post cards, we have seen a wonderfully rich panoply of new results.

There were over 40 experiment talks!

- Standard model confirmations
- Significant reductions in uncertainty
- New physics space ruled out
- New signals and structures
- Hints of new physics
- Tension with the standard model
- Looking beyond the lamp post

# FPCP 2012 Experiment Summary

- Perhaps fewer outstanding experimental issues, less tension with the Standard Model this year
- Growing disquiet over not seeing directions for the answers to the questions listed at the start about

  Matter, Energy, Space, and Time
- No certainty about the direction of the needed New Physics
- Bright new idea could be the lamp post to light our way
- Hard to predict what the post cards will look like next year at Buzios
- Data sets collected and anticipated are reason for hope!

# 谢谢

Thank you.

Thanks, too, to all the presenters and especially to the organizers of this very enjoyable and interesting meeting.

May you all have a safe journey home, whether near or far…