Hyperon Decays with Missing Energy @ BESIII

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- New Physics with Rare Decays
- Flavor-Changing Neutral Currents
- BEPCII and BESIII Experiments
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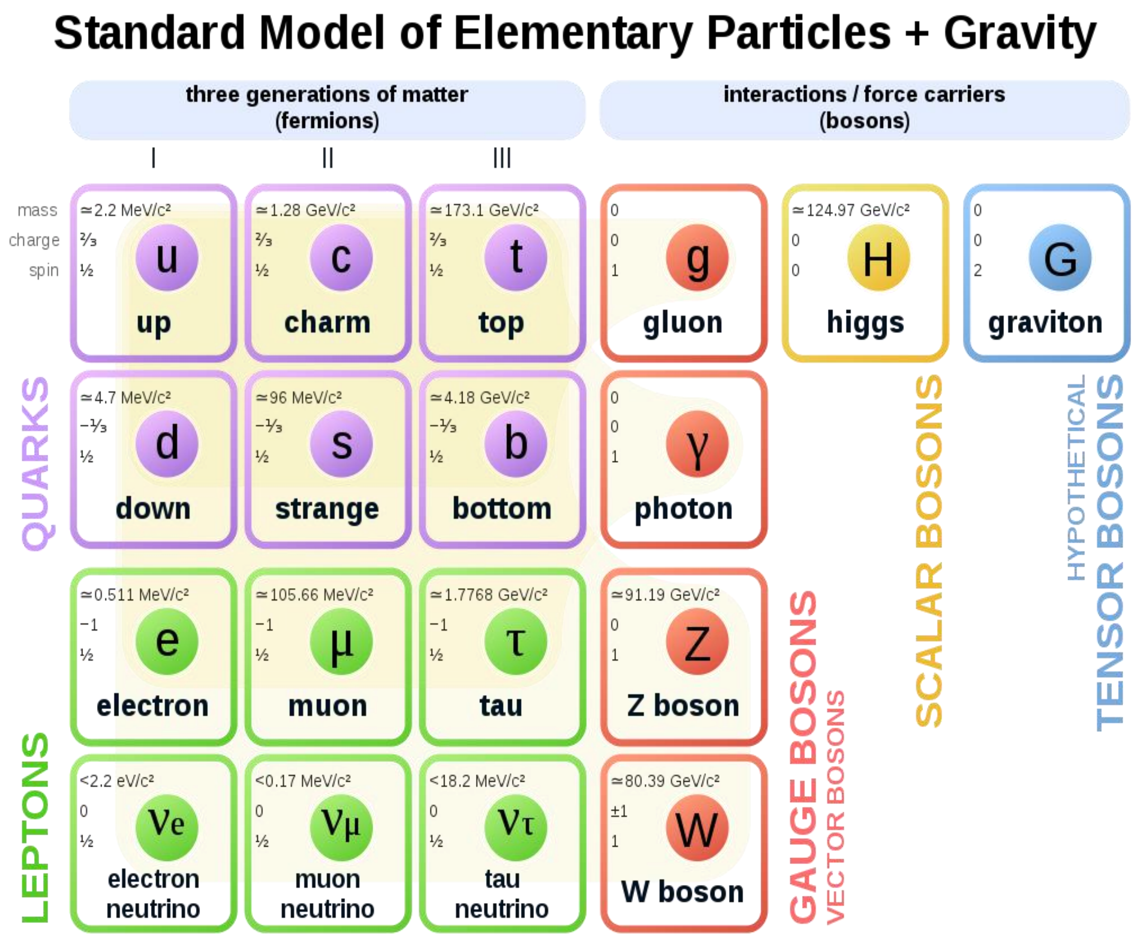
Particle Physics & Beyond the Standard Model

- The Standard Model (SM) of particle physics successfully describes the observed matter constituents and their interactions.
- After the discovery of the HIggs boson, many compelling reasons to believe that the SM is an effective theory valid up to some energy scales above which the new physics phenomena is expected to be observed. The Problems with Standard Model (SM) are:

- ☐ Strong CP problem
- ☐ Neutrino Oscillations
- ☐ Matter-antimatter asymmetry
- ☐ Nature of Dark Matter and Dark Energy
- ☐ Hierarchy Problem: SUSY? Extra Dimension?

- Hence, need to search for Physics Beyond the Standard Model (BSM).



Rare Decays and Hints for New Physics

- The bulk of hadron decays proceed via tree diagrams
  Rare decays involve loop diagrams also z-type penguin.
- New Physics (i.e. beyond the SM) involves new particles, which could also participate in such loops via virtual quantum fluctuations → noticeable effects on decays, in particular since they are suppressed in the SM.

$K \rightarrow \pi\pi\nu\bar{\nu}$

$b \rightarrow s\,\mu^{+}\mu^{-}$

$b \rightarrow c\,\tau\nu$

$h \rightarrow \tau\mu$

  - Additional neutral gauge bosons
  - Leptoquarks
  - Extended Higgs sector

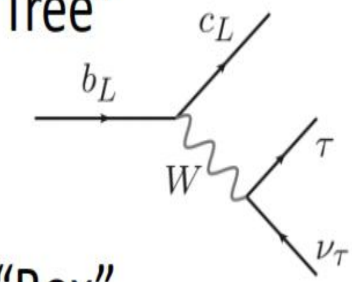
- Some rare and forbidden hyperon decyas are:

$B_i \rightarrow B_f l^+ l^-$ dilepton decays

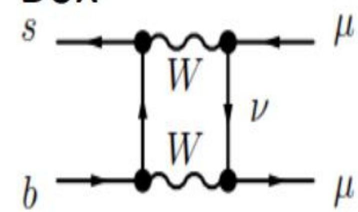
$B_i \rightarrow B_f \nu\bar{\nu}$ decays via a Z-type penguin

Lepton-number-violating decays with $\Delta L = 2$

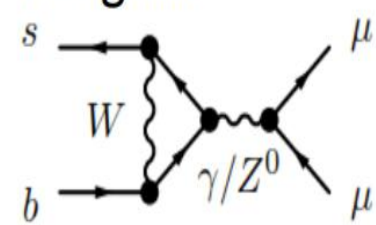
"Tree"



"Box"



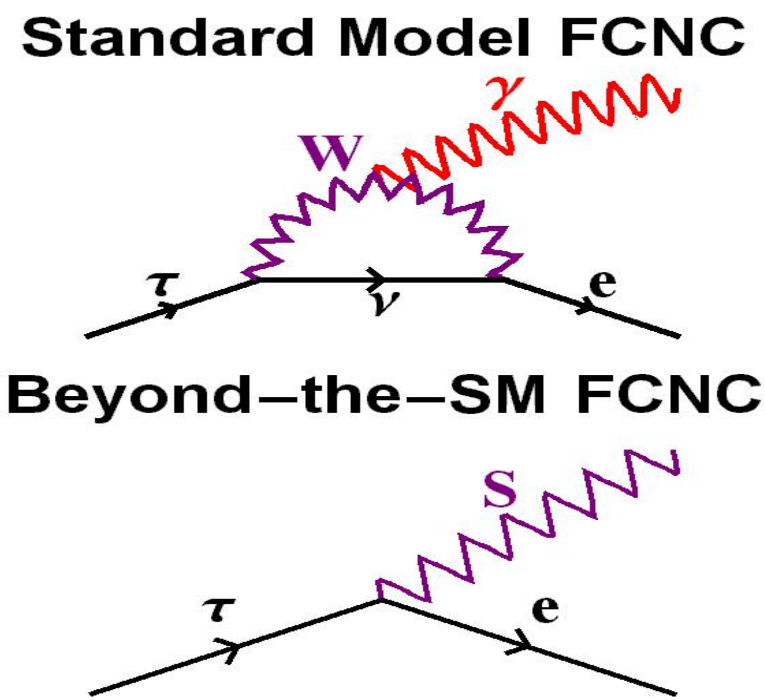
"Penguin"

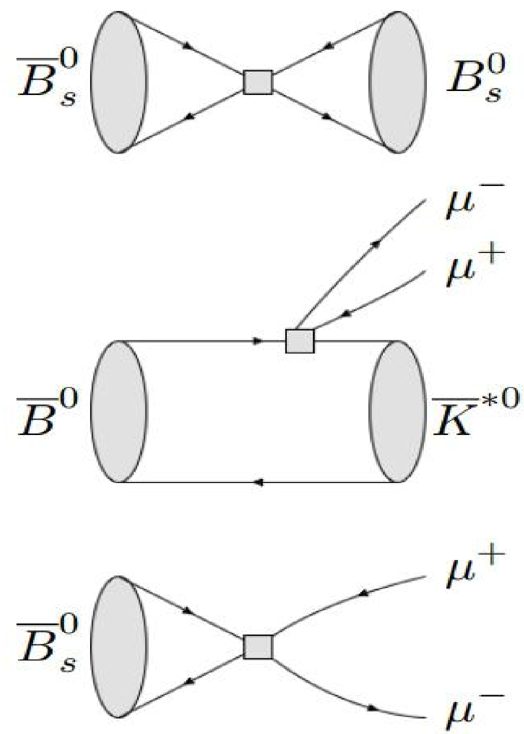


Currently no clear signs of new physics from direct searches at the colliders.

Flavor-Changing Neutral Currents (FCNCs)

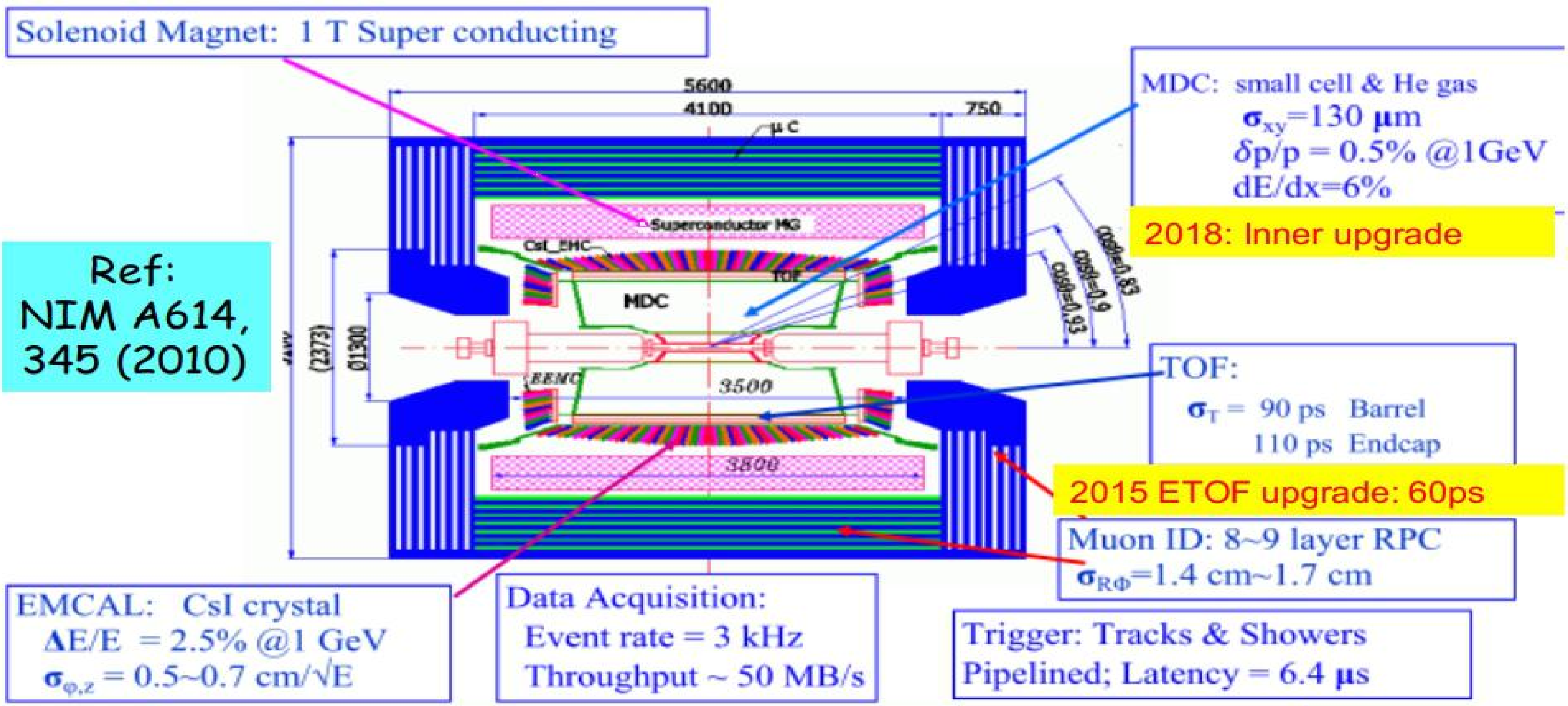
- FCNCs are the processes in which the internal quark structure changes but no alteration in charge.
- Absent in the SM at tree-level as all flavor violation comes from the CKM matrix in the charged W-quark.
- Involved small off-diagonal CKM elements.
- Low-energy experiments provide us with a large amount of valuable information about the dynamics of FCNCs.





BEPCII and BESIII Experiment

- BEPCII is the only collider currently running at tau-charm energy.
- First collision in 2008, physics run started in 2009
- BEPCII reached peak luminosity of $1\times10^{33}cm^{-2}\sec^{-1}$ @1.89GeV in April 2016.
- **Finished J/ψ data taking (10 Billion) in February 2019**.



Clean environment and high luminosity at BESIII are helpful for indirect probe of new physics

Hyperon Production at BESIII

Decay Modes	Branching Fraction(X10^-3)	N_B(X10^6)
J/ψ -> $\Lambda\bar{\Lambda}$	1.89 ± 0.08	18.9 ± 0.8
J/ψ -> $\Sigma^0\bar{\Sigma}^0$	1.172 ± 0.031	11.7 ± 0.3
J/ψ -> $\Sigma^+\bar{\Sigma}^-$	1.50 ± 0.24	15.0 ± 2.4
J/ψ -> $\Sigma(1385)^-\bar{\Sigma}^+$ (or c.c.)	0.31 ± 0.05	3.1 ± 0.5
J/ψ -> $\Sigma(1385)^-\bar{\Sigma}(1385)^+$ (or c.c.)	1.16 ± 0.05	11.6 ± 0.5
J/ψ -> $\Xi^0\bar{\Xi}^0$	1.17 ± 0.04	11.7 ± 0.4
J/ψ -> $\Xi^-\bar{\Xi}^+$	0.97 ± 0.08	9.7 ± 0.8
J/ψ -> $\Xi(1530)^0\bar{\Xi}^0$	0.32 ± 0.14	3.2 ± 1.4
J/ψ -> $\Xi(1530)^-\bar{\Xi}^+$	0.59 ± 0.15	5.9 ± 1.5

Hyperon production from the J/ψ or ψ(2S) two body decays with 10^10 events on the J/ψ peak and 3 × 10^9 events on the ψ(2S) peak.
N_B is the number of expected hyperon pairs.

Hyperon Decays with Missing Energy @BESIII

- Hyperon decays study with missing energy in BESIII is very interesting topic and this will be my leading PhD research work.
- The rare and forbidden hyperon decays will play important role in search for new physics.
- Tag technique is best with known centre-of-mass energy.
- Two-body decays of the J/ψ will be important, specially for rare decays and decays with invisible final states.
- These decays modes are through Z-penguin like weak neutral currents.

Expected no. of hyperons produced ~10^6 - 10^8 with 10 billion J/ψ.
Sensitivity can be achieved 10^-5 - 10^-8.

Signal Processing and analysis

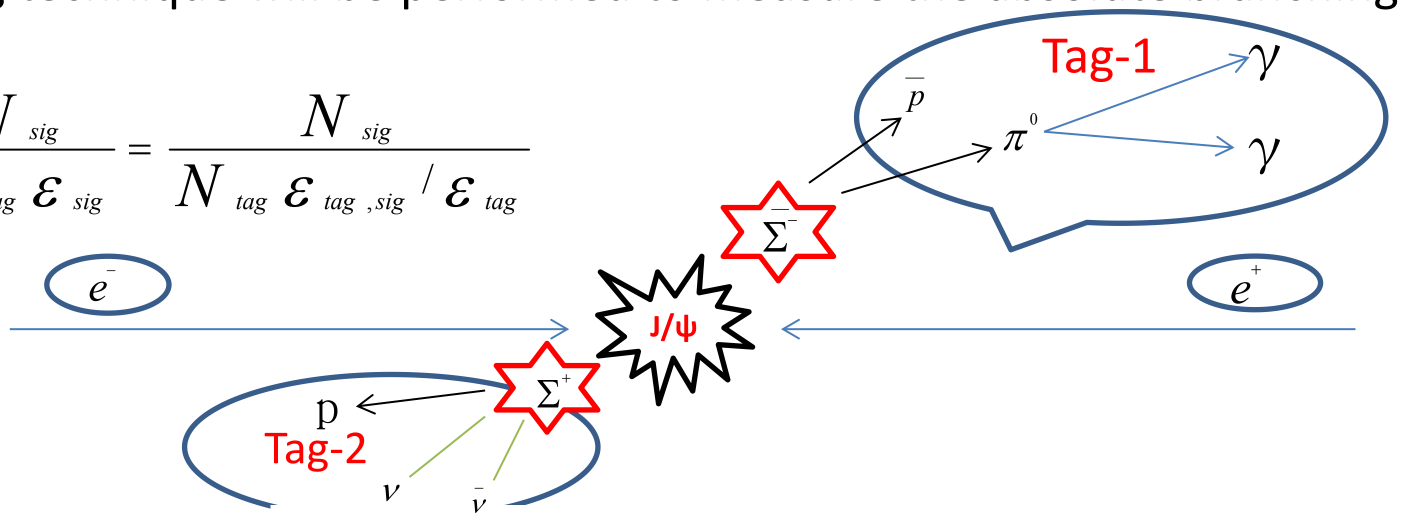
Signal Processes:

- $J/\psi \to \bar{\Sigma}^{-}\Sigma^{+}$ and $\Sigma^{+} \to p\nu\bar{\nu}$
- $J/\psi \to \Lambda\bar{\Lambda}$ and $\Lambda \to n\nu\bar{\nu}$
- $J/\psi \to \Xi^{0}\bar{\Xi}^{0}$ and $\Xi^{0} \to \Lambda\nu\bar{\nu}$
- $J/\psi \to \Xi(1530)^{0}\bar{\Xi}^{0}$ and $\Xi^{0} \to \Sigma^{0}\nu\bar{\nu}$

Decay Mode	Sensitivity B(90%C.L.) (X10^-6)
$\Lambda \to n\nu\bar{\nu}$	<0.3
$\Sigma^{+} \to p\nu\bar{\nu}$	<0.4
$\Xi^{0} \to \Lambda\nu\bar{\nu}$	<0.8
$\Xi^{0} \to \Sigma^{0}\nu\bar{\nu}$	<0.9

Analysis Strategy:

- Double tag technique will be performed to measure the absolute branching fractions.
- $B_{sig} = \frac{N_{sig}}{N_{tag}\,\varepsilon_{sig}} = \frac{N_{sig}}{N_{tag}\,\varepsilon_{tag,sig}/\varepsilon_{tag}}$



Summary

- The CKM mechanism of flavor violation has been confirmed with high precision.
- FCNCs can probe for the contribution to the NP in hyperon sector.
- FCNCs are supressed at tree level and must occur at higher order.
- Their supressed nature and clean environmental signature, make them excellent search channel for NP.
- Using the J/ψ data, official Inc MC samples and signal samples generated, the Hyperon decay modes can be tested.
- Looking for baryonic decay modes only.

Plans

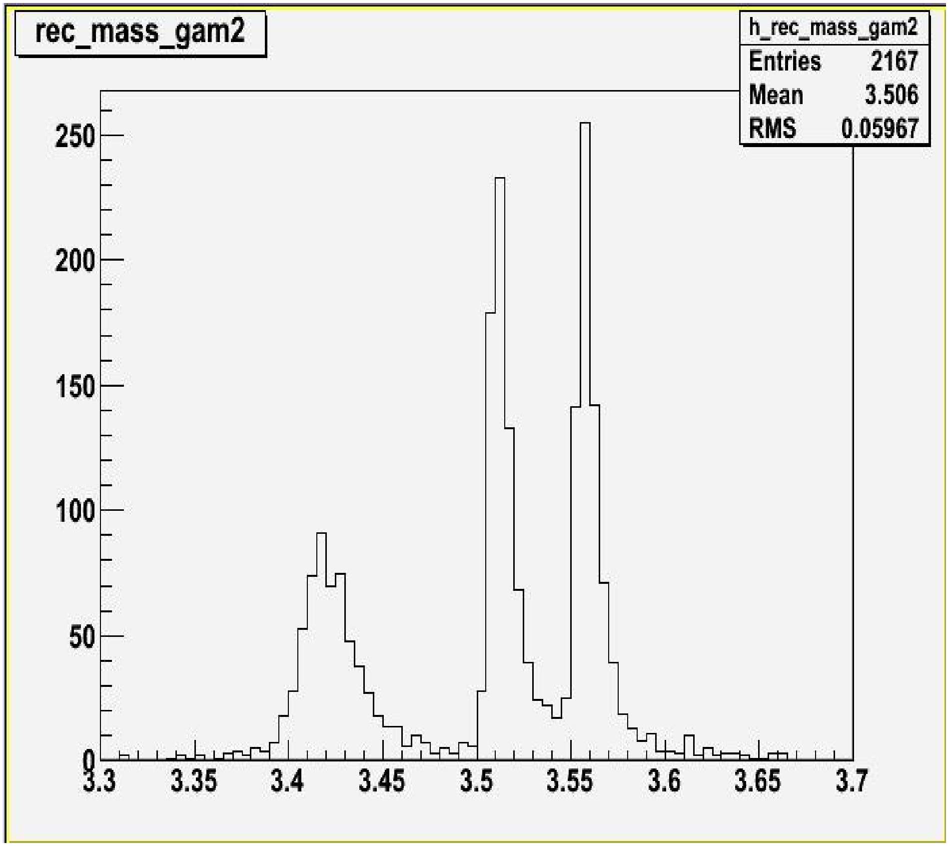
Task	Time Duration
Preparing Proposal, Literature Review and Opening Report Submission	April, 2019
Analysis Starts with Signal and Monte Carlo Studies	April- May, 2019
Statistical Studies and Result Interpretation	August, 2019
Writing Memo	August, 2019

Thank You

Analysis for Dark Photon Search

$$\Psi(2S) -> \gamma \chi_{CJ} \quad and \quad \chi_{CJ} -> \gamma l^+ l^-$$

- I have started analysis for the search of Dark Photon
- I have generated the signal and also done the Inclusive MC test.
- I have used some preliminary cuts for the selection algorithm.
- I have reconstructed the chicj_mass from the final state dilepton mass and the energetic gamma.
- This plot shows the reconstructed mass and the three peaks show the three resonances of chicj.
- There is already well knows analysis for $\chi_{CJ} \rightarrow e^+ e^- J/\psi$
- So, my analysis was targetting for the non-resonant process for searching dark photon.



Reconstructed Mass of Chicj_mass from final dileptons and Energetic Gamma