Study of potentially dangerous events during heavy ion collisions at the LHC

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Commissioned by L. Maiani as a follow-up of the review set up by J. Marberger before the commissioning of RHIC :

"Review of Speculative 'Disaster Scenarios' at RHIC", R.L.Jaffe, W.Busza, J.Sandweiss and F.Wilczek   Sept 1999

Heavy Ion collider : Produce large volume over which high energy densities and numbers of quarks can be achieved

- **Black hole (or gravitational singularity) production**
- **New vacuum state**
- **Formation of a stable strangelet that accretes ordinary matter**

Marberger report : catastrophic scenarios "…are firmly excluded by existing empirical evidence, compelling theoretical arguments, or both."

This study :

- Black hole (and monopole) production { $M_{Planck}^{4+d} \geq 1 TeV$

(•New vacuum state)

- Formation of a stable strangelet

….Implications for LHC in light of new development, both in theoretical studies and experimental results :

➡ **Stability :** New stability study excludes unbroken range of stable negative strangelets from A=6 to A=◎

➡ **Production :** Estimates in the light of recent experimental results

Black Holes

$$ds^2 = dt^2\left(1-2V(r)\right) - \frac{dr^2}{\left(1-2V(r)\right)} - r^2 d\Omega$$

In 4D $\quad V(r) = \frac{GM}{r} \quad \Rightarrow \quad R_{Schwarzchild} = 2GM = 10^{-33}\left(\frac{M}{M_P}\right)$

LHC energy deposited in $\left(1\text{TeV}\right)^{-1} \rightarrow 10^{-17}\,cm$

Production $\Rightarrow$ $\left(\frac{M}{M_P}\right) > 10^{16} \equiv 10^{32}$ nucleons at 1 TeV

No LHC production

Black Holes

$$ds^2 = dt^2\left(1-2V(r)\right) - \frac{dr^2}{\left(1-2V(r)\right)} - r^2 d\Omega$$

In (4+d)D

$$V(r) = \frac{KM}{M_*^{2+d}}\frac{1}{r^{1+d}}, \quad r < R$$

$$= \frac{KM}{M_*^{2+d}}\frac{1}{R^d}\frac{1}{r} \equiv \frac{GM}{r}, \quad r > R$$

Extreme $M_* = 1TeV \quad R \leq 0.7mm, \quad d \geq 2$

$$R_{Schwarzschild} = TeV^{-1}\left(\frac{M}{M_*}\right)^{1/(1+d)}$$

⇨ Copious production at LHC

But macroscopic BH will decay :

Decay $\propto$ Area

$$\Gamma_{\text{Decay}} = T_{BH} . R_s^{2+d}$$

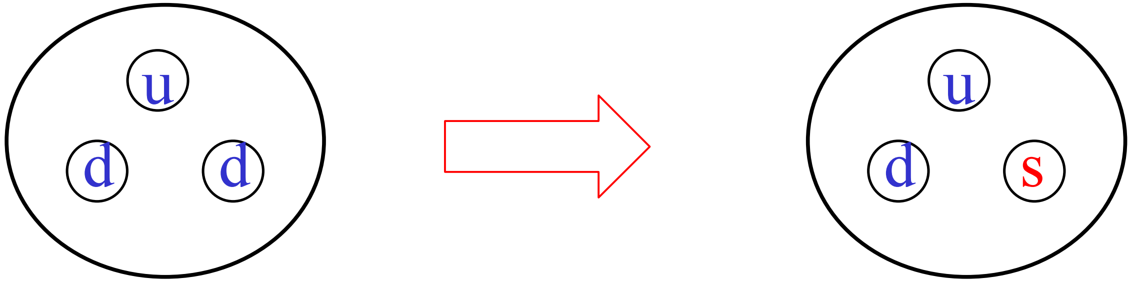
$$\text{Accretion} \quad \Gamma_{\text{A}} = \pi R_s^2 \rho$$

Stable $\quad M > 10^3 . 10^{7(1+d)} GeV > 10^{21}$ nucleons

No LHC production

Strangelets

Pauli exclusion



…overcomes (?) $\delta m = m_s - m_d$

Disaster scenarios : Stable –ve strangelets $A \approx 6$ to $A = \infty$

…unlimited accretion of normal matter

Stable –ve strangelets A≈6 to A=∞ ???

- Abundance of s quarks < u,d quarks due to mass

⇨ Q +ve

- One gluon exchange attractive for massive nonrelativistic quarks

⇨ Q -ve for large α_s?

- Finite size (surface) effects reduces s quark abundance

⇨ $Q_{A<10^7}$ +ve

J. Madsen

Suppression follows from simple quantum mechanical arguments…robust

Constraints from cosmic rays and astrophysics

Most robust…cosmic rays incident on the moon

$$\int_{Moon} collisions >> \int_{LHC} collisions$$

Strangelets fragile …survive only if not moving rapidly through matter

LHC…zero rapidity, Moon….target fragmentation region

Rapidity distribution $$\frac{d\Pi}{dy} = Npy^{\alpha}e^{-by}$$ ⇨ LHC Safe

$\left(\text{c.f.} \frac{d\Pi}{dy} = p\delta(y - Y/2) \right.$ Dar, de Rujula, Heinz $\left. \right)$

Strangelet production

Yield nucleus A

Coalescence $Y_A = B_A (Y_N)^A$ $B_A \sim 1/V_{A-1}$

Coalescence factor

Data $P_F = Y_A / Y_{A-1}$ AGS, SPS, RHIC …good description

$N_A \approx 100 \,.\, P_F^{A-1}$

$\approx 10^{-54}$ RHIC

$\approx 10^{-55}$ LHC

Number nuclei A per collision

A=20, Z=-1, S=22

c.f. 10^{11} collisions 10 year LHC operation. i.e. A≤6 production at most

Conclusions

- Disaster scenarios : Stable –ve strangelets A≈6 to A=∞

  All stability studies exclude this possibility

- Coalescence mechanism reliable. All accumulated evidence implies that LHC will be no more efficient at producing strangelets than RHIC.

> **Marberger report** : catastrophic scenarios "…are firmly excluded by existing empirical evidence, compelling theoretical arguments, or both."

We endorse this conclusion