SpaceGEM
A Novel Electric Ion Thruster for Space Vehicles

Section 1: In-space systems

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Introduction

SPACE Exploration – the inspiration

After Apollo-era we finally witness a renewed interest in a human space exploration program to the Moon and Mars.

SPACE Exploration – where are we?

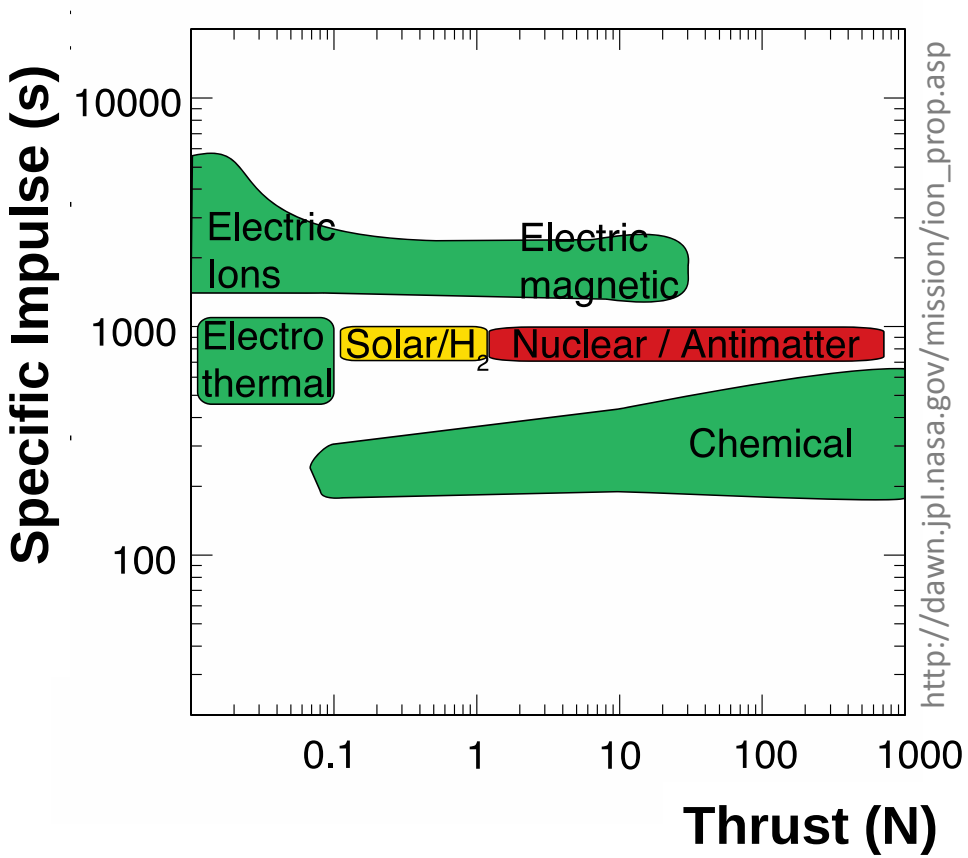
Launch system technology still relies on powerful chemical rockets while interplanetary missions use fly-by, electrical engines in addition to chemical propulsion systems but no real scalable or modular engine for inter-planetary missions...

This is our objective!

"To confine our attention to terrestrial matters would be to limit the human spirit."
S. Hawking

Introduction

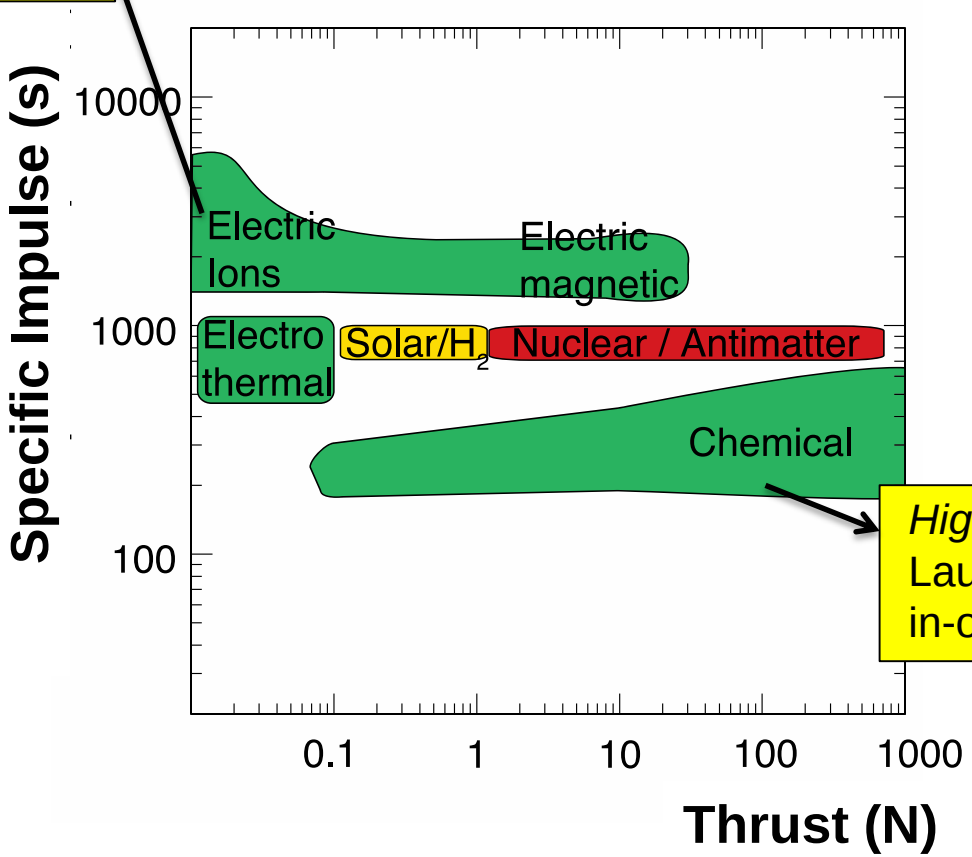
Propulsion system: technologies and applications



Introduction

Propulsion system: technologies and applications

High impulse – Low Thrust
Orbital corrections
Long-term space missions



High Thrust – Low impulse
Launch rockets + satellite in-orbit operation

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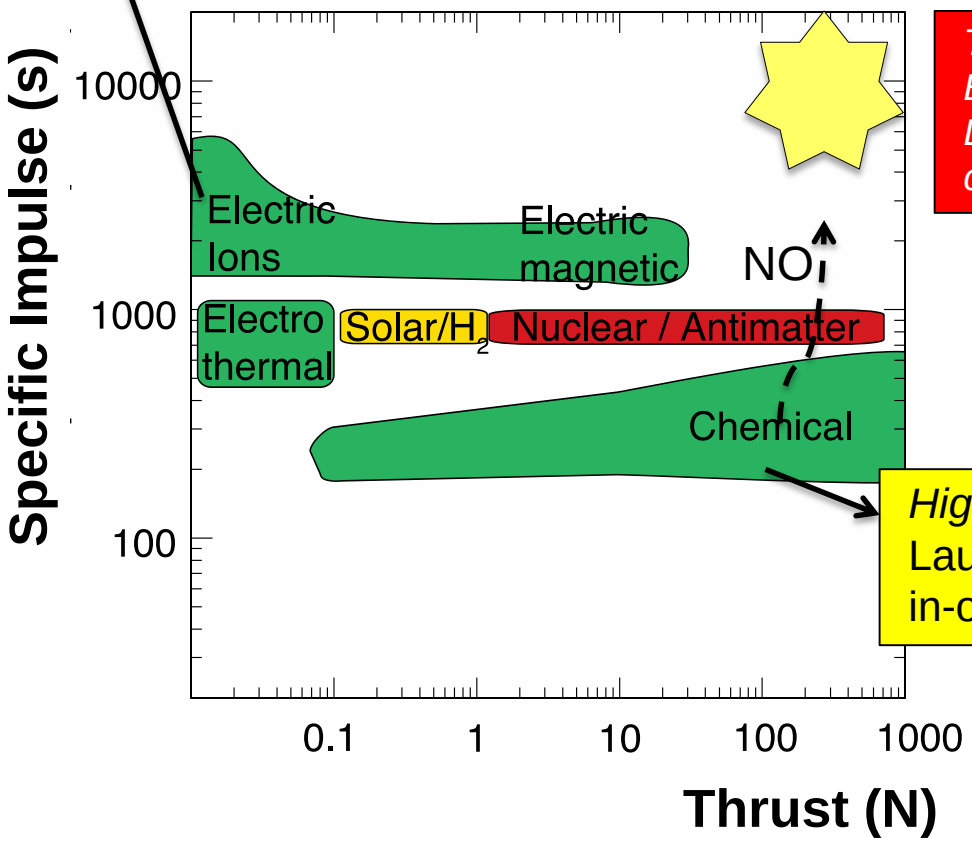

THIS WOULD BE GREAT BUT… Not possible, Limitation is given by chemistry/thermodynamics

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Launch rockets + satellite in-orbit operation

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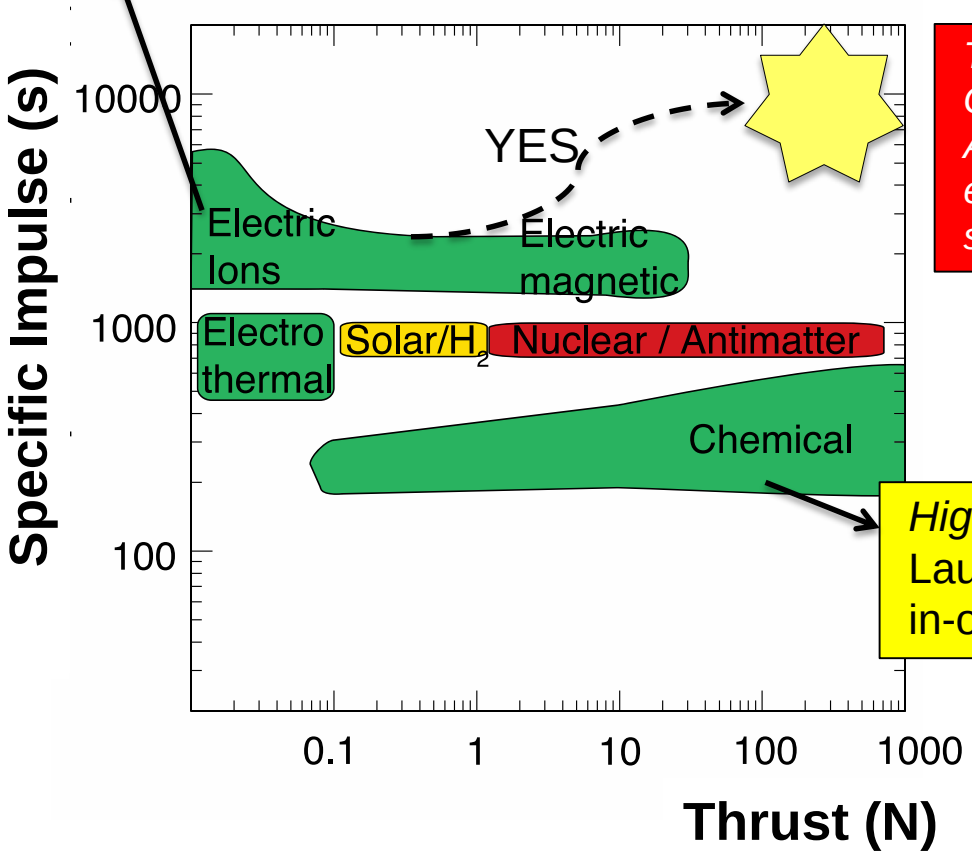

THIS WOULD BE ALSO GREAT AND… possible! Although most of these engines are not easily scalable

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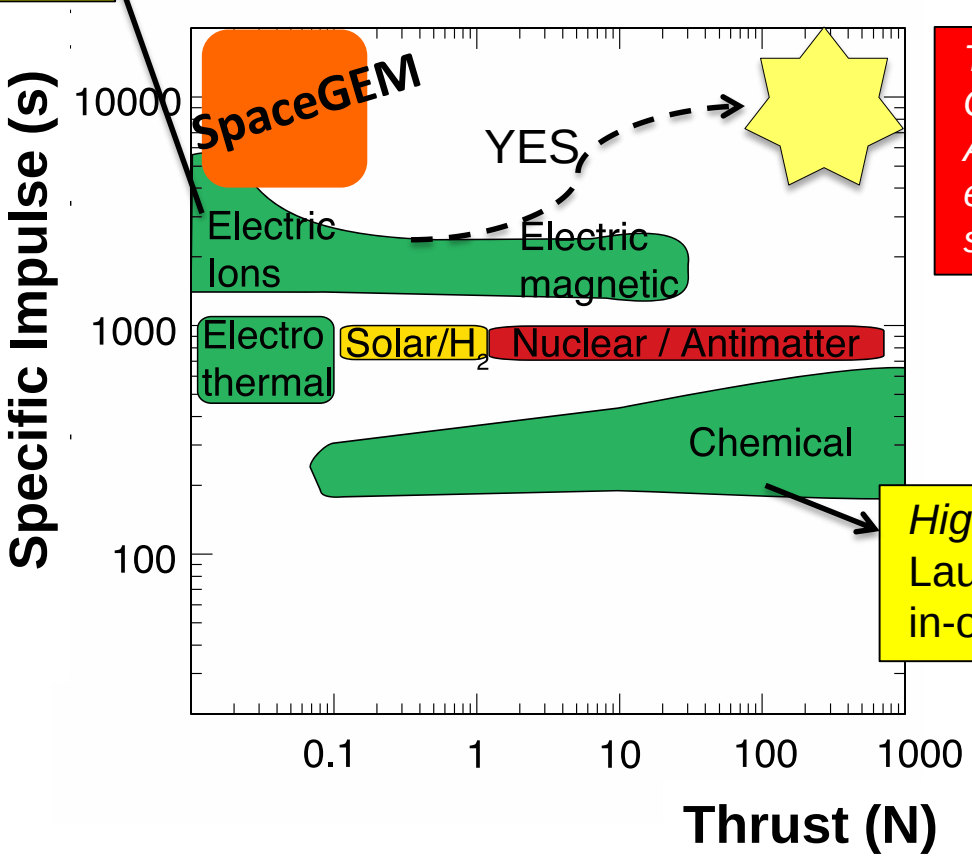

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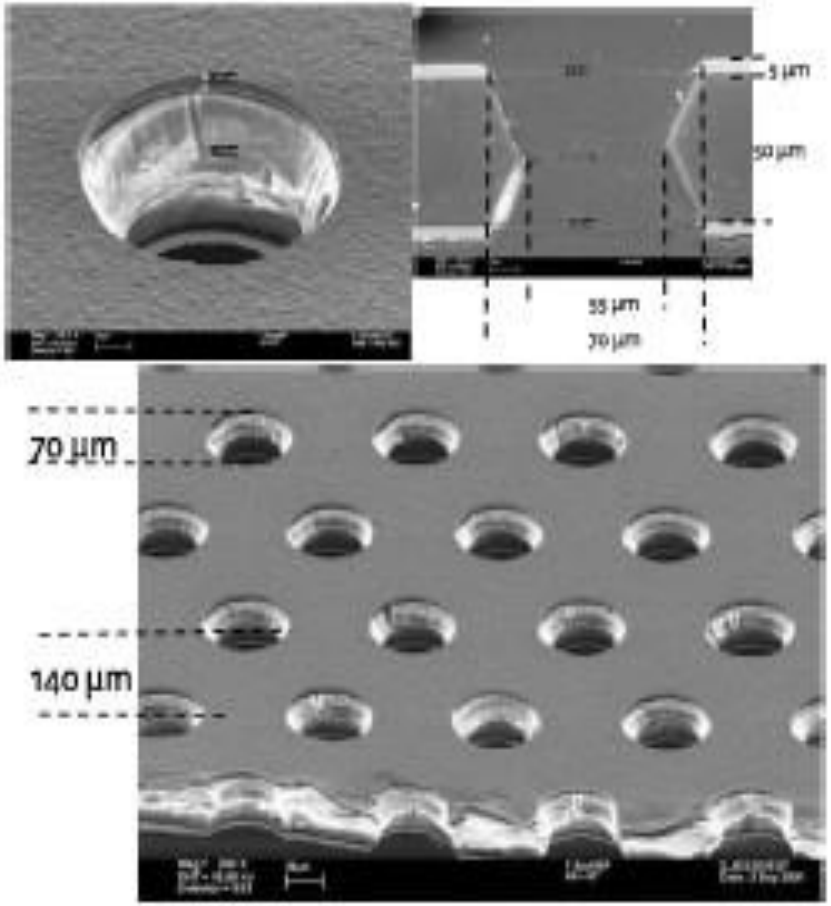
Launch rockets + satellite in-orbit operation

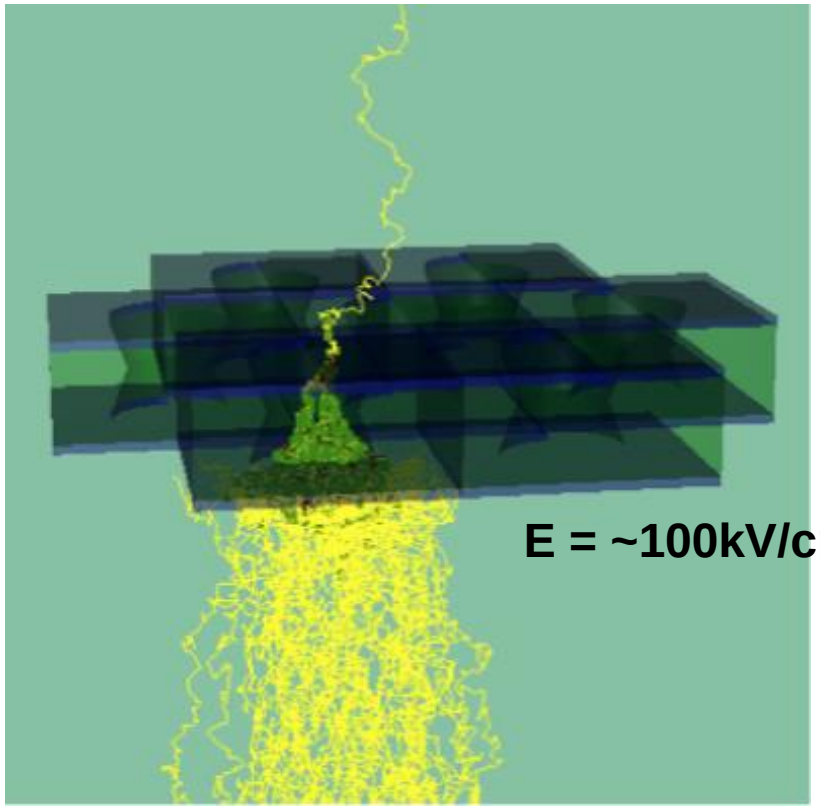
SpaceGEM in a nutshell

- What is a GEM? What is a SpaceGEM?
- How does it work?
- What is the origin of GEM technology?
- SpaceGEM for Mars missions

What's a GEM?

A 50µm thin Kapton foil with 5µm Cu coating on both sides perforated by a large number of microscopic holes





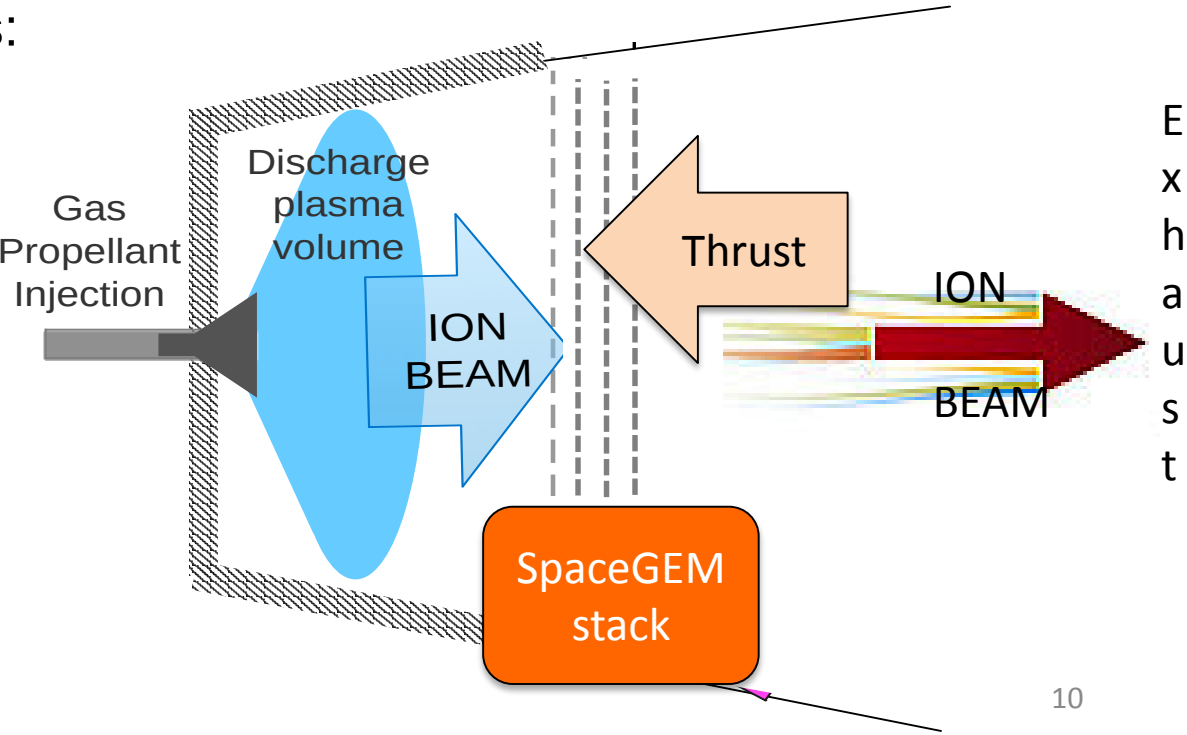
Gas Electron Multipliers

What's a SpaceGEM?

OBJECTIVE
Development of a general-purpose electric thruster for station-keeping, orbit raising, or possibly primary propulsion

Basic concept is the miniaturization of propellant-accelerating stage using millions of "nozzles" where a very intense electrical field can impart momentum on ions:

- Much higher efficiency
- Less engine wear
- Cost-effective
- Modular
- Scalable



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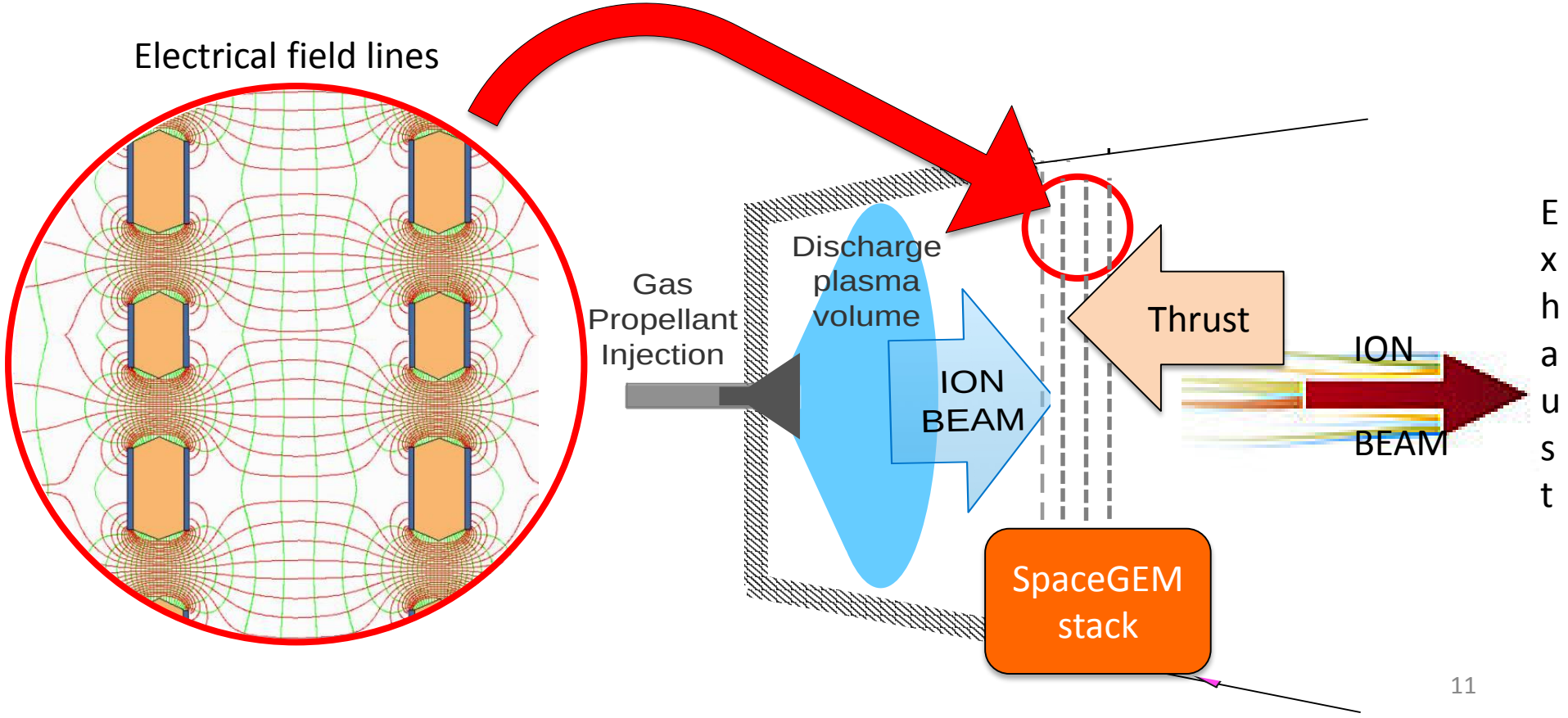


What is the origin of GEM technology?

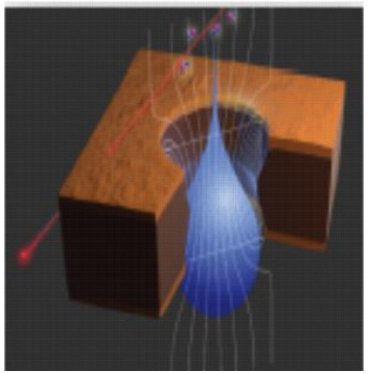
GEM Detectors – Applications

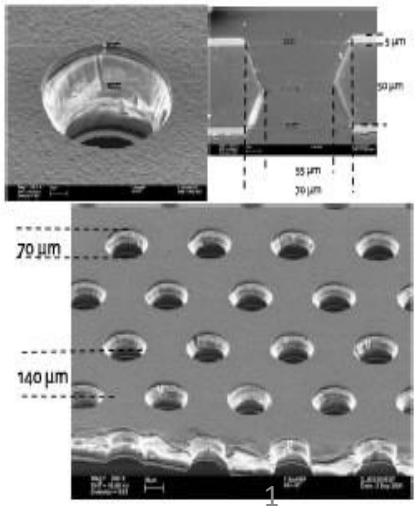
- Particle Detector (High Energy Physics)
- Tomography
- Cosmic ray stations

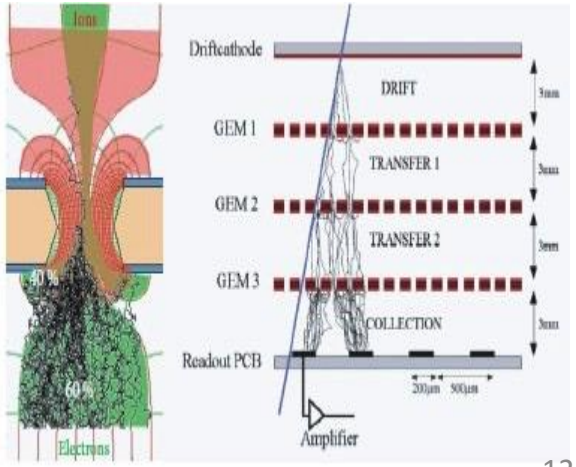
GEM working principle

Collection of the electrons released by radiation ionizing a gas, guiding them to a region with a large electric field and thereby initiating an electron avalanche.

Operation in gas at atmosperic pressure and standard temperature.







SpaceGEM for Mars missions

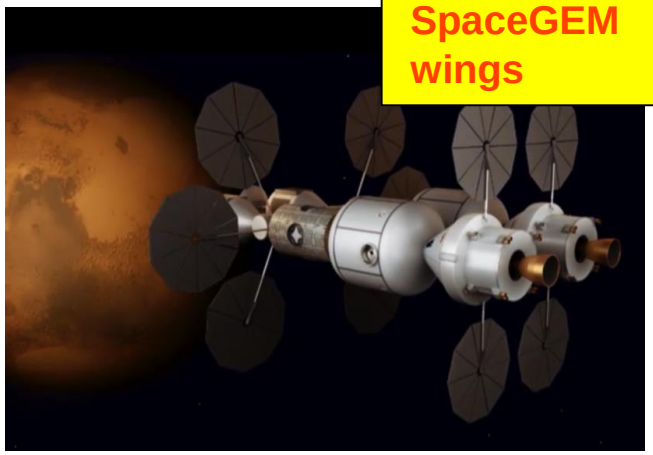
OBJECTIVE
Development of a general purpose electric thruster for stationkeeping, orbit raising, or primary propulsion.

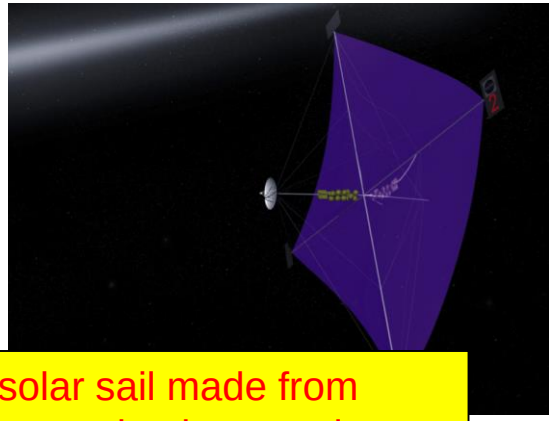
Can a GEM be used as an active panel/wing to actively exploit the ion space concentration and/or the upper atmosphere of Mars?

It will perform similarly to an air-breathing engine without any onboard propellant.

- *Small wings:*
  - *Orbital correction*
  - *Artificial gravity*
- *Large/flexible deployable wings*
  - *Primary propulsion*
  - *Orbit changing*
  - *Rendezvous*

SpaceGEM wings





Could a solar sail made from GEM foils act simultaneously as sail and ion engine?

Proposed Project

OBJECTIVE – FIRST STEP
Measure thrust produced by a small SpaceGEM prototype

Basic setup:

- Vacuum room P/SS (Mars Simulation Chamber?)
- Plasma chamber
- Trial small-sized HEP GEMs
- Diagnostics (beam monitor devices/ micro-balance)

Needed manpower (2 years: 1 post-doc & grad student)

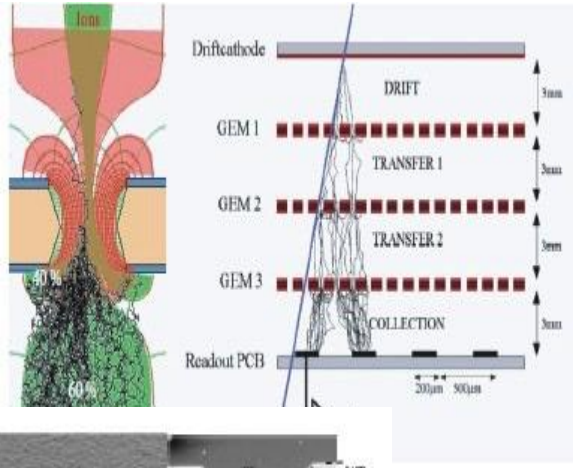
- Physics simulation
- Setup installation
- Data-taking
- Data-analysis/interpretation
- Data-extrapolation and further developments on full-scale prototypes if R&D on small-sized HEP GEMs is positive

BACKUP

What is the origin of GEM technology?

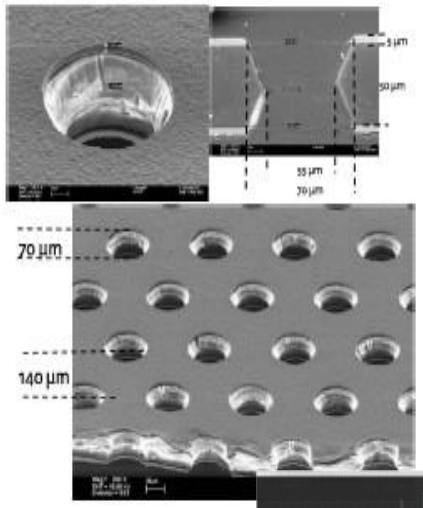
GEM in High Energy Physics – working principle

Collection of the electrons released by radiation ionizing a gas, guiding them to a region with a large electric field and thereby initiating an electron avalanche



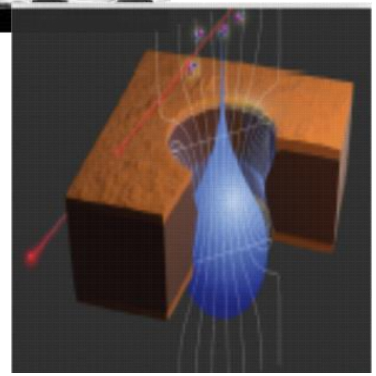
GEM in High Energy Physics – how they are made

- 50 μm kapton foil sheet with 5 μm copper-coated sides perforated with (bi)conical holes is a hexagonal pattern (hole diameter 70 μm, pitch 140 μm)
- Developed using PCB manufacturing techniques Industrial production of large areas (~1m x 2m)



GEM in High Energy Physics – performance

- Electrical Field across holes **~100kV/cm**
- Excellent spatial and time resolution (~100 μm, ~5 ns)
- Efficiency ~98%
- High rate capability ~10^5 Hz/cm^2
- Typical Gas Gain > 10^4
- Radiation hardened



Particle detector / tomography timing measur… High rate expeirment